APPENDIX J

GROUNDWATER QUALITY ASSESSMENT REPORT

GROUNDWATER QUALITY ASSESSMENT
FOR
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

DECEMBER 1994

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EXECUTIVE SUMMARY

This report presents the results of a Groundwater Quality Assessment conducted at the American Steel Foundries Sebring Facility. The assessment was performed in accordance with the procedures described in the Groundwater Quality Assessment Plan (RMT, 1992) which was approved by the Ohio Environmental Protection Agency.

The purpose of the assessment was to determine whether any chemical constituents have been released from the landfill to groundwater. In order to accomplish this objective, additional groundwater monitoring wells were installed, a description of site geology and hydrogeology was prepared, and four quarters of groundwater quality data were collected. Upgradient and downgradient groundwater quality was compared to determine whether groundwater quality had changed. Based on the results of this comparison, an enhanced groundwater monitoring program was developed.

The landfill is located within a former strip mine. After the strip mine ceased operation, foundry waste was placed in the excavation. Mine spoils are present on the site, primarily along the northern, southern, and western perimeters of the landfill. The naturally occurring geologic deposits consist of alternating layers of sandstone and shale with coal and underclay. The uppermost aquifer is the Clarion shale. Groundwater flow is generally toward the west.

A statistical evaluation of groundwater quality data was performed using both the tolerance interval method and, for parameters with a large proportion of "non-detects", the test of proportions. Separate statistical evaluations were performed for wells screened in the shale and for wells screened in the spoils. Because spoils are not present upgradient of the landfill, a sidegradient spoils well was chosen to develop tolerance intervals for spoils wells. The results of the statistical evaluation for spoils wells may not be statistically significant because of the limited available sidegradient data.

The statistical comparison indicates that bicarbonate alkalinity, barium, fluoride, sodium, total organic carbon, and manganese are statistically different in downgradient shale wells compared to upgradient shale wells.

As a result of activities conducted during 1994, an enhanced groundwater monitoring program was developed. The program includes the addition of four groundwater monitoring wells screened in the uppermost aquifer, the Clarion Shale. Semiannual groundwater sampling and reporting will be performed to monitor groundwater flow and quality.

Section 1
INTRODUCTION

This report presents the results of the Groundwater Quality Assessment conducted at the American Steel Foundries (ASF) Alliance, Ohio Sebring facility (landfill).

1.1 Background

The landfill, shown on Figure 1, has been in operation for over 20 years as a disposal site for typical foundry wastes from the Sebring facility, including foundry sand, refractories, slag material, and sludge from the sand washers and wet dust collectors.

The possibility exists that, during the past 20 years, hazardous electric arc furnace baghouse dust was intermixed with typical foundry waste and deposited in the landfill. To assess the possibility that hazardous materials were placed in the landfill and may have impacted the groundwater quality, ASF has agreed, as part of a consent decree, to perform a groundwater quality assessment of the site under RCRA 40 CFR Part 265 Subpart F, and Ohio Administrative Code (OAC) 3745-65, et seq.

1.2 Purpose and Scope

The purpose of this investigation was to determine if releases of hazardous waste or hazardous waste constituents from the landfill to groundwater have occurred. The investigation was conducted in accordance with the Groundwater Quality Assessment Plan (RMT, 1992). The scope of the investigation included the following:

- Installation of additional groundwater monitoring wells.
- Sampling site groundwater monitoring wells on a quarterly basis for a period of one year.
- Preparing quarterly reports and submitting them to the OEPA.
- Summarizing site hydrogeologic data.
- Performing a statistical evaluation of groundwater quality.
- Preparing a long-term groundwater monitoring plan.

Section 2
WORK PERFORMED

The field investigation consisted of installation of eight additional groundwater monitoring wells and sampling of monitoring wells during four quarters.

2.1 Monitoring Well Installation

Monitoring wells MW-19, MW-19P, MW-21, MW-21P, MW-22, MW-22P, MW-23, and MW-23P were installed in November 1993 by Summit Drilling under the supervision of RMT. Wells were constructed using procedures outlined in the Groundwater Sampling Plan (RMT, 1992). Drilling logs and well construction details for these wells are presented in Appendices A and B, respectively. Drilling logs and well construction details for all other wells were presented in the Groundwater Quality Assessment Plan (RMT, 1992). Well construction information for all site monitoring wells is presented in Table 1. Well locations are shown in Figure 1.

2.2 Groundwater Sampling

Groundwater sampling was conducted in December 1993 and March, June, and September, 1994. The Groundwater Quality Assessment Plan (Plan) required that during the first quarterly sampling wells MW-1A, MW-4A, MW-13, MW-14, MW-19, MW-19P, MW-20, MW-21, MW-21P, MW-22, MW-22P, and MW-23 be sampled and analyzed for the following:

- Water quality and indicator parameters (Table 3-1 of the Plan).
- Volatile organic compounds (Table 3-2 of the Plan).
- Appendix IX Metals (Table 3-3 of the Plan).

During the second, third, and fourth quarter monitoring, the following parameters were analyzed:

- Water quality and indicator parameters (Table 3-1 of the Plan).
- Selected Appendix IX metals which were detected above the Practical Quantitation Limits (PQLs) (Table 3-3 of the Plan, revised).
- Compounds found in the ASF waste stream (Table 3-5 of the Plan).

The selected Appendix IX metals list excludes the following compounds that were not detected above the PQL and that are not on Table 3-5 of the Plan: beryllium, cyanide, thallium, and vanadium. Copies of Tables 3-1, 3-2, 3-3, 3-5, from the Plan and Table 3-3 (revised after the first quarter monitoring) are presented in Appendix C.

Well MW-19P produces very little water and recovers very slowly. As a result, samples were not collected from this well during the second and fourth quarters. Bicarbonate alkalinity was not analyzed for the fourth quarter because of a laboratory oversight.

Section 3
SITE CONDITIONS

3.1 Geology

The landfill is located within a former strip-mine pit. The Middle Kittanning No.6 and Lower Kittanning No.5 coal beds were strip mined in addition to the Lower Kittanning Underclay and some of the softer shale beneath it. Subsequently, foundry waste was placed in the excavation created by the strip mine.

Based on a stratigraphic section measured at the site, the strata adjacent to the facility are composed primarily of alternating thick and thin layers of sandstone and shale with varying thicknesses of coal and underclay. The uppermost aquifer in the vicinity of the site is the Clarion Shale which is the unit underlying the coal beds that were mined at the site.

Geologic cross sections were constructed to illustrate site conditions. Cross section locations are shown on Figure 1. Geologic cross section A-A′ (Figure 2) runs along the western perimeter (downgradient perimeter of the landfill with respect to groundwater flow). Geologic cross sections B-B′ and C-C′ (Figure 2) run from east to west (from upgradient to downgradient) through the landfill.

Bedrock crops out on the east side of the landfill and consists of thin interbeds of siltstone, shale and sandstone. Secondary permeability is likely to occur in fractures and along bedding planes in this generally fine-grained sequence of sedimentary rock.

Mine spoils are present in the vicinity of the landfill, primarily along the northern, western and southern borders of the landfill. The spoils material is generally fine-grained. Gravel and cobble sized material found in the spoils usually consists of shale or siltstone bedrock fragments. The thickness of the spoils along the western side of the landfill ranges from approximately 11 feet (well MW-20) to 43 feet (well MW-22P). Based on existing borings, spoils are present along the entire western perimeter of the landfill. The thickest spoils are likely in the northwest corner of the site.

Foundry wastes, including foundry sand, range in texture from poorly graded silty sand to clay. The foundry waste is more than 45 feet thick in the center of the landfill. The foundry waste appears to be in contact with spoils and the Clarion Shale along the western perimeter of the landfill (See Figure 2)

3.2 Hydrogeology

The uppermost aquifer at the site is the Clarion Shale. Groundwater measurements were collected concurrently with groundwater sampling and are presented on Table 2. Water table maps, showing the direction of groundwater flow during the third and fourth quarters respectively, are presented on Figures 3 and 4.

Groundwater flow direction is generally toward the west. The horizontal hydraulic gradient is steeper in the eastern portion of the property (approximately 0.02) compared to the western portion of the property (approximately 0.001). The water table occurs in the shale (wells MW-19 and MW-14) or the underclay (well MW-1A) upgradient of the landfill. Downgradient of the landfill, the water table occurs in the spoils, with the exception of well MW-20 (See geologic cross sections B-B′ and C-C′ on Figure 2).

Vertical gradients were calculated for the well nests and are presented in Table 3. Vertical gradients vary seasonally at well nests MW-1A/MW-1 and MW-4A/MW-4: Gradients are upward during the winter and early spring months and downward (groundwater recharge conditions) during the summer months. The vertical gradient at well nest MW-19/MW-19P is strongly downward, probably a result of the low hydraulic conductivity of the shale. Vertical gradients were consistently downward at well nest MW-21/MW-21P and upward at well nest MW-22/MW-22P.

3.3 Description of Current Groundwater Monitoring Program

The current groundwater monitoring well network is summarized on Table 4. Screen depths are presented on Table 1. The depths of screened intervals are illustrated on the geologic cross sections, Figure 2. This program was originally presented in the Groundwater Assessment Plan (RMT, 1992) and was approved by the Ohio Environmental Protection Agency.

There are four upgradient wells each screened in the shale. There are seven downgradient wells,

three screened in the shale and four screened in the spoils. As indicated in Section 2.2, with one exception, the water table is present in the spoils downgradient of the landfill. There are no upgradient wells screened in spoils because spoils were not encountered upgradient of the landfill. Well MW-23 a sidegradient well and is screened in spoils.

Groundwater quality samples were collected during four quarterly events performed during the period December 1993 through September 1994. Well MW-19P produces very little water and recovers very slowly. As a result, samples were not collected from this well during the second and fourth quarters. The discussion of groundwater quality presented in this report is based on the results of this sampling. Analytical results from the first three quarters were presented in previous reports. Analytical results from the fourth quarter sampling are presented in Appendix D.

3.4 Results of Statistical Analysis of Groundwater Quality Data

Statistical methods were used to compare upgradient monitoring well data with downgradient monitoring well data. This comparison was made to assess whether the landfill was affecting groundwater quality. The statistical methods and results are discussed in the following paragraphs.

