Golder Associates Inc.
CONSULTING ENGINEERS

FINAL REPORT
GEOPHYSICAL INVESTIGATION FOR MITIGATION OF LEACHATE IMPACTED GROUNDWATER FLOW INTO THE NORTH STORM WATER DETENTION POND CATHCART LANDFILL, SNOHOMISH, WASHINGTON

Prepared by:

GOLDER ASSOCIATE INC.
REDMOND, WA

Contract No. 9012
Work Authorization No. 5

September, 1991

913-1402

TABLE OF CONTENTS

1. INTRODUCTION

These final geophysical report findings are submitted in response to a request from the Solid Waste Management Division of the Snohomish County Department of Public Works for assistance in identifying methods to reestablish interception of leachate impacted groundwater at the Cathcart Landfill in Snohomish, Washington. This work has been completed under the Consultant Agreement for On-Call Engineering Services (Master Agreement No. 9012, Work Authorization No. 5) between Golder Associates Inc. (GAI) and Snohomish County as executed June 20, 1990 by the Snohomish County Executive.

Leachate impacted groundwater has been flowing downgradient from Cathcart Landfill to the north storm water detention pond for some time. The groundwater had been intercepted and removed at a rate of approximately 30 gallons per minute (gpm) by extraction well W-1 before it could reach the pond. The leachate impacted groundwater is first treated on-site in an aeration lagoon and then pumped to a local Publicly Owned Treatment Works (POTW) for final treatment and discharge. Well W-1 was effective in extracting the leachate impacted flow due to the hydraulic effect of the level pool of the storm water pond, which maintained a relatively high groundwater table between the pond and the bedrock contact on the adjacent slope.

In the fall of 1990, the north storm water detention pond underwent improvements to increase storage capacity in anticipation of increased surface water runoff from the final closure of Stages 1 and 2 of the Cathcart Landfill. The pond was deepened by removing 10 years of accumulated sediment, and the outlet control was improved. The level pool elevation in the pond was lowered from approximately 208 feet mean sea level (ft. msl.) to approximately 194 ft. msl. As a result, the groundwater elevation in extraction well W-1 dropped below the pump, effectively eliminating W-1 as a viable extraction well under the new groundwater conditions. Concerns were raised that even if the pump in W-1 was lowered, or if well W-1 was deepened, insufficient saturated thickness of groundwater may now exist at this location to provide adequate interception of leachate impacted groundwater flow into the pond.

A geophysical survey was recommended by Golder Associates Inc. (GAI) as the most efficient method of characterizing the subsurface conditions between the landfill and the north storm water detention pond. Topographic maps, old air photos, and the construction history of the landfill suggested that a bedrock ravine may underlie the slope above the pond, which may serve to focus groundwater and simplify extraction. The objective of the survey was to determine the local topography of the subsurface bedrock, the thickness of the overlying sediments and fill, and if possible, establish the location of the groundwater table. With this information, evaluation of the range of expected saturated thickness of groundwater can be made across the slope and the most effective location for a new extraction well (or wells) may be identified. In addition, if the expected conditions are not verified by the survey, the survey results may be used to support conceptual design of other interception and extraction solutions, such as sub-horizontal drains or, as a worst case scenario, a slurry wall and extraction well system.

2. GEOPHYSICAL INVESTIGATION

The geophysical survey was conducted at the Cathcart Landfill on Saturday, September 7, 1991. The survey was conducted by Tom Williams, of Northland Geophysical Company (NGC), with the assistance of John Velimesis of GAI. Seismic Refraction was selected as the method most likely to distinguish between the layers expected beneath the slope. Some minor difficulty was encountered in laying out the survey lines due to an ongoing construction project which resulted in an open excavation up to 25 feet deep across the slope just up slope from the ideal geophysical cross section location. With the assistance of Dave Schonhard, Environmental Monitoring Technician for Snohomish County, two alternate survey lines were successfully laid out and the work was completed without difficulty. GAI field notes are included in Appendix A.

Two seismic refraction lines were established across the slope above the north storm water detention pond and below the road which crosses the slope below the northern extension of the Cathcart Landfill. The lines were labeled LI-1 and LI-2, and are shown in plan on Figures 1 and 2. Line LI-1 consisted of 23 geophones, spaced seven feet apart, with a total length of 154 feet. Line LI-2 included 24 geophones spaced 10 feet apart, with a total length of 230 feet. The response to a series of charges detonated along each line was recorded with a 24 channel digital seismic system, and examined in the field to verify a clear, relatively noise free response. Charges included 500 grain seismic electric shells and one-third pound charges of kinepak two component explosives, detonated with electric caps. The survey was coordinated with on-going site activities to minimize the disturbance in the refraction signals.

At the request of GAI, Snohomish County surveyed each of the 47 geophone locations, and the location of extraction well W-1, early on Monday morning, September 9, 1991. The survey included northing, easting and elevation at each point, and was completed before on-going construction activities were resumed to minimize any disturbance of the survey stakes and to provide ground surface elevations from which the elevation of each velocity transition were computed. The detailed survey results are included as Appendix B.

The raw data collected in the field were reduced and interpreted by NGC using the Generalized Reciprocal Method of seismic refraction interpretation. The results were combined with the survey data to develop cross sections showing the profiles of the velocity transitions which indicate the boundaries between layers of fill, natural soil, and bedrock beneath the seismic lines. The resulting interpreted seismic depth sections were plotted with a vertical exaggeration of 2:1, and are shown in Figures 3 and 4 for seismic lines LI-1 and LI-2, respectively.

3. EVALUATION AND INTERPRETATION OF RESULTS

The arcs shown in Figures 3 and 4 represent the loci of possible points on the bedrock surface refracting the shock waves created by the explosive charges used during the survey. The envelope of these loci is interpreted to be the bedrock surface. The interface between fill and native soil are shown as dashed lines on the figures. No evidence of the location of the groundwater table was produced by the survey. NGC has high confidence in the morphology of the bedrock surface, which shows a buried bedrock channel beneath both seismic lines. The deepest portion of the channel is beneath the eastern end of the lines, which has a broader, shallower shoulder which extends westward.

While the morphology is considered to be accurate, the interpreted cumulative depth to the bedrock interface is less precise due to the substantial thickness and variability of fill soils overlying the native soils. NGC will provide an estimate of the possible error in the depth to bedrock for the final version of this report. Review by a GAI project geophysicst estimates the average error to be five feet, and a maximum error to be 10 feet. The complete NGC Report is included as Appendix C.

GAI compared the results of the geophysical survey with the interpreted geologic cross sections developed by Converse Consultants NW from the logs of nearby boreholes. The logs of the wells that were evaluated are included in Appendix D. While the general form of the bedrock topography is similar, there are differences in the interpretation of the bedrock contact (or lack of contact) in logs for Extraction Well W-1 and Monitoring Wells G-5A and G-6B relative to the geophysical interpretation (refer to Figure 1). For reference, the relative locations of these wells are summarized below:

- Well G-5A is up slope from the seismic cross sections, and is between geophone stations 14 and 15 on LI-1;
- Well G-5A is approximately 30 feet ESE of extraction well W-1;
- W-1 is approximately eight feet up slope from LI-1, between geophone stations 12 and 13;
- Well G-6B is approximately 17 feet down slope from LI-2, between geophone stations four and five.

The inconsistencies between the logs and the seismic profiles may be summarized as follows:

- The log for well W-1 shows no bedrock encountered to elevation 183 ft. msl., while the seismic profile for LI-1 indicates bedrock at elevation 196 ft. msl., plus or minus five feet;

- The log for G-5A encounters bedrock at bottom of hole, at 198 ft. msl., while the seismic profile for LI-1 shows bedrock slightly deeper at approximately 191 feet, plus or minus five feet;

- The log for G-6B shows no bedrock contact to an elevation of 156 ft. msl., while the seismic section for LI-2 predicts bedrock at approximately 220 feet.

A detailed review of the well logs was conducted in an attempt to reconcile these inconsistencies. Well W-1 was drilled using an air rotary technique and a 10 inch tricone bit. The borehole was logged from cuttings. Silt and sand were encountered at elevation 208 ft. msl., and included iron staining. At elevation 203 ft. msl. hard siltstone and sandstone fragments were encountered, and weathering was noted. More iron staining was noted at elevation 202 ft. msl. Below these elevations, to the bottom of the well at elevation 183 ft. msl., silt, sand, gravel and boulders were logged. It is possible that a soft sandstone bedrock contact was encountered between elevations 208 and 202 ft. msl., and is supported both by lithology and iron staining. The contact would have been difficult to log accurately in a 10 inch air rotary hole, and could have been missed. If this explanation is correct, the interpretation of the borehole log below 200 ft. msl. (fill and alluvium) is incorrect, and may need to be reevaluated.

The log for well G-5A indicates bedrock at elevation 198 ft msl. The seismic section for LI-1 shows bedrock at 191 ft. msl. Given the projection of the slope onto seismic section LI-1 and the possible error in the total depth of the seismic interpretation, this may be the western shoulder of the bedrock channel at the borehole location, or the borehole may have been terminated in a rubble zone immediately above the bedrock. Alternatively, this may be native soil, an over consolidated till, which would account for the "hard drilling" noted in the log at the bottom of the hole. Well G-5A was drilled with a four inch auger and was sampled at 2.5 feet intervals using a split spoon sampler. The bottom of the hole is logged as a "very weathered siltstone". The inconsistency between the log and the seismic profile is not great.

The log for well G-6B does not encounter bedrock, and the description which dominates the log below elevation 231 ft msl. is "very weathered siltstone", and "zones of fine grained sandstone" are often noted. This borehole was drilled with an air rotary technique and a six inch tricone bit. It is possible that siltstone encountered at approximately elevation 231 ft. msl. is actually bedrock or behaves as bedrock for seismic refraction. This determination may not have been possible based only on drill cuttings. This resolution is not particularly dependent upon projection of G-6B up slope to LI-2, due to lack of variation in the existing borehole log upon which interpretation of facies changes may be based.

Well logs were also reviewed for shallow wells GP-1 and G-6A. No inconsistencies in these shallows wells became evident relative to the geophysical profiles. Neither the logs or the profile show bedrock occurring at these locations.