3.4.1 Statistical Methods

A tolerance interval approach was used to compare background monitoring well data to downgradient monitoring well data. A tolerance interval is constructed from the data collected from unaffected upgradient background wells. The tolerance interval is constructed by first calculating the mean upgradient concentration of each parameter using all available upgradient data points. Then an interval above and below the mean is created based on the variability of the background data. The upper tolerance limit is calculated as follows:

$$TL = X + K \times S$$

where:

TL is the upper tolerance limit

X is the mean

K is the tolerance factor determine from Table 5, Appendix E, and is based on the number of samples (n)

S is the standard deration

A more detailed description of the statistical procedure and calculations is presented in Appendix E. In the case of several parameters, the measured parameter concentration was

below the detection limit. For parameters where the percentage of non-detects was between 0% and 50%, the tolerance interval approach was used and the detection limit was substituted for non-detect values.

In the case of all parameters except pH, an upper tolerance interval was calculated and compared to the actual value for a specific downgradient well. For pH, both upper and lower tolerance intervals were calculated.

For parameters where the percentage of non-detects exceeded 50%, the tolerance interval approach is not appropriate and a test of proportions was used. The test of proportions is a method to determine whether a difference in the proportion of detected values in the background well data compared to the downgradient well data provides statistically significant evidence of impact. The procedure is described in Appendix E.

Each of the statistical methods used here is described in the U.S. EPA publication "Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities" (U.S. EPA, 1989).

Statistical comparisons of upgradient and downgradient groundwater quality were performed for the following parameters using the method indicated.

Tolerance Interval Method	Test of Proportions Method
Chloride	Arsenic
Specific Conductance	Cadmium
Manganese	Cobalt
Sodium	Copper
Sulfate	Nickel
Sulfide	Zinc
Total Organic Carbon	Bicarbonate Alkalinity
Total Organic Halides	Carbonate Alkalinity
pH	Antimony
Fluoride	Barium
Iron	

Tolerance Interval Method

Nitrogen Nitrate

Phenolics

Volatile organic compounds (VOCs) were analyzed during the first quarterly sampling round. No VOCs were detected with the exception of chloroform at upgradient well MW-19P. VOCs were not analyzed during subsequent rounds and therefore no statistical analysis was performed.

The following inorganic parameters analyzed during the first round did not exceed the Practical Quantitation Limit (PQL) and were therefore not analyzed during subsequent rounds: beryllium, cyanide, thallium, and vanadium. No statistical analysis was performed for these parameters.

The following parameters were analyzed for during all quarters and did not exceed the detection limit in upgradient or downgradient wells during any of the sampling rounds: lead, mercury, selenium, silver, and tin. No statistical analysis was performed for these parameters.

3.4.2 Results of Statistical Analysis

As indicated previously, monitoring wells at the site are screened either in the spoils or the shale. Each of these two units is characterized by different groundwater chemistry. Therefore independent statistical comparisons were made for wells screened in the shale and for wells screened in the spoils. As indicated on Table 4, there are four upgradient shale wells (MW-1A, MW-14, MW-19, and MW-19P).

There is only one sidegradient well screened in the spoils (MW-23) and no spoils wells located directly upgradient. While there is sufficient upgradient data to calculate tolerance intervals for shale wells, there is limited upgradient data (3 to 4 data points per parameter) to calculate tolerance intervals for spoils wells. Regardless, tolerance intervals were calculated based on results from well MW-23. However, the results of the statistical comparison of spoils wells are likely not conclusive because of the limited upgradient data and should be reevaluated based on 1995 monitoring results. In addition, the spoils piles are a result of mining activity and there could be substantial variability in the chemical characteristics of the spoils from location

to location. Conclusions regarding potential groundwater impact in spoils wells as a result of landfill operations should not be made based on this analysis.

Tolerance intervals were calculated based on data from upgradient shale wells and are presented on Table E1, Appendix E. The comparison between observed downgradient constituent concentrations and the tolerance intervals for shale wells is presented in Table E2, Appendix E. Table E2 also presents the results of the test of proportions.

Tolerance intervals based on data from the sidegradient spoils well are presented on Table E3, Appendix E. The comparison between observed downgradient constituent concentrations and the tolerance intervals for spoils wells is presented in Table E4, Appendix E.

Summaries of tolerance interval exceedances for shale wells and spoils wells are presented in Tables 5 and 6, respectively. A discussion of the results of the statistical evaluation follows.

Bicarbonate Alkalinity

A tolerance interval for bicarbonate alkalinity in shale wells was not calculated because there were only three upgradient detects in shale wells. There were 8 downgradient detects in shale wells. The results of the test of proportions suggests that there is a significant difference between upgradient and downgradient bicarbonate alkalinity in the shale.

Carbonate Alkalinity

Carbonate alkalinity concentrations at spoils wells MW-4A, MW-21, and MW-22 exceeded the tolerance interval on one occasion at each well.

Barium

A tolerance interval for barium was not calculated because there were no upgradient detects in shale wells. There were 8 downgradient detects. The results of the test of proportions suggests that there is a significant difference between upgradient and downgradient barium concentrations in the shale. Downgradient concentrations

ranged from 110 ug/L to 240 ug/L, below the U.S. EPA maximum contaminant level (MCL) of 1,000 ug/L.

Fluoride

Fluoride concentrations at downgradient shale wells MW-21P and MW-22P exceeded the tolerance interval at each well on all four sampling dates. Fluoride concentrations at well MW-21P ranged from 2.9 to 3.6 mg/L and fluoride concentrations at well MW-22P ranged from 9 to 10 mg/L. The MCL is 4 mg/L.

Fluoride concentrations at downgradient spoils wells MW-13, MW-21 and MW-22 also exceeded the tolerance interval established using sidegradient well MW-23.

Sodium

The sodium concentration at downgradient shale wells MW-21P and MW-22P exceeded the tolerance interval at each well on three occasions and four occasions, respectively. The sodium concentration at downgradient spoils well MW-21 exceeded the tolerance interval established using sidegradient well MW-23 on four occasions.

Total Organic Carbon

The total organic carbon (TOC) concentration at downgradient shale well MW-21P exceeded the tolerance interval on one occasion. The TOC concentration at downgradient spoils well MW-4A, MW-13, MW-21, and MW-22 exceeded the tolerance interval established using sidegradient well MW-23 on four occasions.

Total Organic Halides

The total organic halide (TOX) concentration at shale well MW-21P exceeded the tolerance interval on one occasion.

Manganese

The manganese concentration at downgradient shale well MW-20 exceeded the tolerance interval on three occasions. The manganese concentration at downgradient spoils wells MW-4A, MW-13, MW-21 and MW-22 exceeded the tolerance interval

established using sidegradient well MW-23. Concentrations ranged from 7,800 to 15,000 ug/L. The secondary drinking water MCL is 50 ug/L.

Zinc

The zinc concentration at downgradient spoils well MW-13 exceeded the tolerance interval established using sidegradient well MW-23 on four occasions. Concentrations ranged from 230 to 370 ug/L. The secondary drinking water MCL is 5,000 ug/L.

In summary, it appears that bicarbonate alkalinity, barium, fluoride, sodium, TOC, TOX and manganese concentrations are statistically different in certain downgradient shale wells compared to upgradient shale wells. Zinc, carbonate alkalinity, fluoride, sodium, TOC and manganese concentrations in several spoils well appear to be statistically different than sidegradient spoils well MW-23. However, this conclusion is based on limited data and because of the substantial potential natural variability of geochemistry in these mine spoils piles, comparison of groundwater quality data from spoils wells may not be appropriate.

Section 4

PROPOSED GROUNDWATER MONITORING SYSTEM

Based on the results of the four quarters of groundwater monitoring, it appears that there are some differences between upgradient and downgradient concentrations for certain parameters. In order to better evaluate these, several modifications to the monitoring program are being recommended. Several additional groundwater monitoring wells are proposed to create better horizontal and vertical coverage of the area downgradient of the landfill. The addition of these wells is consistent with the discussions which occurred between ASF and OEPA during the July 25, 1994 meeting. A summary of the revised monitoring program is presented in Table 7 and a brief description of the program follows.

Each of the proposed monitoring wells will be screened within the uppermost aquifer, the Clarion Shale. Well MW-24 will be installed midway between existing well MW-20 and existing wells MW-21/MW-21P. Well MW-25 will be installed midway between existing wells MW-21/MW-21P and existing wells MW-22/MW-22P. With the addition of these two wells there should be good coverage of the entire western (downgradient) border of the landfill.

Additional wells screened in the shale, MW-12P and MW-13P, are proposed at the existing well MW-12, and MW-13 locations, respectively. Well MW-12P will monitor groundwater leaving toward the southwest of the landfill and also may monitor potential affects from the Pond. Well MW-12 will be monitored for water levels but not water quality. Well MW-13P will monitor groundwater in the shale downgradient of the northern portion of the landill.

No additional wells are proposed to be installed in the spoils because it appears that there is substantial natural variability in the geochemistry of the spoils. In addition, the spoils are not present upgradient of the landfill, making it impossible to perform true upgradient/downgradient comparisons. Monitoring the existing monitoring wells screened in the spoils should be sufficient.

The parameters to be analyzed have been modified as a result of observations made during the past four quarterly samplings. The revised parameter list consists of metals and the field indicator parameters pH, specific conductance, and temperature. Eight parameters were either not detected (mercury, selenium, silver, tin, and lead) or detected only several times (carbonate alkalinity, copper, and chromium), during the past four quarters. Tin, copper, carbonate alkalinity, bicarbonate alkalinity, sulfide, total organic carbon, total organic halides, and sodium are not related to the ASF Sebring Facility waste stream (See Appendix C, Table 3-5) and have therefore been eliminated from the program. Nitrate nitrogen is also unrelated to the ASF waste and has been eliminated. No statistical exceedances for chloride and sulfate were noted during 1994 monitoring and these parameters have therefore been eliminated. Sampling will be conducted on a semi-annual basis. Mercury, selenium, silver, lead, and chromium were present in the ASF waste stream but were not detected or were detected infrequently and will therefore be analyzed on an annual basis.