In general, the confidence in the morphology and the location of the bedrock channel provided by the geophysical survey is high. The general similarity between the seismic profile interpreted by NGC and the geologic profile provided by Converse Consultants NW indicates that a buried bedrock channel does exist beneath the seismic line sections on the site. The inconsistencies provided by well logs are greatest in boreholes drilled with air rotary techniques, where logging of cuttings raises greater uncertainties in interpretation. Despite the implications of these inconsistencies in delineating "sedimentary bedrock" however, the highest velocity unit behaves as if it were a bedrock unit under seismic refraction. This deep layer is therefore expected to be a denser layer which will limit the downward migration of water and tend to encourage flow of groundwater along the contact with overlying layers, down slope toward the storm water detention pond.

4. RECOMMENDATIONS

The results of the geophysical survey indicate a bedrock channel beneath the slope on the north end of the Cathcart Landfill. Figure 2 shows the plan of the two seismic lines and the approximate limits of the bedrock channel. The geophysical cross sections of the channel (Figures 3 and 4) indicate that the channel is wide enough and oriented such that it should concentrate the leachate impacted groundwater flowing from the landfill to the storm water detention pond. Based on the geophysical profiles, the most effective method for extracting groundwater flowing from the landfill to the pond is placement of a new extraction well somewhere along the axis of the centerline of the bedrock channel. The centerline is indicated on Figure 2 from LI-1, station 17 to LI-2, station 20. Given the morphology of the bedrock channel, installation of a monitoring well which may be easily converted to an extraction well on the shoulder of the bedrock channel (between stations 9 and 10 on LI-1) is also recommended.

Recommended locations for the proposed wells are just downslope of the existing roadway and just up slope from the position of LI-1, as shown on Figure 1. These positions straddle the location of existing extraction well W-1, and result in the ability to monitor and extract leachate impacted groundwater from the entire width of the bedrock channel at this location. These locations simplify access for drilling equipment.

For an extraction well to be effective, sufficient saturated thickness must exist to support a radius of influence to develop around the well which spans the saturated width of the buried channel. To maximize the effectiveness of the extraction well, the well should be drilled at least 10 feet into bedrock, with the pump installed in a sump well below the bedrock interface along the channel centerline. This will provide the greatest available saturated thickness, development of the largest radius of influence, and the greatest likelyhood of drawing any leachate impacted groundwater which may be in near bedrock surface fractures.

No evidence regarding the current location of the groundwater elevation in the channel was provided by the geophysical survey. Due to variations in precipitation and leachate generation in the landfill, it is still possible that insufficient saturated thickness will exist, either seasonally or permanently, to make a single extraction well an efficient method for extraction of leachate impacted groundwater. Existing measurements of groundwater elevation in all surrounding wells have been reviewed. The data confirm the strong influence of the pond water surface elevation on water levels in the surrounding wells, including W-1. Based on this behaviour, sufficient saturated thickness is expected at the proposed extraction well location to successfully intercept leachate impacted groundwater while minimizing the volume of non-contaminated water flowing from the pond to the extraction well location.

Installation of an efficient, large diameter extraction with a sump below the bedrock surface will help maximize the capture zone of the pump. If the monitoring program indicates less than satisfactory performance, a sub-horizontal drain may be installed to increase the efficiency of groundwater flow to the well and increase the volume of groundwater which is within the radius of influence of the well pump. The drain would be installed along the axis of the buried bedrock channel, extending up slope from the well toward the perimeter of the landfill. As an alternative to conventional trenching, a perforated drain pipe with granular backfill may be installed using directional drilling techniques, avoiding the need to excavate a trench across the existing roadway and utility rights of way.

The success of the extraction well during periods of low precipitation and lower groundwater flow depends upon maintaining sufficient saturated thickness around the pump. If the static water level in the pond can be maintained at elevations which ensure adequate saturated thickness at the well location, few problems should be encountered during periods of low flow. Maintenance of a water level at or above the design static water level (assumed to be 194 ft. msl.) will enhance the flow rate achievable by the extraction well.

If no combination of conditions and alternatives results in satisfactory performance as determined by the monitoring plan, other options must be pursued. A classical slurry wall and extraction well system has been discussed as an alternative. This solution will be extremely difficult to build on the slope above the pond, and severe slope stability problems are anticipated with this alternative. However, a limited lateral barrier located across a carefully selected section of the bedrock channel might be an equivalent option which avoids these consequences. The proposed extraction well location supports this contingency. A small slurry wall may be located across the buried bedrock channel down slope from the extraction well and be effective in providing a pool of leachate impacted groundwater from which the extraction well may pump. This combination of alternative solutions lends itself to a phased implementation. Careful selection of the extraction well location will allow implementation of the extraction well first, followed by installation of a directional drain, and finally construction of a sub-vertical barrier, as extraction performance warrants.

ND:

Monitoring well

Proposed Extraction Well Location

Proposed Monitoring/Extraction Well Location

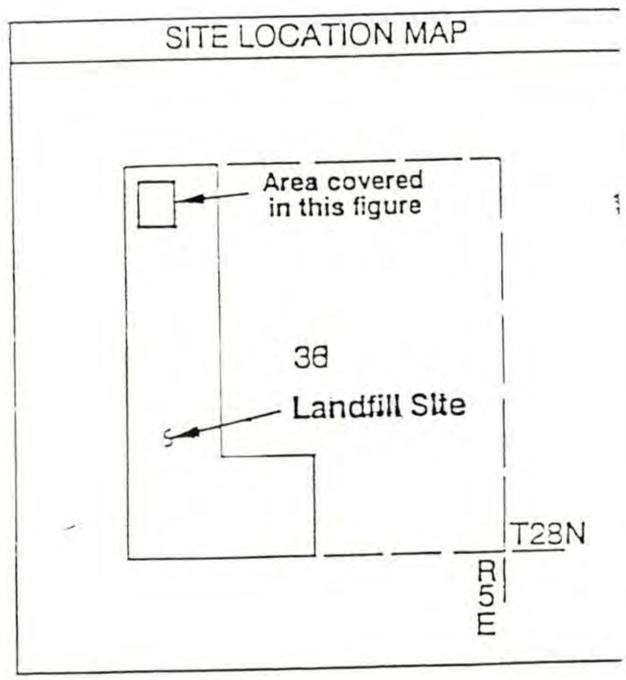


FIGURE 1
SEISMIC LINE LOCATIONS

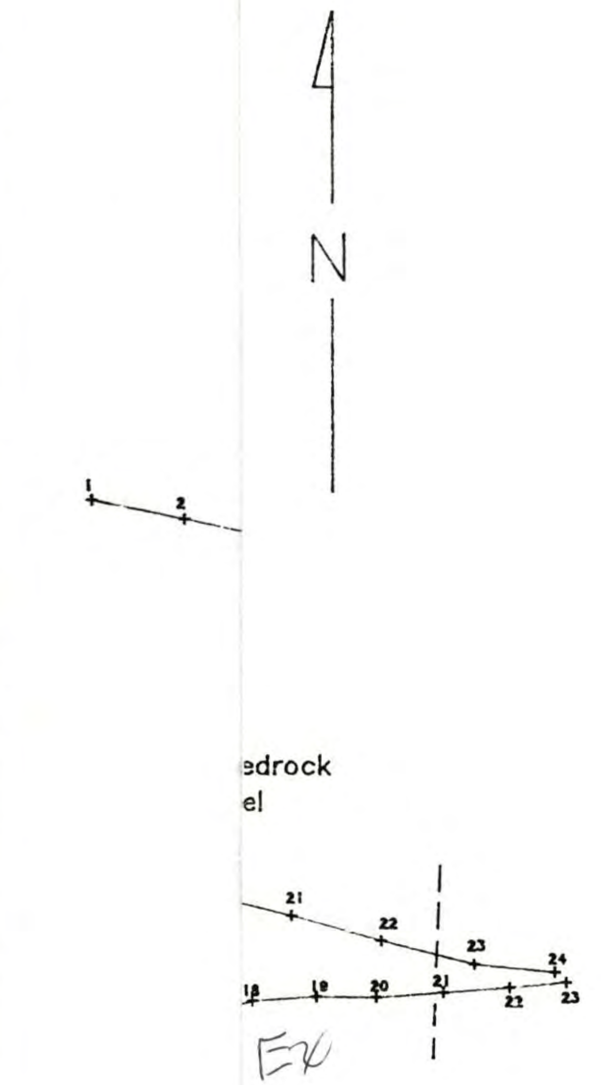
PROPOSED MONITORING WELL LOCATION MAP

Cathcart Landfill
Snohomish County Public Works

SNOHOMISH/CATHCART/WA

913-1402 23727 11/15/91

Golder Associates

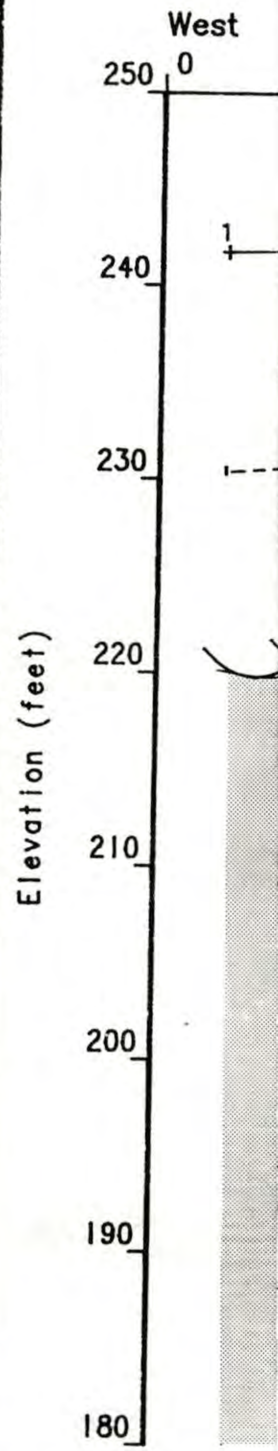


SCALE: 1" = 20'

NORTHLAND GEOPHYSICAL COMPANY

November 1991

FIGURE 2



EXPLANATION

nal Geophone Spacing = 7 ft.

bers in profile represent
ressional wave velocity in
per second (fps).

represent loci of possible
s on the bedrock refractor;
envelope of these loci is
as the surface of the
ctor.

ow (overburden) interfaces
represented by dashed lines.