Iron and manganese concentrations may be indicative of impacts from previous mining operations. These parameters have been retained in the program, but results of these analyses will be evaluated in light of previous mining operations.

Table 1

SUMMARY OF MONITORING WELL CONSTRUCTION INFORMATION

ASF SEBRING FACILITY

AMERICAN STEEL FOUNDRIES

ALLIANCE, OHIO

Well Number	Top of Casing Elevation (feet, MSL)	Ground Elevation (feet, MSL)	Original Well Depth (feet)	Measured Well Depth(1)	Screened Interval (depth in feet)	Screened Interval (elevation in feet)	Formation Well Is Screened In	Groundwater Elevation (2) (feet, MSL)
MW-1	1126.73	1124.2	52	51.1	44.5 to 49.5	1074.7 to 1079.7	Shale	1091.20
MW-1A	1126.09	1123.9	42.2	42.4	30 to 40	1083.9 to 1093.9	Shale	1091.56
MW-2	1101.96	1100.3	36.1	36.6	29.1 to 34.1	1066.2 to 1071.2	Spoils	1076.94
MW-3	1093.14	1091.2	27	26.6	19.8 to 24.8	1066.4 to 1071.4	Spoils	1076.89
MW-4	1085.13	1082.6	32.5	32.2	25 to 30	1052.6 to 1057.6	Spoils	1076.63
MW-4A	1085.2	1082.8	16.9	17.5	4.5 to 14.5	1068.3 to 1078.3	Spoils/Foundry Sand	1076.61
MW-12	1087.94	1085.6	37.3	37.4	25 to 35	1050.6 to 1060.6	Sand and Spoils	1077.63
MW-13	1107.70	1106.2	39.5	39.2	28 to 38	1068.2 to 1078.2	Spoils	1079.10
MW-14	1131.18	1128.9	61.8	61.9	49.5 to 59.5	1069.4 to 1079.4	Shale	1080.58
MW-19	1141.16	1138.7	34.5	34.3	22 to 32	1106.7 to 1116.7	Shale	1113.45
MW-19P	1141.36	1138.9	106.5	108.6	99 to 104	1034.9 to 1039.9	Shale	1039.07
MW-20	1113.21	1110.7	41.5	41.3	29 to 39	1071.7 to 1081.7	Shale	1079.31
MW-21	1101.12	1098.6	32.5	32.4	20 to 30	1068.6 to 1078.6	Spoils	1078.56
MW-21P	1100.17	1097.7	67.5	68.4	60 to 65	1032.7 to 1037.7	Shale	1077.42
MW-22	1091.01	1088.5	24.5	22.0	10 to 20	1068.5 to 1078.5	Spoils	1077.18
MW-22P	1091.23	1088.7	67.5	67.0	60 to 65	1023.7 to 1028.7	Shale	1071.83
MW-23	1107.81	1105.3	28.5	27.5	16 to 26	1079.3 to 1089.3	Spoils	1088.74

(1) Depth measured from top of casing by RMT on September 15, 1994

(2) Water levels from June 15, 16, and 17, 1994

Table 2

GROUNDWATER ELEVATIONS
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

Well Designation	Geologic Material	Top of Casing Elevation	December 14-17, 1993		March 15-16, 1994		June 15-17, 1994		September 13-15, 1994	
			Depth to Water	Groundwater Elevation	Depth to Water	Groundwater Elevation	Depth to Water	Groundwater Elevation	Depth to Water	Groundwater Elevation
MW-1	Shale	1126.73	34.11	1092.62	34.45	1092.28	35.53	1091.20	35.27	1091.46
MW-1A	Shale	1126.09	34.66	1091.43	33.89	1092.20	34.53	1091.56	34.61	1091.48
MW-2	Shale	1101.96	24.32	1076.64	23.42	1078.54	25.02	1076.94	25.00	1076.96
MW-3	Spoils	1093.14	15.53	1076.61	14.62	1078.52	16.23	1076.89	16.30	1076.84
MW-4	Spoils	1085.13	7.90	1077.23	7.07	1078.06	8.50	1076.63	8.40	1076.73
MW-4A	Spoils	1085.20	8.05	1077.15	7.68	1077.52	8.59	1076.61	8.48	1076.72
MW-12	Sand and Spoils	1087.94	9.69	1078.25	9.05	1078.89	10.31	1077.63	10.14	1077.80
MW-13	Spoils	1107.70	27.21	1080.49	24.60	1083.10	28.60	1079.10	29.19	1078.51
MW-14	Shale	1131.18	49.52	1081.66	48.70	1082.48	50.60	1080.58	50.64	1080.54
MW-19	Bedrock	1141.16	27.64	1113.52	25.83	1115.33	27.71	1113.45	28.40	1112.76
MW-19P	Bedrock	1141.36	66.24	1075.12	103.12	1038.24	102.29	1039.07	102.90	1038.46
MW-20	Bedrock	1113.21	41.48	1071.73	29.81	1083.40	33.90	1079.31	34.45	1078.76
MW-21	Spoils	1101.12	21.82	1079.30	20.86	1080.26	22.56	1078.56	23.00	1078.12
MW-21P	Bedrock	1100.17	21.92	1078.25	20.77	1079.40	22.75	1077.42	21.60	1078.57
MW-22	Spoils	1091.01	13.18	1077.83	12.27	1078.74	13.83	1077.18	13.81	1077.20
MW-22P	Bedrock	1091.23	19.60	1071.63	18.63	1072.60	19.40	1071.83	20.03	1071.20
MW-23	Spoils	1107.81	18.16	1089.65	18.75	1089.06	19.07	1088.74	19.21	1088.60

Table 3
VERTICAL GROUNDWATER GRADIENTS
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

Well Nest	Formation Well Is Screened In	12/14-17/93 Groundwater Elevation	12/14-17/93 Vertical Gradient	3/15-16/94 Groundwater Elevation	3/15-16/94 Vertical Gradient	6/15-17/94 Groundwater Elevation	6/15-17/94 Vertical Gradient	9/13-15/94 Groundwater Elevation	9/13-15/94 Vertical Gradient
MW-1A	Shale	1091.43	-0.0836	1092.2	-0.0053	1091.56	0.0251	1091.48	0.0014
MW-1	Shale	1092.62	(1,2)	1092.28		1091.2		1091.46	
MW-4A	Spoils\Foundry Sand	1077.15	-0.0036	1077.52	-0.0241	1076.61	0.0130	1076.72	-0.0005
MW-4	Spoils	1077.23		1078.06		1076.33		1076.73	
MW-19	Shale	1113.52	0.5168	1115.33	1.0376	1113.45	1.0011	1112.76	1.0000
MW-19P	Shale	1075.12	(3)	1038.24		1039.07		1038.46	
MW-21	Spoils	1079.3	0.0273	1080.26	0.0224	1078.56	0.0297	1079.52	0.0612
MW-21P	Shale	1078.25		1079.4		1077.42		1077.17	
MW-22	Spoils	1077.83	0.1201	1078.74	0.1169	1077.18	0.1049	1077.2	0.1176
MW-22P	Shale	1071.63		1072.6		1071.83		1071.2	

Notes:
(1) Negative value for vertical gradient indicates upward vertical gradient
(2) Positive value for vertical gradient indicates downward vertical gradient
(3) Vertical gradients for well nest MW-19/MW-19P may not be accurate because this well recovers very slowly.

AJS - c:\projects\asf\vertgra.wk3; date 27-Oct-94

TABLE 4
SUMMARY OF GROUNDWATER MONITORING PROGRAM
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

Upgradient Wells		Downgradient\Sidegradient Wells	
Shale	Spoils	Shale	Spoils
MW-1A MW-19 MW-19P MW-14	MW-23**	MW-20 MW-21P MW-22P	MW-4A* MW-13 MW-21 MW-22

* - Spoils and Foundry Sand
** - Sidegradient well

Table 5
SUMMARY OF STATISTICAL EXCEEDANCES OF TOLERANCE INTERVALS - SHALE WELLS
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

WELL ID.	DATE	PARAMETER	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	FORMATION WELL IS SCREENED IN
MW21P	17-Dec-93	FLUORIDE	3.3	mg/L	2.04	Shale
MW21P	16-Mar-94	FLUORIDE	3.6	mg/L	2.04	Shale
MW21P	16-Jun-94	FLUORIDE	3.1	mg/L	2.04	Shale
MW21P	14-Sep-94	FLUORIDE	2.9	MG/L	2.04	Shale
MW22P	16-Dec-93	FLUORIDE	9	mg/L	2.04	Shale
MW22P	15-Mar-94	FLUORIDE	10	mg/L	2.04	Shale
MW22P	16-Jun-94	FLUORIDE	9.5	mg/L	2.04	Shale
MW22P	14-Sep-94	FLUORIDE	9.5	MG/L	2.04	Shale
MW20	16-Dec-93	MANGANESE, DISSOLVED	10000	ug/L	2748	Shale
MW20	16-Mar-94	MANGANESE, DISSOLVED	8200	ug/L	2748	Shale
MW20	14-Sep-94	MANGANESE, DISSOLVED	8300	UG/L	2748	Shale
MW21P	17-Dec-93	SODIUM, DISSOLVED	290000	ug/L	212143	Shale
MW21P	16-Jun-94	SODIUM, DISSOLVED	330000	ug/L	212143	Shale
MW21P	14-Sep-94	SODIUM, DISSOLVED	340000	UG/L	212143	Shale
MW22P	16-Dec-93	SODIUM, DISSOLVED	470000	ug/L	212143	Shale
MW22P	15-Mar-94	SODIUM, DISSOLVED	470000	ug/L	212143	Shale
MW22P	16-Jun-94	SODIUM, DISSOLVED	580000	ug/L	212143	Shale
MW22P	14-Sep-94	SODIUM, DISSOLVED	500000	UG/L	212143	Shale
MW21P	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC	43	MG/L	35.5	Shale
MW21P	14-Sep-94	TOTAL ORGANIC HALIDE	59	ug/L	52	Shale

Table 6

SUMMARY OF STATISTICAL EXCEEDANCES OF TOLERANCE INTERVALS - SPOILS WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

DOWNGRADIEN WELL ID.	DATE	PARAMETER	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	FORMATION WELL IS SCREENED IN
MW04A	15-Mar-94	ALKALINITY, BICARBONATE	480	mg/L	423	Spoils
MW04A	16-Jun-94	ALKALINITY, BICARBONATE	450	mg/L	423	Spoils
MW04A	14-Sep-94	ALKALINITY, CARBONATE	420	MG/L	55	Spoils
MW21	14-Sep-94	ALKALINITY, CARBONATE	350	MG/L	55	Spoils
MW22	14-Sep-94	ALKALINITY, CARBONATE	140	MG/L	55	Spoils
MW13	15-Mar-94	FLUORIDE	0.38	mg/L	0.37	Spoils
MW13	15-Jun-94	FLUORIDE	0.84	mg/L	0.37	Spoils
MW13	14-Sep-94	FLUORIDE	0.88	MG/L	0.37	Spoils
MW21	16-Dec-93	FLUORIDE	0.49	mg/L	0.37	Spoils
MW21	15-Mar-94	FLUORIDE	0.55	mg/L	0.37	Spoils
MW21	17-Jun-94	FLUORIDE	0.85	mg/L	0.37	Spoils
MW21	14-Sep-94	FLUORIDE	0.66	MG/L	0.37	Spoils
MW22	15-Dec-93	FLUORIDE	0.45	mg/L	0.37	Spoils
MW22	15-Mar-94	FLUORIDE	0.66	mg/L	0.37	Spoils
MW22	15-Jun-94	FLUORIDE	0.5	mg/L	0.37	Spoils
MW22	14-Sep-94	FLUORIDE	0.6	MG/L	0.37	Spoils
MW04A	16-Dec-93	MANGANESE, DISSOLVED	7800	ug/L	7221	Spoils
MW13	15-Dec-93	MANGANESE, DISSOLVED	13000	ug/L	7221	Spoils
MW13	15-Mar-94	MANGANESE, DISSOLVED	11000	ug/L	7221	Spoils
MW13	15-Jun-94	MANGANESE, DISSOLVED	15000	ug/L	7221	Spoils
MW13	14-Sep-94	MANGANESE, DISSOLVED	12000	UG/L	7221	Spoils
MW21	16-Dec-93	MANGANESE, DISSOLVED	13000	ug/L	7221	Spoils
MW21	15-Mar-94	MANGANESE, DISSOLVED	11000	ug/L	7221	Spoils
MW21	17-Jun-94	MANGANESE, DISSOLVED	14000	ug/L	7221	Spoils
MW21	14-Sep-94	MANGANESE, DISSOLVED	10000	UG/L	7221	Spoils
MW22	15-Dec-93	MANGANESE, DISSOLVED	8000	ug/L	7221	Spoils
MW21	16-Dec-93	SODIUM, DISSOLVED	130000	ug/L	84733	Spoils
MW21	15-Mar-94	SODIUM, DISSOLVED	130000	ug/L	84733	Spoils
MW21	17-Jun-94	SODIUM, DISSOLVED	130000	ug/L	84733	Spoils
MW21	14-Sep-94	SODIUM, DISSOLVED	120000	UG/L	84733	Spoils
MW04A	16-Dec-93	TOTAL ORGANIC CARBON AS NPOC	7	mg/L	2.1	Spoils
MW04A	15-Mar-94	TOTAL ORGANIC CARBON AS NPOC	13	mg/L	2.1	Spoils
MW04A	16-Jun-94	TOTAL ORGANIC CARBON AS NPOC	2.4	mg/L	2.1	Spoils
MW04A	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC	18	MG/L	2.1	Spoils
MW13	15-Dec-93	TOTAL ORGANIC CARBON AS NPOC	8.2	mg/L	2.1	Spoils
MW13	15-Mar-94	TOTAL ORGANIC CARBON AS NPOC	4.3	mg/L	2.1	Spoils
MW13	15-Jun-94	TOTAL ORGANIC CARBON AS NPOC	3.3	mg/L	2.1	Spoils
MW13	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC	24	MG/L	2.1	Spoils
MW21	16-Dec-93	TOTAL ORGANIC CARBON AS NPOC	15	mg/L	2.1	Spoils
MW21	15-Mar-94	TOTAL ORGANIC CARBON AS NPOC	5.5	mg/L	2.1	Spoils
MW21	17-Jun-94	TOTAL ORGANIC CARBON AS NPOC	16	mg/L	2.1	Spoils
MW21	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC	7.4	MG/L	2.1	Spoils
MW22	15-Dec-93	TOTAL ORGANIC CARBON AS NPOC	27	mg/L	2.1	Spoils
MW22	15-Mar-94	TOTAL ORGANIC CARBON AS NPOC	3.6	mg/L	2.1	Spoils
MW22	15-Jun-94	TOTAL ORGANIC CARBON AS NPOC	4	mg/L	2.1	Spoils
MW22	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC	23	MG/L	2.1	Spoils
MW13	15-Dec-93	ZINC, DISSOLVED	250	ug/L	122	Spoils
MW13	15-Mar-94	ZINC, DISSOLVED	230	ug/L	122	Spoils
MW13	16-Jun-94	ZINC, DISSOLVED	370	ug/L	122	Spoils
MW13	14-Sep-94	ZINC, DISSOLVED	240	UG/L	122	Spoils

Tolerance interval constructed using data from sidegradient well MW-23

Table 7

PROPOSED GROUNDWATER MONITORING PROGRAM
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

Monitoring Wells	
Upgradient	**Downgradient**
MW-1A MW-14 MW-19 MW-19P(1) MW-23 (sidegradient)	MW-4A MW-13 MW-13P(2) MW-20 MW-21 MW-21P MW-22 MW-22P MW-24(2) MW-25(2) MW-12P(2)

Parameters to be Analyzed	
Semiannually	**Annually**
Specific Conductance(3) pH(3) Temperature (3) Iron Fluoride Barium Manganese Arsenic Cadmium Cobalt Zinc Nickel	Chromium Lead Mercury Selenium Silver

(1) Well MW-19P will be purged several days prior to sampling so that sufficient water is available for sampling.

(2) Proposed Monitoring Well

(3) Specific conductance temperatures and pH will be measured in the field. Water levels will also be measured at each well in the program on a semi-annual basis.

APPENDIX A
BORING LOGS

LOG OF TEST BORING

F-203 (R 01-87)

PROJECT NAME	ASF Sebring MW Installation	BORING NO.	MW-19P
LOCATION	Alliance, Ohio	SHEET NO.	1 OF 3
CONTRACTOR	Summit Drilling	PROJECT NO.	2169.17
DRILLING METHOD	HSA, Core, Tricone	INSTALLATION	
		SURFACE ELEV.	
		BOREHOLE DIA.	4 IN.

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
1	SS	19/25/36		MW19		SILTY SAND (SM), fine grained, 20% silt, yellowish brown, 10YR 5/6, very dense, moist, weathered sandstone
2	SS	50/5				
3	SS	50/4			5	S.A.A., but light yellowish brown, 10YR 6/4
						SILT (ML), highly compacted, light yellowish brown, 2.5Y 6/4, moist, very dense, weathered siltstone
4	RC		80	MW19P	10	SANDSTONE, fine grained, light yellowish brown, 10YR 6/4, rqd=40%, moderately cemented, small amount of brownish yellow, 10YR 6/8, mottling
					15	
5	RC		95		20	SILTSTONE, micaceous, light brownish gray, 10YR 6/2, moderately cemented, distinct, 1.2 mm bedding planes, large concentration of iron staining in vertical and horizontal fractures, rqd=0%, numerous bedding plan fractures
					25	SHALE, very micaceous, dark gray and gray, 2.5Y5N5 and 2.5Y5N5, "zebra" striped, very thin (1-10 mm), undulcting bedding planes, small amount of iron staining along horizontal bedding plan fractures, relatively hard and massive, easily separated along bedding planes, rqd=25% Very soft 6" layer at 28'-28.5'
6	RC		90		30	S.A.A. Rqd=40%
					35	
7	RC		65			

GENERAL NOTES

DATE STARTED	NOV 11 93
DATE COMPLETED	NOV 22 93
RIG	CME 75
CREW CHIEF	E. Pucci
LOGGED	R. Welch
CHECKED	REH

WATER LEVEL OBSERVATIONS

WHILE DRILLING ▽	
AT COMPLETION ▼	
AFTER DRILLING	
CAVE-IN: DATE/TIME	DEPTH
WATER: DATE/TIME	DEPTH

LOG OF TEST BORING

F-203 (R 01-87)

PROJECT NAME	ASF Sebring MW Installation	BORING NO.	MW-19P
LOCATION	Alliance, Ohio	SHEET NO.	2 OF 3
CONTRACTOR	Summit Drilling	PROJECT NO.	2169.17
DRILLING METHOD	HSA, Core, Tricone	INSTALLATION	
		SURFACE ELEV.	
		BOREHOLE DIA.	4 IN.

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
						Shale, as above, some iron staining in horizontal fractures, extensive in vertical fractures, rqd=10%
					45	
				MW19P		Void from 47'-52'
8	RC		75		50	
						SHALE, soft, clay like where wet (bottom 1'), very friable when dry (top 1'), 2.5Y5N5/, gray, rqd=0%
					55	
9	RC		85		60	
						SHALE, gray, 2.5Y5N5/, medium hardness, friable, rqd=0%, moderately defined bedding, moist, very fractured horizontal and vertical
					65	SHALE, gray, 2.5Y5N5/, medium hardness, rqd=80%, moderately defined bedding
10	RC		90		70	S.A.A., but dark green, 2.5Y 4N4/
					75	
						S.A.A., but softer and dark gray to very dark gray
11	RC		90		80	Grades into coal
						COAL, black, 2.5Y 2N2/, rqd=35%
					85	SHALE, very dary gray, 2.5Y 3N3/, medium hardness, somewhat massive, indistinct bedding, plant material present

LOG OF TEST BORING

F-203 (R 01-87)

PROJECT NAME: ASF Sebring MW Installation
LOCATION: Alliance, Ohio
CONTRACTOR: Summit Drilling
DRILLING METHOD: HSA, Core, Tricone

BORING NO.: MW-19P
SHEET NO. 3 OF 3
PROJECT NO.: 2169.17
INSTALLATION:
SURFACE ELEV.:
BOREHOLE DIA.: 4 IN.