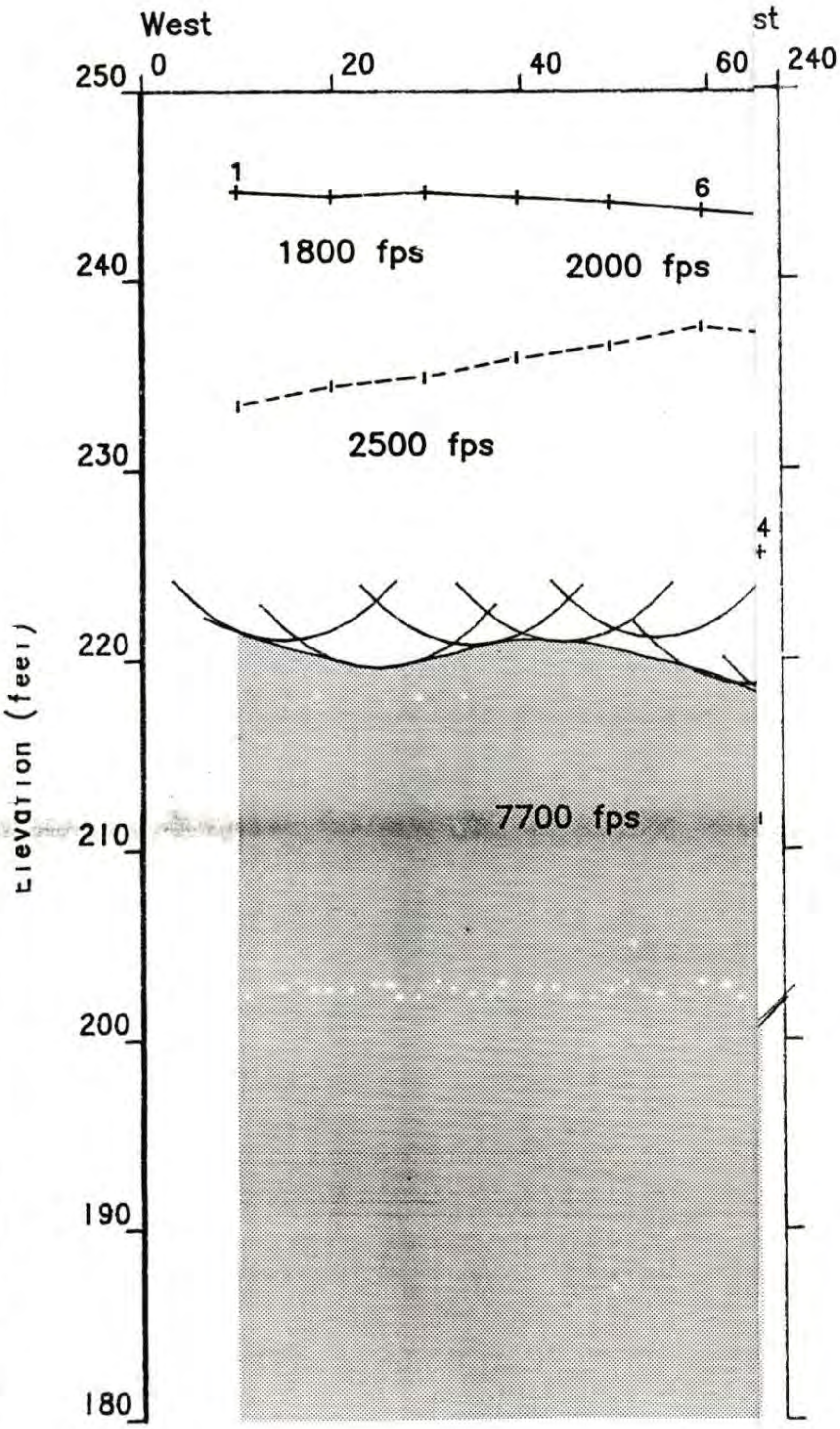
ORTHLAND GEOPHYSICAL
Seattle, Washington

DEPTH SECTION

SEISMIC LINE LI–1

Cathcart Landfill Extraction Well

or. Scale: 1"=20'	November 1991
rt. Scale: 1"=10'	**FIGURE 3**



EXPLANATION

Nominal Geophone Spacing = 10 ft.

Numbers in profile represent compressional wave velocity in feet per second (fps).

Arcs represent loci of possible points on the bedrock refractor; the envelope of these loci is taken as the surface of the refractor.

Shallow (overburden) interfaces are represented by dashed lines.

NORTHLAND GEOPHYSICAL
Seattle, Washington

DEPTH SECTION

SEISMIC LINE LI-2

Cathcart Landfill Extraction Well

Hor. Scale: 1"=20'	November 1991
Vert. Scale: 1"=10'	FIGURE 4

APPENDIX A

FIELD NOTES

[redacted]

J. Verimesis

No. 612

09-07-91 — 313-1462.100, Snohomish Co./Cathcart Geop/LWA — pg. 1

08:30 On site @ Cathcart Landfill office – meet Dave Schonhard (Sno Co. [illegible] monitor tech) + Tom Williams (Northland Geophysics)

Weather: Light rain, full clouds, breeze 0-5 kt, ~ 55°F humid!

[illegible] [illegible] [illegible] excavations have expanded!, [illegible] 2 lines now restricted to very narrow traverses

08:[illegible] Begin setting stakes for leachate investigation (LI) Line 1 = 23 stakes @ 7 ft intervals west to east for total length = 154 ft ; LI 1-1 thru LI 1-23.

1st line parallel to old road approx 6 ft. north of well W-1.

09:30 Begin setting geophysics probes line 1.

Photo #1 looking east along line 1 from LI 1-1 showing line 1 relative to MW-1 & existing excavations.

9:35 - 10:15 Ken Miller arrives on-site for A. [illegible]

9:35 Dave Schonhard & Gary Parke help set 3 [illegible] on corner apron of pad for former tool shack [illegible] pipe, are LI 1 - 15, 16 + 17 ; all 3 are [illegible] pipes

10:40 All 23 probes for LI 1 are set & main lines run & connected.

10:45 TESTING 23 CHANNEL RECEPTION ON ELECTRONICS
- 1ST TEST WILL BE SHOT GUN SHELL B/T
LI1-12 & 13 (500 GR BLACK POWDER)

11:00 FIRST TEST SHOT - OK PICK UP BUT
[illegible] TIME BASE ON MONITOR
[illegible] 500 MS;

11:20 2ND SHOT B/T LI1-12+13. GOOD SHOT
ACTUALLY, 100MS TIME BASE IS ADEQUATE

11:35 SET UP FOR SHOT B/T LI1-7+8
PHOTO #2: LOOKING DOWN INTO EXCAVATION AT THE
EAST END OF THE 1ST LINE, LI1-21, 22, 23.
PHOTO #3: LOOKING SOUTH TO BACKWALL OF
EXCAVATION AT EAST END OF LI1-22, 23
NOTE: BEDROCK CONTACT ON BACKWALL (SOUTH WALL)

11:45 3RD SHOT B/T LI1-7+8 = GOOD STUFF

12:10 4TH SHOT B/T LI1-3+4 =

12:20 5TH SHOT @ LI1-1; MOVE GEOPHONE 3.5 FT
TO LI1-1+3.5

12:30 TENTATIVE END SHOT AT WEST SIDE OF [illegible]
POND W/ 1/2 LB DYNAMITE CHARGE.

12:45 JSV OFF-SITE FOR LUNCH.
(DAVE + TOM FIRE 1ST [illegible] END SHOT)

13:40 JSV BACK ON-SITE - TOM SETTING UP
6TH SHOT B/T LI1-17+18.

JSV

13:50 7TH & FINAL SHOT AT LI1-23, MOVE
GEOPHONE #23 TO LI1-22+3.5 FT
NO 1/3 LB DYNAMITE. PAST END SHOT ON EAST END

15:20 WITH [illegible] WORK & DAVE SCHOENHARDT'S
[illegible], THE SECOND GEOPHONE
LINE IS IN THE GROUND & READY TO
GO. 24 GEOPHONES AT 10 FT INTERVAL
FOR 230 FT. SPAN. NOMENCLATURE IS
LI2-1 TO 24 FROM WEST TO EAST.
NOTE: GEOPHONE LI2-24 IS AT SAME
EAST END POINT AS LI1-23 = COMMON
POINT OF DATA!!

15:35 SHOT #1 (500 GR SHELL) @ LI2-24; MOVE
GEOPHONE #24 TO LI2-23+5.0 FT.
SHOT GOOD ON PHONES 13-24; WEAK ON 1-12.

16:00 SHOT #2 AT LI2-18+5.0 FT (B/T 18+19)
PHONE 24 BACK AT LI2-24., VERY WEAK

16:25 SET 1/3 LB CHARGE AT LI2-18+5.0 FT. TO
GET MORE SIGNAL.; SHOT = GOOD

16:50 SET 1/2 LB CHARGE AT LI2-12+5.0 FT.
SHOT = GOOD.

JSV

J. Verimese

8-1-91 | 913-1102.0 | 540.00/CATHCART GOOD/WA | PG 4

17:00 SET 500GR SHOT # 3 AT LI2-6+5.0FT
(B/T PHONES 6+7) ON COMPACT ROADWAY
SUB BASE NEAR LEACHATE POND ON WEST
END OF LINE, SHOT =
17:25 FIRED 1/3 LB END SHOT FOR WEST END
PAST LEACHATE POND, WEST OF LI2-1.
17:10 SET 500 GR SHOT # 4 AT LI2-1,
MOVE PHONE # 1 TO LI2-1+5.0 FT,
B/T LI2-1+2.
17:15 SHOT # 4 = OK
RESET GEOPHONE # 1 AT LI2-1 = 0'
17:45 SET & FIRE 1/3 LB END SHOT WEST OF LI2-1
SHOT = GOOD
17:50 BEGIN PULLING GEOPHONES & SETTING
SURVEY STAKES.
18:10 BEGIN SITE CLEANUP
18:30 ALL CREW PACKED UP.
- LEFT TOM W. DIAGRAM LI1 & LI2
FOR SURVEYORS TO MAP ON MONDAY AM
- LEFT MAP W/ DAVE SCHONIVAN.
18:45 - VERIMESE + WILLIAMS OFF-SITE
- END FIELD WORK

JW

APPENDIX B

SNOHOMISH COUNTY SURVEY DATA FOR
LOCATION OF GEOPHYSICAL SURVEY LINES

	Serial no 0000 Angle : Degrees Temp : Fahrenht	09-Sep-91 15:44 Dist : Feet Coord : N-E-Elv	 Press : Inch Hg H.obs : Right
JOB	Job ID CRP 91-425		
NOTE	CATHCART LANDFILL CLOSURE-SEISMIC POINTS		
NOTE	SPICER MUTT ANDERSON		
NOTE	FUNTION 970		
SCALE	S.F. 1.000000000		
NOTE CP	Sea level cn: N		
NOTE CP	C & R crn: Y		
NOTE CP	Atmos crn: Y		
NOTE TS	09-Sep-91 08:38		
INSTR	SET Theo <No text> V.obs : Zenith P.C. mm 0.000	EDM <No text> Serial no 000000 Edm o/s <Null>	Serial no 085064 Mount: not applc Refl o/s <Null>
POS TP 0131	Nrth 321356.294 Code 2701-735	East 1684580.620	Elv 254.980
POS TP 0501	Nrth 320824.905 Code GPS-REF 3	East 1684596.320	Elv 262.550
POS TP 0768	Nrth 321416.862 Code 301-774B	East 1684849.800	Elv 242.350
STN TP 0768	Nrth 321416.862 Theo ht 5.290	East 1684849.800 Code 301-774B	Elv 242.350
ATMOS	Press 30.00	Temp 70.0	
STN TP 0768	Nrth 321416.862 Theo ht 5.270	East 1684849.800 Code 301-774B	Elv 242.350
TRGET	Target ht 4.820		
BKB TP 0768-0131	Dircn 257-19'08"	H.obs 0-00'00"	
OBS TP 0768-0131	Dist <Null> Code 2701-735	V.obs 87-36'25"	H.obs 0-00'00"
POS TP 1000	Nrth 321401.371 Code LI1-1	East 1684843.250	Elv 241.757
POS TP 1001	Nrth 321401.523 Code LI1-2	East 1684849.940	Elv 241.833
POS TP 1002	Nrth 321401.937 Code LI1-3	East 1684857.030	Elv 242.020
POS TP 1003	Nrth 321401.769 Code LI1-4	East 1684864.020	Elv 242.022
POS TP 1004	Nrth 321402.011	East 1684871.090	Elv 240.976

POS TP 1005	Nrth 321401.850 Code LI1· 6	East 1684877.830	Elv 240.449
POS TP 1006	Nrth 321402.429 Code LI1-7	East 1684884.690	Elv 238.438
POS TP 1007	Nrth 321402.336 Code LI1-8	East 1684891.760	Elv 235.296
POS TP 1008	Nrth 321402.918 Code LI1--9	East 1684898.400	Elv 234.674
POS TP 1009	Nrth 321403.347 Code LI1-10	East 1684905.800	Elv 233.560
POS TP 1010	Nrth 321403.905 Code LI1-11	East 1684912.550	Elv 234.306
POS TP 1011	Nrth 321404.562 Code LI1-12	East 1684919.490	Elv 234.013
POS TP 1012	Nrth 321404.836 Code LI1-13	East 1684926.590	Elv 233.939
POS TP 1013	Nrth 321405.009 Code LI1-14	East 1684933.440	Elv 233.938
POS TP 1014	Nrth 321406.052 Code LI1-15	East 1684940.150	Elv 234.029
POS TP 1015	Nrth 321405.464 Code LI1-16	East 1684946.820	Elv 234.626
POS TP 1016	Nrth 321405.999 Code LI1-17	East 1684954.100	Elv 233.485
POS TP 1017	Nrth 321407.134 Code LI1-18	East 1684961.510	Elv 233.302
POS TP 1018	Nrth 321407.567 Code LI1-19	East 1684969.370	Elv 232.853
POS TP 1019	Nrth 321407.528 Code LI1-20	East 1684974.770	Elv 229.521
POS TP 1020	Nrth 321408.034 Code LI1-21	East 1684981.850	Elv 226.110
POS TP 1021	Nrth 321408.545 Code LI1-22	East 1684988.070	Elv 225.002
POS TP 1022	Nrth 321409.079 Code LI1-23	East 1684994.900	Elv 225.585
POS TP 1023	Nrth 321410.124 Code LI2-24	East 1684993.690	Elv 225.571
POS TP 1024	Nrth 321410.938 Code LI2-23	East 1684985.130	Elv 224.275
POS TP 1025	Nrth 321413.367 Code LI2-22	East 1684975.310	Elv 226.206
POS TP 1026	Nrth 321415.956	East 1684965.740	Elv 227.201

POS TP 1027	Nrth 321418.231 Code LI2-20	East 1684956.080	Elv 227.054
POS TP 1028	Nrth 321420.393 Code LI2-19	East 1684946.390	Elv 226.506
POS TP 1029	Nrth 321422.335 Code LI2-18	East 1684936.610	Elv 226.267
POS TP 1030	Nrth 321424.706 Code LI2-17	East 1684926.740	Elv 225.512
POS TP 1031	Nrth 321426.500 Code LI2-16	East 1684917.070	Elv 224.767
POS TP 1032	Nrth 321428.746 Code LI2-15	East 1684907.300	Elv 222.909
POS TP 1033	Nrth 321430.810 Code LI2-14	East 1684897.430	Elv 223.388
POS TP 1034	Nrth 321432.733 Code LI2-13	East 1684887.030	Elv 223.926
POS TP 1035	Nrth 321434.910 Code LI2-12	East 1684877.480	Elv 225.017
POS TP 1036	Nrth 321437.333 Code LI2-11	East 1684868.210	Elv 227.678
POS TP 1037	Nrth 321439.399 Code LI2-10	East 1684858.380	Elv 233.767
POS TP 1038	Nrth 321440.642 Code LI2-9	East 1684849.580	Elv 237.360
POS TP 1039	Nrth 321443.409 Code LI2-8	East 1684840.410	Elv 240.937
POS TP 1040	Nrth 321445.619 Code LI2-7	East 1684830.800	Elv 243.341
POS TP 1041	Nrth 321448.069 Code LI2-6	East 1684821.010	Elv 243.691
POS TP 1042	Nrth 321450.176 Code LI2-5	East 1684811.360	Elv 244.118
POS TP 1043	Nrth 321452.493 Code LI2-4	East 1684801.610	Elv 244.376
POS TP 1044	Nrth 321454.969 Code L12-3	East 1684791.850	Elv 244.662
POS TP 1045	Nrth 321457.002 Code LI2-2	East 1684782.120	Elv 244.425
POS TP 1046	Nrth 321459.011 Code LI2-1	East 1684772.220	Elv 244.686
POS TP 1047	Nrth 321396.773 Code TOP WELL W-1	East 1684922.290	Elv 240.208

* END OF REPORT *

APPENDIX C

NORTHLAND GEOPHYSICAL COMPANY
FINAL REPORT

NORTHLAND GEOPHYSICAL COMPANY
2366 Eastlake Avenue East, Suite 435
Seattle, Washington 98102
(206) 323-5995

November 15, 1991

Mr. John S. Velimesis
GOLDER ASSOCIATES, INC.
4104 - 148th Ave. N.E.
Redmond, Washington 98052

SUBJECT: Final Report / Cathcart Landfill Seismic Survey

Dear Mr. Velimesis:

Enclosed please find four figures constituting the final report on the results of the seismic refraction survey at the Cathcart Landfill conducted on September 7, 1991.

The first figure in the set is a copy of Figure 8 of the Converse Consultants report of August 1988. I have superimposed on this figure the approximate location of the two seismic lines which we surveyed (Lines LI-1 and LI-2). The seismic lines are plotted to scale, and their location on the 1988 base map is based on my best estimate of the location of Well W-1. A more current base map with the plotted location of Well W-1 would help to precisely locate the seismic lines.

Figure 2 is a larger drawing at a scale of 1"=20' showing the seismic line positions relative to Well W-1. This drawing was plotted using the X-Y coordinates of the geophones, which were provided by the Snohomish County Department of Public Works.

Figures 3 and 4 are the interpreted seismic depth sections plotted at a horizontal scale of 1"=20' and a vertical scale of 1"=10' (with a resulting vertical exaggeration of 2:1). The nominal geophone spacing for Line LI-1 was 7 feet, while the spacing for LI-2 was 10 feet. The numbers posted in the depth sections represent seismic wave velocity in feet per second (fps). The arcs represent loci of possible points on the bedrock refractor; the envelope of these loci is taken as the surface of the refractor. Shallow (overburden) interfaces are represented by dashed lines.

Both depth sections depict substantial thicknesses of relatively loose fill (800 - 1500 fps) overlying native(?) soils with a velocity of approximately 2000 - 2500 fps. Because of these substantial fill thicknesses, as well as the scatter in the seismic travel-time plots caused by the variability of the fill, it is difficult to precisely map the depth to the native soil interface. This is particularly true on the eastern half of Line LI-2, where question marks (?) have been superimposed on the position of the fill/native soil interface.

No indications of seismic velocities representative of saturated soils were observed in the seismic travel-time curves. Such a saturated zone above bedrock may have been present as a "hidden layer" at the time of the seismic survey, however. Travel-time computer modeling demonstrates that saturated thicknesses less than half of the overburden depth are often not detectable by the seismic refraction method due to the "hidden-layer" problem.

The seismic depth sections indicate that computed bedrock velocities ranged from 5400 fps to 7700 fps. These velocity determinations were somewhat hampered by the inability to obtain off-the-end shot positions to the east of the seismic lines due to parked construction equipment and the proximity of residential housing on the eastern border of the landfill property. The low velocity range which was computed indicates that the bedrock underlying this portion of the site is of relatively weak composition.