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
12	RC		95	MW19P	90	S.A.A., rqd=65%
					95	
13	RC		85		100	S.A.A., rqd=40%
					105	End of boring 105 feet
					110	
					115	
					120	
					125	
					130	

LOG OF TEST BORING

F-203 (R 01-87)

PROJECT NAME	ASF Sebring MW Installation	BORING NO.	MW-20
LOCATION	Alliance, Ohio	SHEET NO.	1 OF 1
CONTRACTOR	Summit Drilling	PROJECT NO.	2169.17
DRILLING METHOD	4 1/4" ID HSA	INSTALLATION	
		SURFACE ELEV.	
		BOREHOLE DIA.	10 IN.

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
1	SS	7/8/8	12			LEAN CLAY (CL), black, 7.5YR, moist (qu=2.5), very stiff, slightly plastic, spoils
2	SS	10/12/12	12			
3	SS	7/9/10	14		5	LEAN CLAY (CL), 50% silt, reddish yellow and gray, 7.5YR 6/6, and 10YR 6/1, dry-moist (qu>4.5), hard, slightly plastic, spoils
4	SS	5/5/10	10			
5	SS	3/6/7	12			
6	SS	4/6/3	10		10	S.A.A., but noncohesive and dry
7	SS	5/3/4	12			SHALE, very friable,light brownish gray, 10YR 6/2, dry, powdered, spoils
8	SS	15/13/14	12			
9	SS	10/15/19	14		15	
10	SS	10/15/19	13			
11	SS	15/13/13	12			
12	SS	12/20/26	13			
13	SS	13/16/21	12		20	
14	SS	12/17/16	10			
15	SS	17/10/10	11			
					25	
					30	SHALE, more competent, light gray, 7.5YR N7/, dry
					▽	S.A.A., wet
					35	S.A.A.
					40	End of boring 39.5 feet

MW20

GENERAL NOTES

DATE STARTED NOV 8 93

DATE COMPLETED NOV 8 93

RIG CME 75

CREW CHIEF E. Pucci

LOGGED R. Welch CHECKED REH

WATER LEVEL OBSERVATIONS

WHILE DRILLING ▽ 32.0

AT COMPLETION ▼

AFTER DRILLING

CAVE-IN: DATE/TIME _____ DEPTH _____

WATER: DATE/TIME _____ DEPTH _____

LOG OF TEST BORING

F-203 (R 01-87)

RMT

PROJECT NAME	ASF Sebring MW Installation	BORING NO.	MW-21
LOCATION	Alliance, Ohio	SHEET NO.	1 OF 1
CONTRACTOR	Summit Drilling	PROJECT NO.	2169.17
DRILLING METHOD	4 1/4" ID HSA	INSTALLATION	
		SURFACE ELEV.	
		BOREHOLE DIA.	IN.

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
					5	No samples taken See boring log MW-21P for description of lithology
					10	
					15	
					20	
					25	
					30	
					35	

GENERAL NOTES

DATE STARTED NOV 24 93

DATE COMPLETED NOV 24 93

RIG CME 75

CREW CHIEF E. Pucci

LOGGED R. Welch CHECKED

WATER LEVEL OBSERVATIONS

WHILE DRILLING ▽

AT COMPLETION ▼

AFTER DRILLING

CAVE-IN: DATE/TIME DEPTH

WATER: DATE/TIME DEPTH

LOG OF TEST BORING

F-203 (R 01-87)

BORING NO. MW-21P
SHEET NO. 1 OF 2
PROJECT NO. 2169.17
INSTALLATION
SURFACE ELEV.
BOREHOLE DIA. 10 IN.

PROJECT NAME ASF Sebring MW Installation
LOCATION Alliance, Ohio
CONTRACTOR Summit Drilling
DRILLING METHOD 4 1/4" ID HSA, Core

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
1	SS	4/6/7	4	MW21P		LEAN CLAY (CL), grayish brown, 10YR 5/2 (qu=3.5), very stiff, plastic, mottling throughout, spoils
2	SS	8/6/4	4			
3	SS	3/5/3	6			
4	SS	3/6/6/7	8		5	
5	SS	7/7/5/6	2	MW21		S.A.A., but dark gray, 10YR 4/1
6	SS	3/4/5/8	12			
7	SS	7/8/7/10	10		10	
8	SS	3/5/8/7	11			
9	SS	7/7/7/8	10			
10	SS	7/8/7/12	12			
11	SS	6/8/8/8	16		15	S.A.A., but gray, 5Y 5/1, shale fragments
12	SS	4/4/6/7	8			LEAN CLAY (CL), as above, brown, 10YR 5/3
13	SS	10/7/8/7	12			
14	SS	6/7/22/11	10		20	
15	SS	4/6/7/8	10			
16	SS	3/6/7/7	10			
17	SS	6/7/8/3	12		25	
						S.A.A.
					30	S.A.A., but wet

GENERAL NOTES

DATE STARTED NOV 23 93
DATE COMPLETED NOV 23 93
RIG CME 75
CREW CHIEF E. Pucci
LOGGED R. Welch CHECKED REH

WATER LEVEL OBSERVATIONS

WHILE DRILLING ▽
AT COMPLETION ▼
AFTER DRILLING
CAVE-IN: DATE/TIME DEPTH
WATER: DATE/TIME DEPTH

LOG OF TEST BORING

F-203 (R 01-87)

PROJECT NAME: ASF Sebring MW Installation
LOCATION: Alliance, Ohio
CONTRACTOR: Summit Drilling
DRILLING METHOD: 4 1/4" ID HSA, Core

BORING NO.: MW-21P
SHEET NO. 2 OF 2
PROJECT NO.: 2169.17
INSTALLATION:
SURFACE ELEV.:
BOREHOLE DIA.: 10 IN.

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL NO.	INTERVAL TYPE	RECOVERY N	RECOVERY IN	MOISTURE	DEPTH	
				MW21P		Sandy seam at 37.5'-39.5'
					40	
						SHALE, gray, 7.5YR N6/, soft weathered, clay like
					45	
18	RC		100		50	SHALE, gray, 7.5YR N5/, hard, rqd=40%, distinct, light to dark gray laminous bedding
					55	
19	RC		100		60	S.A.A.
					65	End of boring 65 feet
					70	
					75	

LOG OF TEST BORING

F-203 (R 01-87)

PROJECT NAME	ASF Sebring MW Installation	BORING NO.	MW-22
LOCATION	Alliance, Ohio	SHEET NO.	1 OF 1
CONTRACTOR	Summit Drilling	PROJECT NO.	2169.17
DRILLING METHOD	4 1/4" ID HSA	INSTALLATION	
		SURFACE ELEV.	
		BOREHOLE DIA.	10 IN.

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
					5	No samples taken See boring log MW-22P for description of lithology
					10	
					15	
					20	
					25	

GENERAL NOTES

DATE STARTED NOV 11 93

DATE COMPLETED NOV 11 93

RIG CME 75

CREW CHIEF B. Krakow

LOGGED R. Welch CHECKED

WATER LEVEL OBSERVATIONS

WHILE DRILLING ▽

AT COMPLETION ▼

AFTER DRILLING

CAVE-IN: DATE/TIME DEPTH

WATER: DATE/TIME DEPTH

LOG OF TEST BORING

F-203 (R 01-87)

PROJECT NAME	ASF Sebring MW Installation	BORING NO.	MW-22P
LOCATION	Alliance, Ohio	SHEET NO.	1 OF 2
CONTRACTOR	Summit Drilling	PROJECT NO.	2169.17
DRILLING METHOD	4 1/4" ID HSA, Core	INSTALLATION	
		SURFACE ELEV.	
		BOREHOLE DIA.	10 IN.

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL NO.	INTERVAL TYPE	RECOVERY N	RECOVERY IN	MOISTURE	DEPTH	
1	SS	6/7/4	12	M		POORLY GRADED SAND (SP), very dark gray, 10YR 3/1, moist, medium dense, foundry sand
2	SS	6/8/6	13	W		
3	SS	3/3/5	13	2	5	S.A.A.
4	SS	3/5/3	14	2		LEAN CLAY (CL), approximately 10% silt, gray, 10YR 5/1, moist (qu=2.0), stiff, slightly plastic, spoils
5	SS	3/4/6	10	M		
6	SS	8/3/4	11	W	10	S.A.A.
7	SS	3/5/5	13	2		SILT (ML), 5-10% medium coarse sand, dark gray, 7.5YR N4/, wet, medium dense, spoils/foundry sand
8	SS	3/10/9	12	2		
9	SS	4/8/15	12	P	15	S.A.A.
10	SS	4/8/7	14			
11	SS	9/10/15	15			S.A.A.
12	SS	7/12/18	12			
13	SS	4/12/13	15		20	LEAN CLAY (CL), 40% slt, slightly plastic, light brownish gray, 10YR 6/2, wet (qu=1), medium stiff to stiff, very angular rock (sandstone/siltstone) fragments' interspersed throughout, very inconsistent color
14	SS	5/10/16	14			
15	SS	10/18/18	15			SHALE, weathered, soft clay like, plastic, light gray, 10YR 6/1
16	SS	12/11/16	16		25	LEAN CLAY (CL), 30-40% silt, slightly plastic, dark grayish brown, 10YR 4/2, wet (qu=5), soft, very inconsistent color, siltstone fragments throughout
17	SS	9 11	10			
18	SS	50/3"	4			
19	SS	50/6" 50/3"	2		30	S.A.A.