The two depth sections indicate that a buried bedrock channel is present beneath the two seismic lines. The deepest portion of this channel appears to lie beneath the eastern ends of the lines, while a broader, somewhat shallower, bedrock depression extends farther to the west. I have attempted to indicate the extent of the broader channel and the "incised" channel on Figure 2.

Computed depths to the bedrock interface are not considered to be as reliable as would be the case under more natural geologic conditions, due to the difficulty in determining an accurate velocity distribution in the overburden. Non-detection of a possible saturated zone would add to this error, in which case computed bedrock depths would be too shallow. If the bedrock interface is sloping steeply to the north, the phenomenon of "sideswipe" may also add to errors in the bedrock depth estimates. Sideswipe results from refracted bedrock arrivals from out-of-the-(vertical) plane, wherein the shortest travel-time path occurs in a plane which is perpendicular to the bedrock surface. This geometrical phenomenon can also lead to (vertical) bedrock depth estimates which are too shallow.

The possibility of all of the above errors makes it difficult to estimate the potential error in the plotted depth sections. Under good conditions, the seismic refraction method is considered to be reliable to within about 5-10% of the true depth to the target refractor. Since this seismic survey was conducted under poor field conditions, the possible error in the depth estimates to the bottom of the channel is more likely in the 10-20% range (5-10 feet), and may be as high as 30-35% (15 feet). The close agreement between the depth estimates for the two independent seismic lines at the location of the channel adds confidence to the results, however.

The important point that should be made is that my confidence in the determination of the morphology of the bedrock interface (as evidenced by both the travel-time plots and the subsequent seismic delay-time plots) is much higher than in the actual depth estimates. Thus the morphology of the channel-like feature toward the east end of the seismic lines is thought to accurately reflect subsurface conditions.

I trust that the seismic results will be useful for planning the location of the new extraction well at the north end of the Cathcart Landfill. Please call if there are any questions on the interpretation of the seismic results.

Sincerely yours,

Tom Williams

Thomas R. Williams
Consulting Geophysicist

Enclosures

APPENDIX D

WELL LOGS

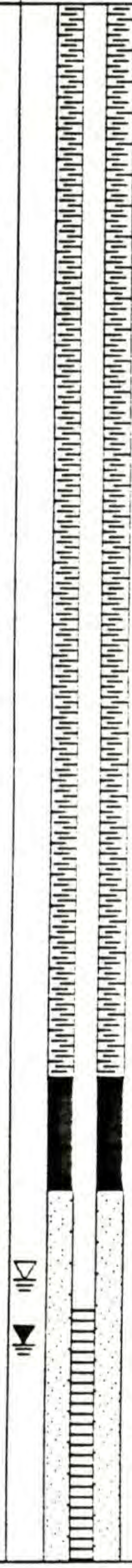
Converse GES

Monitoring Well Geologic & Construction Log

Project Number	Well Number	Sheet
89-35164-03	W-1	Sheet 1 of 2

Project Cathcart Landfill Hydrogeologic Investigation
Location Snohomish County, Washington
Elevation (Approx. Top of Well Casing)
Surface Elevation (Approx.) 239
Water Level Elev. (Approx.) 206
Start Date February 8, 1989
Drilling Contractor Jensen Drilling
Finish Date February 9, 1989
Drilling Method Air Rotary

Depth feet	Well Construction 239'	Lab Tests	ST	Blows/ 6"	USCS Symbol	Description
						FILL GRAVEL AND COBBLES; gray-green road fill
2						
						SANDY SILT; gray-brown; fine sand; scattered organic fragments; loose; (ML)
4		C	Drive Barrel			
						SILT; gray-brown; little to some fine gravel, rounded; trace to little fine to coarse sand; moist; loose; (ML)
6						
8						locally gray-green
10	well casing, 6" ID Type 316 stainless steel					
12						reddish brown; occasional wood fragments; loose to medium dense
14						
16						
18	cement grout annular seal					
20						trace fine to coarse gravel
22						gray-green; abundant organic fragments; medium dense (?)
24						
26						little to some coarse sand to fine gravel
28						little fine to coarse sand; little fine gravel; no organic fragments observed
30	bentonite pellets					scattered cobbles; occasional organic fragments
32						SILT AND SAND; gray-green; fine to medium sand; trace fine gravel; local iron-oxide staining; moist; (ML)
34	centering guide					
36	well screen, 6" ID Type 316 stainless steel, 0.010" slot width					little fine gravel consisting primarily of hard siltstone and sandstone fragments, some fragments weathered
38	filter pack, Aqua 8 sand					mottled gray-brown, iron-oxide stained; fine to coarse gravel



ST - Sampler Type:
- 4" I.D. Split Spoon
- Bulk Grab Sample
- Drive Barrel

Lab Tests:
- S - Soil Properties
- C - Chemical Properties
- Water Level

Logged by: WRH/BMF
Approved by: DRH

Figure No.

Converse GES — Monitoring Well Geologic & Construction Log

Project Number: 89-35164-03
Well Number: W-1
Sheet 2 of 2

Project: Cathcart Landfill Hydrogeologic Investigation
Location: Snohomish County, Washington
Elevation (Approx. Top of Well Casing):
Surface Elevation (Approx.) 239
Water Level Elev. (Approx.) 206
Start Date: February 8, 1989
Drilling Contractor: Jensen Drilling
Finish Date: February 9, 1989
Drilling Method: Air Rotary

Depth feet	Well Construction	Lab Tests	ST	Blows/ 6"	USCS Symbol	Description
42						**FILL** SILT AND SAND; gray-brown; little to some fine to coarse gravel, subrounded borehole producing water, flow rate about 30 gpm
44	well screen, 6" ID Type 316 stainless steel, 0.010" slot width					**ALLUVIUM** GRAVEL AND SAND; gray, green, and brown clasts; fine to coarse gravel, subrounded to rounded; fine to coarse sand; scattered organic fragments; wet; loose; (GW)
46						
48	filter pack, Aqua 8 sand					boulders encountered, 48 to 52.5 feet
50						
52						
54	centering guide end cap					SANDY SILT; gray-green; fine to coarse sand; little to some fine to coarse gravel, subangular to subrounded; medium dense; (ML)
56						
58	NOTES (1) Stainless steel centering guides used (2) 9" ID aluminum surface casing to 2.8 feet (3) Locking aluminum surface cap used					Total depth, 56.0 feet
60						
62						
64						
66						
68						
70						
72						
74						
76						
78						

ST - Sampler Type:
- 4" I.D. Split Spoon
- Bulk Grab Sample
- Drive Barrel

Lab Tests:
- S - Soil Properties
- C - Chemical Properties
- Water Level

Logged by: WRH/BMF
Approved by: DRH
Figure No.

DATE DRILLED: 3/3/88

SUMMARY: BORING NO. G-5A

ELEVATION:

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.

239'

DEPTH IN FEET	SAMPLE NO.*	SAMPLE	BLOWS/6"	OTHER TESTS**	FIELD MOISTURE % OF DRY WEIGHT	DRY DENSITY PCF	DESCRIPTION	SYMBOL	MOISTURE	CONSISTENCY
0							SANDY SILT WITH GRAVEL (fill); dark gray mottled brown, fine to medium sand, fine gravel, wood fragments, slightly plastic			
	1A		6 10 12						moist	
5	2A		12 13 11				SANDY SILT; brown mottled rust, fine to medium sand, trace coarse, occasional pockets of sand, slightly plastic		moist	
	3A		9 13 18				sample driven on rock, few sandstone fragments in shoe			
10	4A		10 7 8				no sample recovery			
	5A		6 7 6				GRAVEL (rock fragments); dark gray siltstone with pockets of slightly plastic silt and occasional fine to medium sand, trace coarse		moist	
15	6A		6 3 3				GRAVEL (crushed rock) AND SILT; dark gray mottled brown, fine to coarse sand, slightly plastic, dark green siltstone		moist	
	7A		6 7 17				siltstone fragments, small amount of organics very gravelly drilling methane coming out of ground around auger		moist	
20										

(continued)

* A. 2" split-spoon sampler
B. 3" O.D. thin-wall sampler C. 3-1/4" O.D. x 2-1/2" liner
D. 3-1/2" O.D. split barrel sampler X. sample not recovered

** A - Atterberg, C - consolidation, DS - direct shear, G - grain size, T - triaxial, P - permeability

water level
impervious seal
piezometer tip

Cathcart Landfill
Snohomish County Public Works

Project No. 88-35169

Figure No.

Converse Consultants — Geotechnical Engineering and Applied Sciences

DATE DRILLED: 3/3/88

SUMMARY: BORING NO. G-5A (Cont.)

ELEVATION:

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.

DEPTH IN FEET	SAMPLE NO.*	BLOWS/6"	OTHER TESTS**	FIELD MOISTURE % OF DRY WEIGHT	DRY DENSITY PCF	DESCRIPTION	SYMBOL	MOISTURE	CONSISTENCY
20	8A	4 2 2				SILTSTONE FRAGMENTS & SILT (fill); pushing rocks through silt		moist to very moist	
	9A	27 6 7				no sample recovery			
25	10A	9 18 19				SAND AND SILT; gray mottled brown, fine to coarse sand, fine gravel, silt slightly plastic, local pockets of sand, sandy silt		moist	
	11A	6 7 17				GRAVEL (rock fragments); fine to coarse		moist to very moist	
30	12A	7 34 50/6"				SAND			
						SILT (native); gray brown mottled rust, trace fine sand, local pockets of fine sand, gray silt with fine sand, stained fracture	ML	dry	
	13A	30 50/5"						dry	
35	14A	29 34 50/6"							
						SILTY SAND	SM	wet	
	15A	18 24 41				SILT; dark gray brown mottled rust and gray, laminations non-plastic pockets of light gray silt grades to brown	ML	moist to very moist	
40									

(continued)

* A. 2" split-spoon sampler B. 3" O.D. thin-wall sampler C. 3-1/4" O.D. x 2-1/2" liner D. 3-1/2" O.D. split barrel sampler X. sample not recovered

** A - Atterberg, C - consolidation, DS - direct shear, G - grain size, T - triaxial, P - permeability

water level
impervious seal
piezometer tip

Cathcart Landfill
Snohomish County Public Works

Project No. 88-35169

Figure No.

Converse Consultants Geotechnical Engineering and Applied Sciences

DATE DRILLED: 3/3/88

SUMMARY: BORING NO. G-5A (Cont.)