GENERAL NOTES

DATE STARTED NOV 9 93

DATE COMPLETED NOV 9 93

RIG CME 75

CREW CHIEF E. Pucci

LOGGED R. Welch CHECKED REH

WATER LEVEL OBSERVATIONS

WHILE DRILLING ▽ 12.5

AT COMPLETION ▼

AFTER DRILLING

CAVE-IN: DATE/TIME _____ DEPTH _____

WATER: DATE/TIME _____ DEPTH _____

LOG OF TEST BORING

F-203 (R 01-87)

PROJECT NAME	ASF Sebring MW Installation	BORING NO.	MW-22P
LOCATION	Alliance, Ohio	SHEET NO.	2 OF 2
CONTRACTOR	Summit Drilling	PROJECT NO.	2169.17
DRILLING METHOD	4 1/4" ID HSA, Core	INSTALLATION	
		SURFACE ELEV.	
		BOREHOLE DIA.	10 IN.

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
				MW22P		S.A.A., but 2" sand layer at top
					40	
						SHALE, soft, weathered, clay like, gray, 7.5YR N6/
					45	
20	RC		60		50	Auger refused at 50' 50' change from HSA to rock coring SHALE, hard, gray, 7.5YR N5/, massive, distinct bedding laminating, rqd=0%
					55	
21	RC		95		60	S.A.A.
						64' vertical fractures
					65	End of boring 65 feet
					70	
					75	

LOG OF TEST BORING

F-203 (R 01-87)

BORING NO. MW-23
SHEET NO. 1 OF 1
PROJECT NO. 2169.17
INSTALLATION
SURFACE ELEV.
BOREHOLE DIA. 12 IN.

PROJECT NAME ASF Sebring MW Installation
LOCATION Alliance, Ohio
CONTRACTOR Summit Drilling
DRILLING METHOD 6 1/4" ID HSA

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
1	SS	3/7/9	6	M		LEAN CLAY (CL), reddish yellow, 7.5YR 6/6, dry (qu=4.5+), hard, slightly-moderately plastic, dark brown mottling, spoils
2	SS	6/7/7	7	W		
3	SS	7/4/9	7	2		
4	SS	6/6/7	9		5	
5	SS	9/8/8	8	3		
6	SS	8/9/8	10			
7	SS	6/9/9	12		10	
8	SS	10/8/8	14			
9	SS	9/7/8	14			
10	SS	6/7/9	12			
11	SS	7/7/10	16		15	LEAN CLAY (CL), 10YR 5/4, yellowish brown, moist (qu=4.0-4.5), hard, plastic, some strong brown mottling with shale fragments throughout
12	SS	12/10/9	12			
13	SS	11/11/11	8			
14	SS	13/11/12	10		20	
15	SS	12/4/8	12			
16	SS	7/9/12	12			
17	SS	10/7/7	14		25	
18	SS	7/9/11	12			
19	SS	8/6/10	14			
					30	
					35	
						End of boring 36.5 feet

GENERAL NOTES

DATE STARTED NOV 22 93
DATE COMPLETED NOV 23 93
RIG CME 75
CREW CHIEF B. Krakow
LOGGED R. Welch CHECKED REH

WATER LEVEL OBSERVATIONS

WHILE DRILLING ▽
AT COMPLETION ▼
AFTER DRILLING
CAVE-IN: DATE/TIME DEPTH
WATER: DATE/TIME DEPTH

LOG OF TEST BORING

F-203 (R 01-87)

BORING NO. MW-19
SHEET NO. 1 OF 1
PROJECT NO. 2169.17
INSTALLATION
SURFACE ELEV.
BOREHOLE DIA. IN.

PROJECT NAME ASF Sebring MW Installation
LOCATION Alliance, Ohio
CONTRACTOR Summit Drilling
DRILLING METHOD 6 1/4" HSA, Tricone

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
					5	No samples taken See boring log MW-19P for description of lithology
					10	
					15	
					20	
					25	
					30	
					35	
					40	
					45	

GENERAL NOTES

DATE STARTED NOV 23 93
DATE COMPLETED NOV 23 93
RIG CME 75
CREW CHIEF B. Krakow
LOGGED R. Welch CHECKED

WATER LEVEL OBSERVATIONS

WHILE DRILLING ▽
AT COMPLETION ▼
AFTER DRILLING
CAVE-IN: DATE/TIME DEPTH
WATER: DATE/TIME DEPTH

APPENDIX B

WELL CONSTRUCTION DETAILS

American Steel Foundries

PROJECT NAME: Sebring Facility NO. 2169.17

WELL NO. MW-19P

DATE INSTALLED 11-22-93

FTI

Form 11 (Revised 7-17 (8 11-85))

ELEV. (T.O.C.) 1141.16

GROUND SURF. ELEV. 1138.9

BENTONITE PELLETS/GRANULAR/POWDER 3/8" Holeplug Benlonite Pellets — DEPTH FROM GROUND SURFACE 0 FT.

BACKFILL MATERIAL 3/8" Holeplug Benlonite Chips

LENGTH OF SOLID PIPE 101.5 FT.

BACKFILL METHOD: PIPE TREMIE, INNER TREMIE, CAVITY FILLED

BOREHOLE DIA. 6 IN. 0-55' / 4 IN. 55-104 — 95 FT.

BENTONITE PELLETS/GRANULAR/POWDER — 95 FT.

SILICA SAND FILTER PACK MATERIAL: Fine Colorado Silica Sand — 97 FT.

99 FT.

WELL SCREEN LENGTH 5 FT.

Coarse Silica Sand

WELL BOTTOM ELEV. — 104 FT. / 104 FT.

SEAL MATERIAL: NA — FT.

BACKFILL MATERIAL: NA — FT.

1) CASING DETAILS

A) TYPE OF PIPE: (PVC) STAINLESS, TEFLON, OTHER

PIPE SCHEDULE 80

B) TYPE OF PIPE JOINTS: COUPLINGS, (THREADED) (W/TAPE?), OTHER

C) WAS SOLVENT USED? YES OR (NO)

D) TYPE OF WELL SCREEN: (PVC) STAINLESS, TEFLON, OTHER

E) WELL SCREEN SLOT SIZE 0.010

F) PIPE DIA: ID IN. 2.0 OD IN. 2.3

G) INSTALLED PROTECTOR PIPE W/LOCK? (YES) OR NO

PROTECTOR PIPE DIA. 4 IN.

2) WELL DEVELOPMENT

A) METHOD: (BAILING) PUMPING, (SURGING) COMPRESSED AIR

OTHER

(NOTE ADDITIONAL COMMENTS BELOW)

B) TIME SPENT FOR DEVELOPMENT? 30 min.

C) APPROXIMATE WATER VOLUME: REMOVED 12 gal.

ADDED

D) WATER CLARITY BEFORE DEVELOPMENT: CLEAR, (TURBID), OPAQUE

E) WATER CLARITY AFTER DEVELOPMENT: (CLEAR), SLIGHTLY TURBID, TURBID, OPAQUE

F) ODOR? YES OR (NO)

3) WATER LEVEL SUMMARY

A) DEPTH FROM TOP OF CASING AFTER DEVELOPMENT? FT. OR (DRY)

B) OTHER MEASUREMENTS (T.O.C.):

DATE/TIME Static 55.5 FT.

DATE/TIME FT.

DATE/TIME FT.

ADDITIONAL COMMENTS:

American Steel Foundries

PROJECT NAME: Sebring Facility NO. 2169.17

WELL NO. MW-19

DATE INSTALLED 11-22-93

ELEV. (T.O.C.)

GROUND SURF. ELEV. 1141.16

1138.7

DEPTH FROM GROUND SURFACE 0 FT.

BENTONITE PELLETS/GRANULAR/POWDER 3/8" Holeplug Benlonite Chips ____ FT.

BACKFILL MATERIAL 3/8" Holeplug Benlonite Chips

LENGTH OF SOLID PIPE 24.5 FT.

BACKFILL METHOD PIPE TREMIE/AUGER TAMPER GRAVITY FILLED

BOREHOLE DIA. 10 IN. ____ FT.

BENTONITE PELLETS/GRANULAR/POWDER SAA 3/8" Holeplug Benlonite Chips 18 FT.

SILICA SAND Fine Colorado Silica Sand 20 FT.

FILTER PACK MATERIAL Coarse Silica Sand 22 FT.

WELL SCREEN LENGTH 10 FT.

WELL BOTTOM ELEV. ____ 32 FT. 32 FT.

SEAL MATERIAL 3/8" Holeplug Benlonite Chips 34 FT.

BACKFILL MATERIAL Coarse Silica Sand 44 FT.

1) CASING DETAILS

A) TYPE OF PIPE: (PVC) STAINLESS, TEFLON, OTHER ____

PIPE SCHEDULE 40

B) TYPE OF PIPE JOINTS: COUPLINGS, (THREADED) (W/TAPE?), OTHER ____

C) WAS SOLVENT USED? YES OR (NO)

D) TYPE OF WELL SCREEN: (PVC) STAINLESS, TEFLON, OTHER ____

E) WELL SCREEN SLOT SIZE 0.010

F) PIPE DIA: ID IN. 2.0 OD IN. 2.3

G) INSTALLED PROTECTOR PIPE W/LOCK? (YES) OR NO

PROTECTOR PIPE DIA. 4 IN.

2) WELL DEVELOPMENT

A) METHOD (BAILING) PUMPING, (SURGING) COMPRESSED AIR

OTHER ____

(NOTE ADDITIONAL COMMENTS BELOW)

B) TIME SPENT FOR DEVELOPMENT? 20 min.

C) APPROXIMATE WATER VOLUME: REMOVED 2 gal.

ADDED ____

D) WATER CLARITY BEFORE DEVELOPMENT? CLEAR, (TURBID), OPAQUE

E) WATER CLARITY AFTER DEVELOPMENT? CLEAR, (SLIGHTLY TURBID), TURBID, OPAQUE

F) ODOR? YES OR (NO)

3) WATER LEVEL SUMMARY

A) DEPTH FROM TOP OF CASING AFTER DEVELOPMENT? ____ FT. OR (DRY)

B) OTHER MEASUREMENTS (T.O.C.):

DATE/TIME Static 27 FT.

DATE/TIME ____ FT.

DATE/TIME ____ FT.

ADDITIONAL COMMENTS: ____

American Steel Foundries

PROJECT NAME: Sebring Facility NO. 2169.17

WELL NO. MW-20

DATE INSTALLED 11-8-93

ELEV. (T.O.C.) 1113.21

GROUND SURF. ELEV. 1110.7

DEPTH FROM GROUND SURFACE 0 FT.