ELEVATION:

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.

DEPTH IN FEET	SAMPLE NO.*	SAMPLE	BLOWS/6"	OTHER TESTS**	FIELD MOISTURE % OF DRY WEIGHT	DRY DENSITY PCF	DESCRIPTION	SYMBOL	MOISTURE	CONSISTENCY
40	16A		50/5"				SILT (continued)	ML	moist to v. moist	
	17A		50/6"				BEDROCK (very weathered siltstone); dark gray, massive, trace organics, occasional shell fragments hard drilling		dry	
45							Bottom of boring at depth 43 feet. Well Installation: screen 40' to 30' SiO2 41' to 27' bentonite pellets 27' to 23' Volclay grout 23' to 5' bentonite chips to 2' locking SS monument concrete to surface			
50										

* A. 2" split-spoon sampler
B. 3" O.D. thin-wall sampler C. 3-1/4" O.D. x 2-1/2" liner
D. 3-1/2" O.D. split barrel sampler X. sample not recovered

** A - Atterberg, C - consolidation, DS - direct shear, G - grain size, T - triaxial, P - permeability

water level
impervious seal
piezometer tip

Cathcart Landfill
Snohomish County Public Works

Project No. 88-35169

Figure No.

Converse Consultants Geotechnical Engineering and Applied Sciences

DATE DRILLED: 3/7/88

SUMMARY: BORING NO. G-6A

ELEVATION:

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.

DEPTH IN FEET	SAMPLE NO.*	SAMPLE	BLOWS/6"	OTHER TESTS**	FIELD MOISTURE % OF DRY WEIGHT	DRY DENSITY PCF	DESCRIPTION	SYMBOL	MOISTURE	CONSISTENCY
0							SILTSTONE FRAGMENTS (fill); dark gray			
	1A		9 9 7						dry	
5										
							SILTY SAND (native); brown mottled gray and rust, fine to medium, local pockets of sandy silt, silt, and sand	SM		
	2A		8 6 7						moist	
10										
	3A		8 15 50/4"						moist to very moist	
15							grading to very weathered siltstone trace organics on fractures, with iron staining joint and fractures hard drilling			
	4A		50/6"				sample taken out of lead auger			
							SILTSTONE; gray, little fine sand, trace organics, massive			
							Bottom of boring at depth 19 feet.			
20										

Well Installation:
screen 19' to 9'; Si02 19' to 5'
bentonite pellets 5' to 2'; locking
SS monument, concrete to surface

* A. 2" split-spoon sampler
B. 3" O.D. thin-wall sampler
C. 3-1/4" O.D. x 2-1/2" liner
D. 3-1/2" O.D. split barrel sampler
X. sample not recovered

**A - Atterberg, C - consolidation, DS - direct shear, G - grain size, T - triaxial, P - permeability

water level
impervious seal
piezometer tip

Cathcart Landfill
Snohomish County Public Works

Project No. 88-35169

Figure No.

Converse Consultants Geotechnical Engineering and Applied Sciences

DATE DRILLED: 3/7/88

SUMMARY: BORING NO. G-6A

ELEVATION:

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.

DEPTH IN FEET	SAMPLE NO.*	SAMPLE	BLOWS/6"	OTHER TESTS**	FIELD MOISTURE % OF DRY WEIGHT	DRY DENSITY PCF	DESCRIPTION	SYMBOL	MOISTURE	CONSISTENCY
0							SILTSTONE FRAGMENTS (fill); dark gray			
	1A		9 9 7						dry	
5										
							SILTY SAND (native); brown mottled gray and rust, fine to medium, local pockets of sandy silt, silt, and sand	SM		
	2A		8 6 7						moist	
10										
	3A		8 15 50/4"						moist to very moist	
15							grading to very weathered siltstone trace organics on fractures, with iron staining joint and fractures hard drilling			
	4A		50/6"				sample taken out of lead auger SILTSTONE; gray, little fine sand, trace organics, massive			
							Bottom of boring at depth 19 feet.			
20										

Well Installation:
screen 19' to 9'; SiO2 19' to 5'
bentonite pellets 5' to 2'; locking
SS monument, concrete to surface

* A. 2" split-spoon sampler
B. 3" O.D. thin-wall sampler C. 3-1/4" O.D. x 2-1/2" liner
D. 3-1/2" O.D. split barrel sampler X. sample not recovered

** A - Atterberg, C - consolidation, DS - direct shear, G - grain size, T - triaxial, P - permeability

water level
impervious seal
piezometer tip

Cathcart Landfill
Snohomish County Public Works

Project No. 88-35169

Figure No.

Converse Consultants Geotechnical Engineering and Applied Sciences

DATE DRILLED: 4/8/88

SUMMARY: BORING NO. G-6B

ELEVATION:

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.

DEPTH IN FEET	SAMPLE NO.*	SAMPLE	BLOWS/6"	OTHER TESTS**	FIELD MOISTURE % OF DRY WEIGHT	DRY DENSITY PCF	DESCRIPTION	SYMBOL	MOISTURE	CONSISTENCY
0							SILT & SAND (fill); brown, with gray siltstone fragments			
5							SILTY SAND (native); brown, fine to medium, occasional pockets of brown silt			
10							SILTSTONE; gray, very weathered, occasional zones of fine-grained sandstone			
15										
20										

(continued)

* A. 2" split-spoon sampler
B. 3" O.D. thin-wall sampler C. 3-1/4" O.D. x 2-1/2" liner
D. 3-1/2" O.D. split barrel sampler X. sample not recovered

** A - Atterberg, C - consolidation, DS - direct shear, G - grain size, T - triaxial, P - permeability

water level
impervious seal
piezometer tip

DATE DRILLED:

SUMMARY: BORING NO. G-6B (Cont)

ELEVATION:

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.

DEPTH IN FEET	SAMPLE NO.*	SAMPLE	BLOWS/6"	OTHER TESTS**	FIELD MOISTURE % OF DRY WEIGHT	DRY DENSITY PCF	DESCRIPTION	SYMBOL	MOISTURE	CONSISTENCY
20							SILTSTONE; gray, very weathered, occasional zones of fine-grained sandstone			
25										
							grades to slightly weathered gray Siltstone			
30										
35										
40										

(continued)

* A. 2" split-spoon sampler
B. 3" O.D. thin-wall sampler C. 3-1/4" O.D. x 2-1/2" liner
D. 3-1/2" O.D. split barrel sampler X. sample not recovered

** A - Atterberg, C - consolidation, DS - direct shear, G - grain size, T - triaxial, P - permeability

water level
impervious seal
piezometer tip

Cathcart Landfill
Snohomish County Public Works

Project No. 88-35169

Figure No.

Converse Consultants Geotechnical Engineering and Applied Sciences

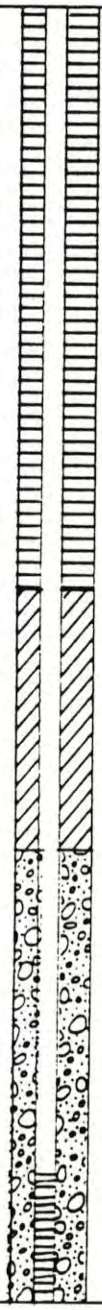
DATE DRILLED:

SUMMARY: BORING NO. G-6B (Cont.)

ELEVATION:

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.

DEPTH IN FEET	SAMPLE NO.*	SAMPLE	BLOWS/6"	OTHER TESTS**	FIELD MOISTURE % OF DRY WEIGHT	DRY DENSITY PCF	DESCRIPTION	SYMBOL	MOISTURE	CONSISTENCY
40							SILTSTONE; gray, very weathered, occasional zones of fine-grained sandstone			
45										
50							grades to unweathered dark gray Siltstone			
55										
60										



(continued)

* A. 2" split-spoon sampler
B. 3" O.D. thin-wall sampler C. 3-1/4" O.D. x 2-1/2" liner
D. 3-1/2" O.D. split barrel sampler X. sample not recovered

**A - Atterberg, C - consolidation, DS - direct shear, G - grain size, T - triaxial, P - permeability

water level
impervious seal
piezometer tip

Cathcart Landfill
Snohomish County Public Works

Project No. 88-35169

Figure No.

Converse Consultants Geotechnical Engineering and Applied Sciences

DATE DRILLED:

SUMMARY: BORING NO. G-6B (Cont.)

ELEVATION:

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.

DEPTH IN FEET	SAMPLE NO.*	SAMPLE	BLOWS/6"	OTHER TESTS**	FIELD MOISTURE % OF DRY WEIGHT	DRY DENSITY PCF	DESCRIPTION	SYMBOL	MOISTURE	CONSISTENCY
60							SILTSTONE; gray, very weathered, occasional zones of fine-grained sandstone possible fracture zone 60.5' to 62.5', some groundwater observed			
65										
70							approximately 6" zone of rough drilling, small amount of groundwater observed			
75										
80										

(continued)

* A. 2" split-spoon sampler
B. 3" O.D. thin-wall sampler C. 3-1/4" O.D. x 2-1/2" liner
D. 3-1/2" O.D. split barrel sampler X. sample not recovered

** A - Atterberg, C - consolidation, DS - direct shear, G - grain size, T - triaxial, P - permeability

water level
impervious seal
piezometer tip

Cathcart Landfill
Snohomish County Public Works

Project No. 88-35169

Figure No.

Converse Consultants — Geotechnical Engineering and Applied Sciences

DATE DRILLED:

SUMMARY: BORING NO. G-6B (Cont.)

ELEVATION:

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.

DEPTH IN FEET	SAMPLE NO.*	SAMPLE	BLOWS/6"	OTHER TESTS**	FIELD MOISTURE % OF DRY WEIGHT	DRY DENSITY PCF	DESCRIPTION	SYMBOL	MOISTURE	CONSISTENCY
80							SILTSTONE; gray, very weathered, occasional zones of fine-grained sandstone			
85										
90							Bottom of boring at depth 88 feet. Well installation: screen 88' to 58' silica sand 88' to 53' bentonite pellets 53' to 49' volclay grout 49' to 3' locking SS monument 3' to +3'			

*A. 2" split-spoon sampler
B. 3" O.D. thin-wall sampler C. 3-1/4" O.D. x 2-1/2" liner
D. 3-1/2" O.D. split barrel sampler X. sample not recovered

**A - Atterberg, C - consolidation, DS - direct shear,
G - grain size, T - triaxial, P - permeability

water level
impervious seal
piezometer tip

Cathcart Landfill
Snohomish County Public Works

Project No. 88-35169

Figure No.