BENTONITE PELLETS/GRANULE/POWDER 3/8" Holeplug Benlonite Chips — NA FT.

BACKFILL MATERIAL 3/8" Holeplug Benlonite Chips

LENGTH OF SOLID PIPE 31.5 FT.

BACKFILL METHOD PIPE TREMIE/AUGER TREMIE GRAVITY FILL

BOREHOLE DIA. ___ IN.

NA FT.

BENTONITE PELLETS/GRANULE/POWDER SAA 3/8" Holeplug Benlonite Chips — 24 FT.

SILICA SAND Fine Colorado Silica Sand — 27 FT.

FILTER PACK MATERIAL Coarse Silica Sand — 29 FT.

WELL SCREEN LENGTH 10 FT.

WELL BOTTOM ELEV. ___ — 29 FT. / 39 FT.

SEAL MATERIAL NA — ___ FT.

BACKFILL MATERIAL NA — ___ FT.

1) CASING DETAILS

A) TYPE OF PIPE: (PVC) STAINLESS, TEFLON, OTHER ___

PIPE SCHEDULE 80

B) TYPE OF PIPE JOINTS: COUPLINGS, (THREADED) (W/TAPE), OTHER ___

C) WAS SOLVENT USED? YES OR (NO)

D) TYPE OF WELL SCREEN: (PVC) STAINLESS, TEFLON, OTHER ___

E) WELL SCREEN SLOT SIZE 0.010

F) PIPE DIA: ID IN. 2.0 OD IN. 2.3

G) INSTALLED PROTECTOR PIPE W/LOCK? (YES) OR NO
PROTECTOR PIPE DIA. 4 IN.

2) WELL DEVELOPMENT

A) METHOD (BAILING) PUMPING, (SURGING) COMPRESSED AIR

OTHER ___

(NOTE ADDITIONAL COMMENTS BELOW)

B) TIME SPENT FOR DEVELOPMENT? 3 hrs.

C) APPROXIMATE WATER VOLUME: REMOVED 70 gal.
ADDED ___

D) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR (TURBID) OPAQUE

E) WATER CLARITY AFTER DEVELOPMENT?
CLEAR, SLIGHTLY TURBID, (TURBID) OPAQUE

F) ODOR? YES OR (NO)

3) WATER LEVEL SUMMARY

A) DEPTH FROM TOP OF CASING AFTER DEVELOPMENT?
___ FT. OR DRY

B) OTHER MEASUREMENTS (T.O.C.):

DATE/TIME Static 33.1 FT.

DATE/TIME ___ FT.

DATE/TIME ___ FT.

ADDITIONAL COMMENTS: ___

American Steel Foundries

PROJECT NAME: Sebring Facility NO. 2169.17

WELL NO. MW-21

DATE INSTALLED 11-24-93

F-17 (2 11-85)

ELEV. (T.O.C.) 1101.12

GROUND SURF. ELEV. 1098.6

BENTONITE PELLETS/GRANULAR/POWDER 3/8" Holeplug Benlonite Chips — DEPTH FROM GROUND SURFACE 0 FT.

BACKFILL MATERIAL 3/8" Holeplug Benlonite Chips — NA FT.

22.5 FT. LENGTH OF SOLID PIPE

BACKFILL METHOD PIPE TREMIE/AUGER TAMPER GRAVITY FILLED — BOREHOLE DIA. 10 IN.

BENTONITE PELLETS/GRANULAR/POWDER SAA — NA FT.

SILICA SAND Fine Colorado Silica Sand — 16 FT.

FILTER PACK MATERIAL Coarse Silica Sand — 18 FT.

10 FT. WELL SCREEN LENGTH — 20 FT.

WELL BOTTOM ELEV. — 30 FT. / 31 FT.

SEAL MATERIAL NA — FT.

BACKFILL MATERIAL NA — FT.

1) CASING DETAILS

A) TYPE OF PIPE: PVC, STAINLESS, TEFLON, OTHER ____

PIPE SCHEDULE 40

B) TYPE OF PIPE JOINTS: COUPLINGS, THREADED (W/TAPE?), OTHER ____

C) WAS SOLVENT USED? YES OR NO

D) TYPE OF WELL SCREEN: PVC, STAINLESS, TEFLON, OTHER ____

E) WELL SCREEN SLOT SIZE 0.010

F) PIPE DIA: ID IN. 2.0 OD IN. 2.3

G) INSTALLED PROTECTOR PIPE W/LOCK? YES OR NO

PROTECTOR PIPE DIA. 4 IN.

2) WELL DEVELOPMENT

A) METHOD: BAILING, PUMPING, SURGING, COMPRESSED AIR, OTHER ____

(NOTE ADDITIONAL COMMENTS BELOW)

B) TIME SPENT FOR DEVELOPMENT: 45 min.

C) APPROXIMATE WATER VOLUME: REMOVED 30 gal. ADDED ____

D) WATER CLARITY BEFORE DEVELOPMENT: CLEAR, TURBID, OPAQUE

E) WATER CLARITY AFTER DEVELOPMENT: CLEAR, SLIGHTLY TURBID, TURBID, OPAQUE

F) ODOR? YES OR NO

3) WATER LEVEL SUMMARY

A) DEPTH FROM TOP OF CASING AFTER DEVELOPMENT: ____ FT. OR DRY

B) OTHER MEASUREMENTS (T.O.C.):

DATE/TIME Static 22.1 FT.

DATE/TIME ____ FT.

DATE/TIME ____ FT.

ADDITIONAL COMMENTS: ____

American Steel Foundries

PROJECT NAME: Sebring Facility NO. 2169.17

WELL NO. MW-21P

DATE INSTALLED 11-24-93

ELEV. (T.O.C.) 1100.17

GROUND SURF. ELEV. 1097.7

BENTONITE PELLETS/GRANULAR/POWDER 3/8" Holeplug Benlonite Chips — 3 FT.

BACKFILL MATERIAL 3/8" Holeplug Benlonite Chips

BACKFILL METHOD PIPE TREMIE/AUGER TREMIE CAVITY FILLED — 53 FT.

BENTONITE PELLETS/GRANULAR/POWDER 3/8" Benlonite Pellets — 56 FT.

SILICA SAND Fine Colorado Silica Sand — 60 FT.

FILTER PACK MATERIAL Coarse Silica Sand — 60 FT.

WELL BOTTOM ELEV. — 65 FT. / 65 FT.

SEAL MATERIAL NA — FT.

BACKFILL MATERIAL NA — FT.

LENGTH OF SOLID PIPE 625 FT.

WELL SCREEN LENGTH 5 FT.

DEPTH FROM GROUND SURFACE — FT.

BOREHOLE DIA. 10 IN.

1) CASING DETAILS

A) TYPE OF PIPE: PVC STAINLESS, TEFLON, OTHER

PIPE SCHEDULE 80

B) TYPE OF PIPE JOINTS; COUPLINGS, THREADED (W/TAPE?), OTHER

C) WAS SOLVENT USED? YES OR NO

D) TYPE OF WELL SCREEN: PVC STAINLESS, TEFLON, OTHER

E) WELL SCREEN SLOT SIZE 0.010

F) PIPE DIA: ID IN. 2.0 OD IN. 2.3

G) INSTALLED PROTECTOR PIPE W/LOCK? YES OR NO

PROTECTOR PIPE DIA. 4 IN.

2) WELL DEVELOPMENT

A) METHOD BAILING PUMPING SURGING COMPRESSED AIR

OTHER

(NOTE ADDITIONAL COMMENTS BELOW)

B) TIME SPENT FOR DEVELOPMENT? 20 min.

C) APPROXIMATE WATER VOLUME: REMOVED 10 gal.

ADDED

D) WATER CLARITY BEFORE DEVELOPMENT? CLEAR TURBID, OPAQUE

E) WATER CLARITY AFTER DEVELOPMENT? CLEAR SLIGHTLY TURBID, TURBID, OPAQUE

F) ODOR? YES OR NO

3) WATER LEVEL SUMMARY

A) DEPTH FROM TOP OF CASING AFTER DEVELOPMENT?

FT. OR DRY

B) OTHER MEASUREMENTS (T.O.C.):

DATE/TIME Static 22.1 FT.

DATE/TIME FT.

DATE/TIME FT.

ADDITIONAL COMMENTS:

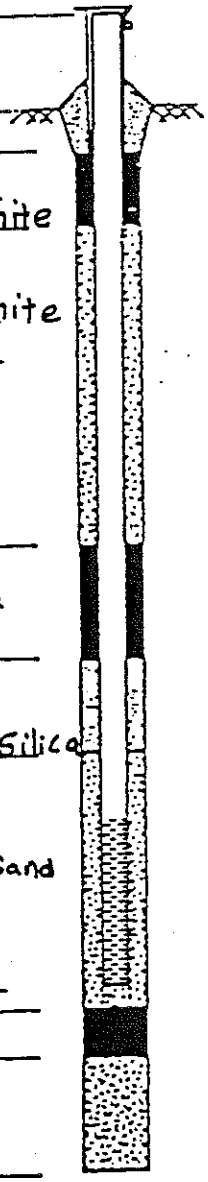
American Steel Foundries

PROJECT NAME: Sebring Facility NO. 2169.17

WELL NO. MW-22

DATE INSTALLED 11-11-93

Well Diagram F-17 (R 11-85)



ELEV. (T.O.C.) 1091.01		
GROUND SURF. ELEV. 1088.5	DEPTH FROM GROUND SURFACE	0 FT.
BENTONITE PELLETS/GRANULAR/POWDER 3/8" Holeplug Benlonite Chips		NA FT.
BACKFILL MATERIAL 3/8" Holeplug Benlonite Chips		
BACKFILL METHOD	BOREHOLE DIA.	10 IN.
PIPE TREMIE/AUGER TREMIE GRAVITY FILLED		NA FT.
BENTONITE PELLETS/GRANULAR/POWDER SAA		6 FT.
SILICA SAND Fine Colorado Silica Sand		8 FT.
FILTER PACK MATERIAL Coarse Silica Sand		10 FT.
WELL BOTTOM ELEV.		20 FT. 20 FT.
SEAL MATERIAL NA		FT.
BACKFILL MATERIAL NA		FT.