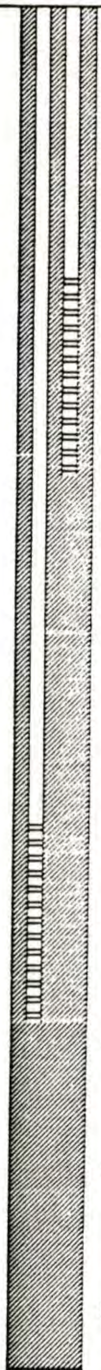
Converse Consultants
Geotechnical Engineering and Applied Sciences

Converse GES

Monitoring Well Geologic & Construction Log

Project Number	Well Number	Sheet
89-35164-03	GP-1	1 of 1

Project: Cathcart Landfill Hydrogeologic Investigation
Location: Snohomish County, Washington
Elevation (Approx. Top of Well Casing):
Surface Elevation (Approx.):
Water Level Elev. (Approx.):
Start Date: February 16, 1989
Drilling Contractor: Jensen Drilling
Finish Date: February 21, 1989
Drilling Method: Air Rotary



Depth feet	Well Construction	Lab Tests	ST	Blows/ 6"	USCS Symbol	Description
0–2	cement annular seal					FILL GRAVEL AND COBBLES; gray-green road fill
2–4						SAND AND SILT; brown; fine to medium sand; scattered fine gravel; scattered organic fragments; loose; (SM)
4–6	bentonite pellets annular seal					SAND; orange-brown; fine to medium; little fine gravel, rounded; trace to little sand; loose; (SP-SM)
6–8	1/2" ID Sch 80 PVC					SILT AND SAND; orange-brown; fine to medium sand; little fine gravel; loose; (ML)
8–14	1/2" ID machine-slotted Sch 80 PVC, 0.020" slot width pea gravel filter pack					GRAVELLY SAND; brown; fine to coarse; fine gravel, rounded; some silt; loose; (SM) abundant wood fragments
14–20	bentonite pellets annular seal 1/2" ID Sch 80 PVC					SAND AND SILT; gray; fine to medium sand; trace to little fine gravel, subrounded to rounded; abundant wood fragments; loose; (SM) organic odor
20–27	1/2" ID machine-slotted Sch 80 PVC, 0.020" slot width pea gravel filter pack					GRAVEL; brown; fine to coarse, subangular to subrounded; little (?) fine to coarse sand; little (?) silt; scattered wood fragments; (GM)
27–35	bentonite pellets backfill pea gravel backfill					RESIDUUM (?) SILT AND SAND; orange-brown; fine to medium sand; little (?) fine to coarse gravel composed of weathered sandstone and siltstone fragments; loose to medium dense; (ML)
35	NOTES (1) 9" ID aluminum surface casing (2) Locking aluminum surface cap used (3) Flush-threaded PVC used					Total depth, 35.0 feet

ST - Sampler Type:
- 4" I.D. Split Spoon
- Bulk Grab Sample
- Drive Barrel

Lab Tests:
- S - Soil Properties
- C - Chemical Properties
- Water Level

Logged by: WRH
Approved by: DRH

Figure No.

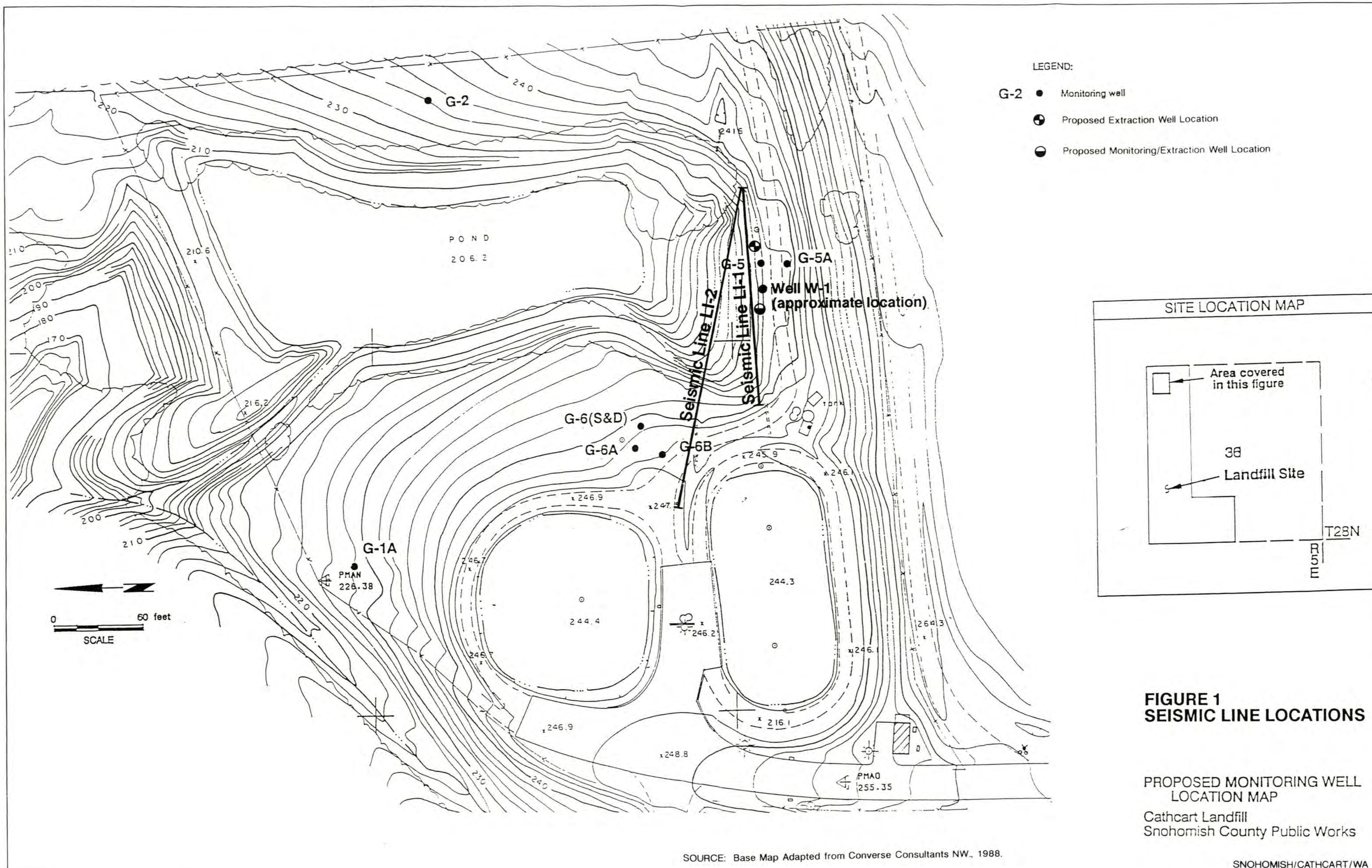


FIGURE 1
SEISMIC LINE LOCATIONS

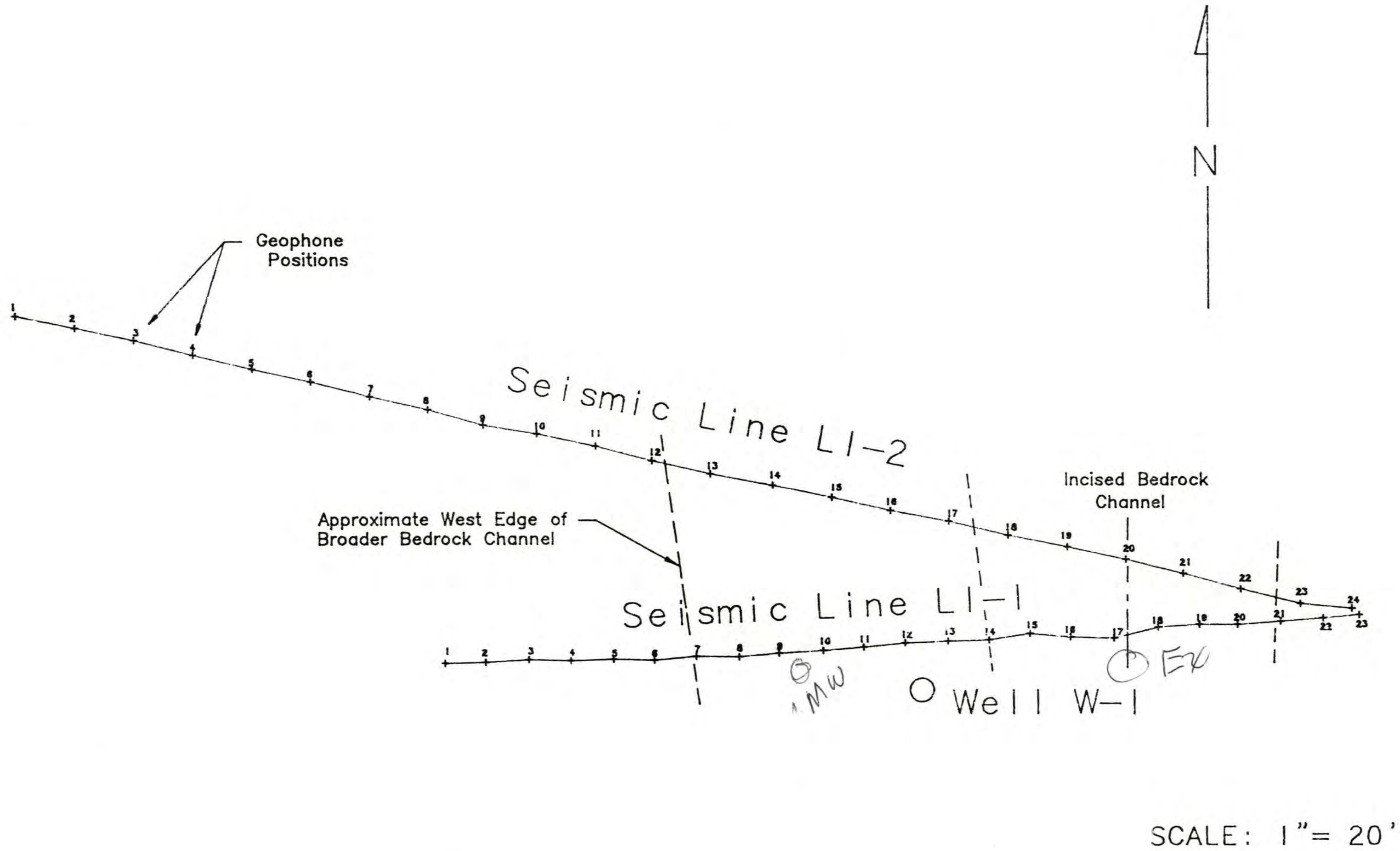
SOURCE: Base Map Adapted from Converse Consultants NW., 1988.

PROPOSED MONITORING WELL LOCATION MAP
Cathcart Landfill
Snohomish County Public Works

SNOHOMISH/CATHCART/WA

913-1402 23727 11/15/91 HP

Golder Associates

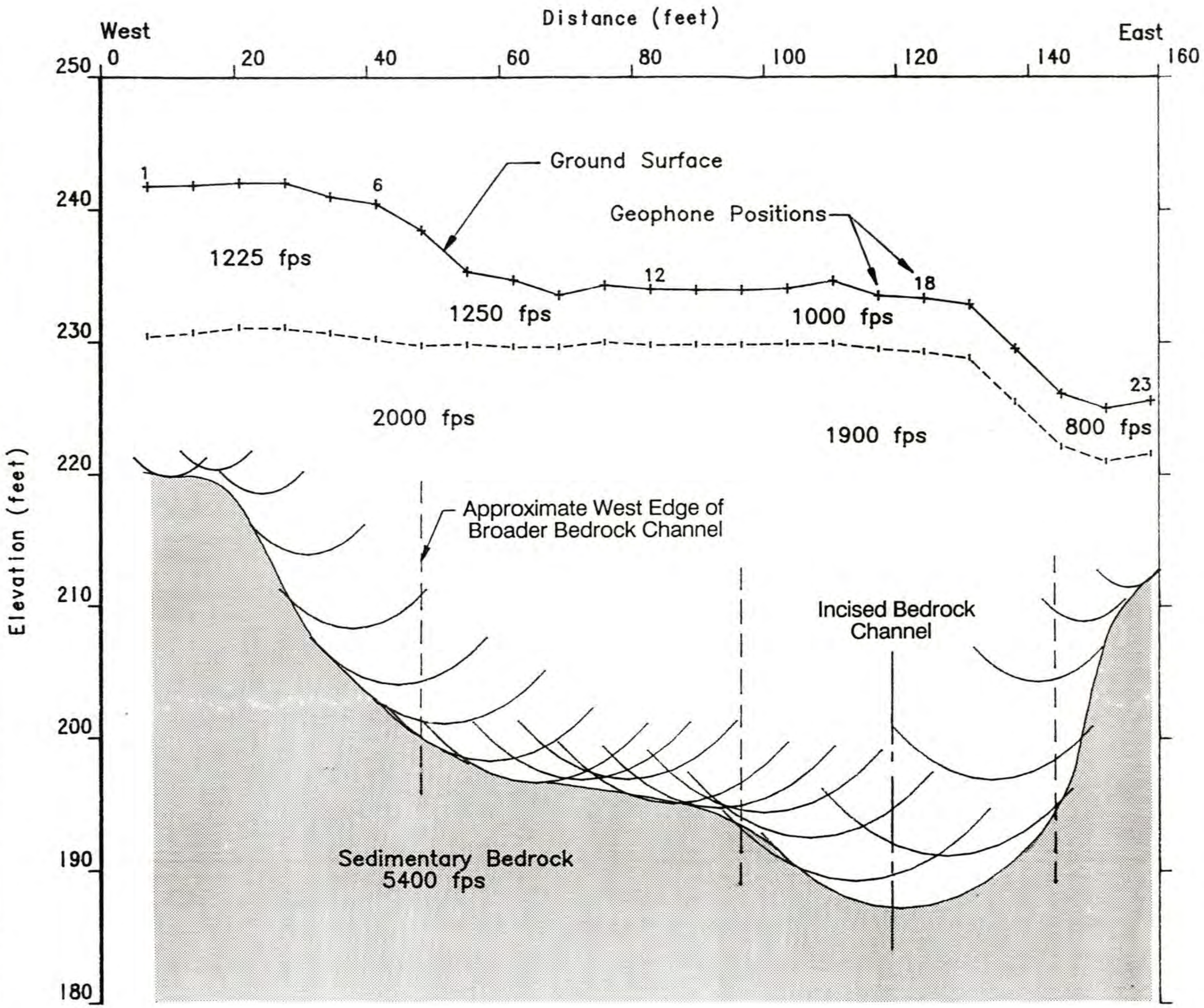


NORTHLAND GEOPHYSICAL COMPANY

CATHCART LANDFILL SEISMIC LINE LOCATIONS

November 1991

FIGURE 2



EXPLANATION

Nominal Geophone Spacing = 7 ft.

Numbers in profile represent compressional wave velocity in feet per second (fps).

Arcs represent loci of possible points on the bedrock refractor; the envelope of these loci is taken as the surface of the refractor.

Shallow (overburden) interfaces are represented by dashed lines.

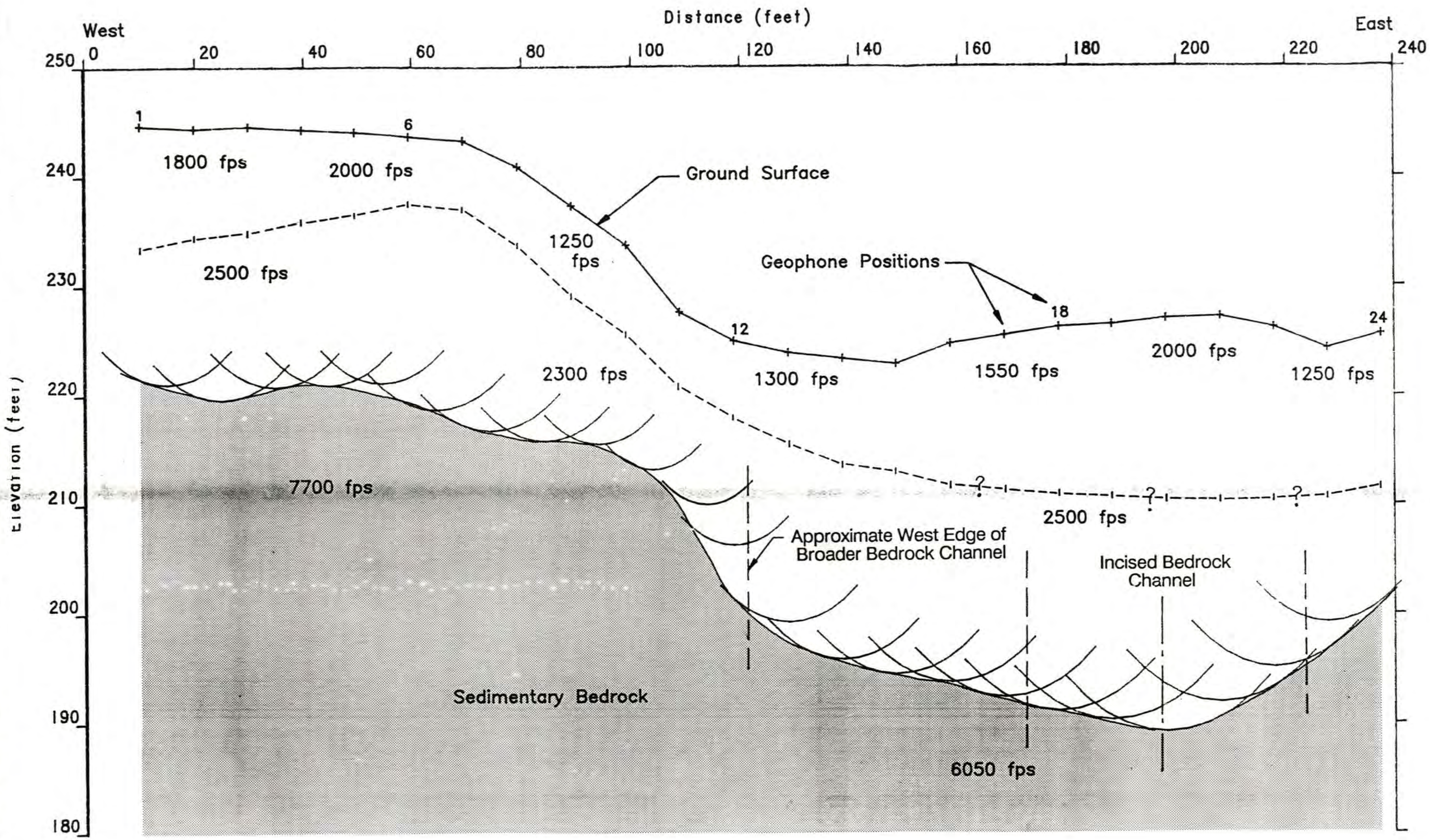
NORTHLAND GEOPHYSICAL
Seattle, Washington

DEPTH SECTION

SEISMIC LINE LI–1

Cathcart Landfill Extraction Well

Hor. Scale: 1"=20'	November 1991
Vert. Scale: 1"=10'	**FIGURE 3**



EXPLANATION

Nominal Geophone Spacing = 10 ft.

Numbers in profile represent compressional wave velocity in feet per second (fps).

Arcs represent loci of possible points on the bedrock refractor; the envelope of these loci is taken as the surface of the refractor.

Shallow (overburden) interfaces are represented by dashed lines.

NORTHLAND GEOPHYSICAL Seattle, Washington	
DEPTH SECTION SEISMIC LINE LI-2 Cathcart Landfill Extraction Well	
Hor. Scale: 1"=20'	November 1991
Vert. Scale: 1"=10'	FIGURE 4