LENGTH OF SOLID PIPE: 14.5 FT.

WELL SCREEN LENGTH: 10 FT.

1) CASING DETAILS

A) TYPE OF PIPE:

PVC, STAINLESS, TEFLON, OTHER _____

PIPE SCHEDULE 40

B) TYPE OF PIPE JOINTS:

COUPLINGS, THREADED (W/TAPE?), OTHER _____

C) WAS SOLVENT USED? YES OR NO

D) TYPE OF WELL SCREEN:

PVC, STAINLESS, TEFLON, OTHER _____

E) WELL SCREEN SLOT SIZE 0.010

F) PIPE DIA: ID IN. 2.0 OD IN. 2.3

G) INSTALLED PROTECTOR PIPE W/LOCK? YES OR NO

PROTECTOR PIPE DIA. 4 IN.

2) WELL DEVELOPMENT

A) METHOD

BAILING, PUMPING, SURGING, COMPRESSED AIR

OTHER _____

(NOTE ADDITIONAL COMMENTS BELOW)

B) TIME SPENT FOR DEVELOPMENT? 35 min.

C) APPROXIMATE WATER VOLUME: REMOVED 5 gal.

ADDED _____

D) WATER CLARITY BEFORE DEVELOPMENT?

CLEAR, TURBID, OPAQUE

E) WATER CLARITY AFTER DEVELOPMENT?

CLEAR, SLIGHTLY TURBID, TURBID, OPAQUE

F) ODOR? YES OR NO

3) WATER LEVEL SUMMARY

A) DEPTH FROM TOP OF CASING AFTER DEVELOPMENT?

_____ FT. OR DRY

B) OTHER MEASUREMENTS (T.O.C.):

DATE/TIME Static 13.4 FT.

DATE/TIME _____ FT.

DATE/TIME _____ FT.

ADDITIONAL COMMENTS: _____

American Steel Foundries

PROJECT NAME: Sebring Facility NO. 2169.17

WELL NO. MW-22P

DATE INSTALLED 11-10-93

Well Diagram F-17 (8 11-85)

ELEV. (T.O.C.) 1091.23

GROUND SURF. ELEV. 1088.7

DEPTH FROM GROUND SURFACE 17 FT.

BENTONITE PELLETS/GRANULAR/POWDER 3/8" Holeplug Benlonite Chips — 6 FT.

BACKFILL MATERIAL 3/8" Holeplug Benlonite Chips Slurry

LENGTH OF SOLID PIPE 625 FT.

BACKFILL METHOD PIPE TREMIE/AUGER TREMIE GRAVITY FILLED

BOREHOLE DIA. 10 IN.

56 FT.

BENTONITE PELLETS/GRANULAR/POWDER 3/8" Pellets — 58 FT.

SILICA SAND Fine Colorado Silica Sand — 58 FT.

FILTER PACK MATERIAL Coarse Silica Sand — 60 FT.

WELL SCREEN LENGTH 5 FT.

WELL BOTTOM ELEV. — 65 FT. / 65 FT.

SEAL MATERIAL NA — FT.

BACKFILL MATERIAL NA — FT.

1) CASING DETAILS

A) TYPE OF PIPE: PVC, STAINLESS, TEFLON, OTHER

PIPE SCHEDULE 80

B) TYPE OF PIPE JOINTS: COUPLINGS, THREADED (W/TAPE?), OTHER

C) WAS SOLVENT USED? YES OR NO

D) TYPE OF WELL SCREEN: PVC, STAINLESS, TEFLON, OTHER

E) WELL SCREEN SLOT SIZE 0.010

F) PIPE DIA: ID IN. 2.0 OD IN. 2.3

G) INSTALLED PROTECTOR PIPE W/LOCK? YES OR NO

PROTECTOR PIPE DIA. 4 IN.

2) WELL DEVELOPMENT

A) METHOD

BAILING, PUMPING, SURGING, COMPRESSED AIR

OTHER

(NOTE ADDITIONAL COMMENTS BELOW)

B) TIME SPENT FOR DEVELOPMENT? 35 min.

C) APPROXIMATE WATER VOLUME: REMOVED 39 gal.

ADDED

D) WATER CLARITY BEFORE DEVELOPMENT?

CLEAR, TURBID, OPAQUE

E) WATER CLARITY AFTER DEVELOPMENT?

CLEAR, SLIGHTLY TURBID, TURBID, OPAQUE

F) ODOR? YES OR NO

3) WATER LEVEL SUMMARY

A) DEPTH FROM TOP OF CASING AFTER DEVELOPMENT?

FT. OR DRY

B) OTHER MEASUREMENTS (T.O.C.):

DATE/TIME Static 15.7 FT.

DATE/TIME FT.

DATE/TIME FT.

ADDITIONAL COMMENTS:

American Steel Foundries

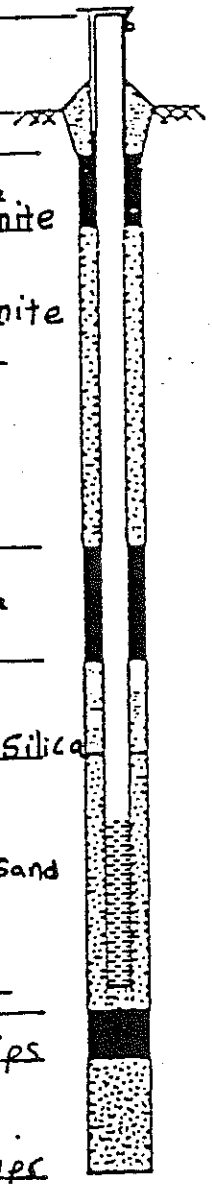
PROJECT NAME: Sebring Facility NO. 2169.17

WELL NO. MW-23

DATE INSTALLED 11-23-93

FTI

Well Diagram
F-17 (R 11-85)



ELEV. (T.O.C.) 1107.81

GROUND SURF. ELEV. 1105.3

DEPTH FROM GROUND SURFACE 0 FT.

BENTONITE PELLETS/GRANULAR/POWDER 3/8" Holeplug Benlonite Chips — NA FT.

BACKFILL MATERIAL 3/8" Holeplug Benlonite Chips

18.5 FT. — LENGTH OF SOLID PIPE

BACKFILL METHOD — BOREHOLE DIA. 10 IN.

PIPE TREMIE/AUGER TREMIE GRAVITY FILLED — NA FT.

BENTONITE PELLETS/GRANULAR/POWDER SAA — 13 FT.

SILICA SAND Fine Colorado Silica Sand — 14 FT.

FILTER PACK MATERIAL — 16 FT.

10 FT. — WELL SCREEN LENGTH

Coarse Silica Sand

WELL BOTTOM ELEV. — 26 FT. 27 FT.

SEAL MATERIAL 3/8" Holeplug Chips — 30 FT.

BACKFILL MATERIAL 3/8" Holeplug Chips — 35 FT.

1) CASING DETAILS

A) TYPE OF PIPE:

PVC STAINLESS, TEFLON, OTHER _____

PIPE SCHEDULE 40

B) TYPE OF PIPE JOINTS:

COUPLINGS, THREADED (W/TAPE?), OTHER _____

C) WAS SOLVENT USED? YES OR NO

D) TYPE OF WELL SCREEN:

PVC STAINLESS, TEFLON, OTHER _____

E) WELL SCREEN SLOT SIZE 0.010

F) PIPE DIA: ID IN. 2.0 OD IN. 2.3

G) INSTALLED PROTECTOR PIPE W/LOCK? YES OR NO

PROTECTOR PIPE DIA. 4 IN.

2) WELL DEVELOPMENT

A) METHOD

BAILING, PUMPING, SURGING, COMPRESSED AIR

OTHER _____

(NOTE ADDITIONAL COMMENTS BELOW)

B) TIME SPENT FOR DEVELOPMENT? 35 min.

C) APPROXIMATE WATER VOLUME: REMOVED 18 gal.

ADDED _____

D) WATER CLARITY BEFORE DEVELOPMENT?

CLEAR, TURBID, OPAQUE

E) WATER CLARITY AFTER DEVELOPMENT?

CLEAR, SLIGHTLY TURBID, TURBID, OPAQUE

F) ODOR? YES OR NO

3) WATER LEVEL SUMMARY

A) DEPTH FROM TOP OF CASING AFTER DEVELOPMENT?

_____ FT. OR DRY

B) OTHER MEASUREMENTS (T.O.C.):

DATE/TIME Static 18.5 FT.

DATE/TIME _____ FT.

DATE/TIME _____ FT.

ADDITIONAL COMMENTS: _____

APPENDIX C

TABLES SUMMARIZING MONITORING PROGRAM FROM GROUNDWATER ASSESSMENT PLAN

TABLE 3-1

WATER QUALITY PARAMETERS AND WASTE CONSTITUENT ANALYTICAL METHODS AND PRACTICAL QUANTITATION LIMITS

Parameters	SW-846 Analytical Method	Practical Quantitation Limits
pH	9040/9041	0.1 pH unit
Alkalinity, Carbonate/Bicarbonate	403	20 mg/L
Total Organic Carbon	9060	0.25 mg/L
Total Organic Halogen	9020	0.010 mg/L
Iron - ICP	6010	0.10 mg/L
Chloride	9250	2.0 mg/L
Fluoride	EPA 340.2	0.1 mg/L
Manganese - ICP	6010	0.005 mg/L
Nitrate, Nitrogen	9200	0.05 mg/L
Phenols (colorimetric)	9066	0.01 mg/L
Sodium - ICP	6010	0.50 mg/L
Specific Conductance	9050	10 μmhos/cm
Sulfate	9036	10 mg/L

Notes:

Practical Quantitation Limits are for RMT Laboratories.

ICP - Inductively Coupled Plasma Emission Spectrophotometry.

TABLE 3-2

APPENDIX IX - VOLATILE ORGANIC COMPOUNDS AND PRACTICAL QUANTITATION LIMITS (PQL's) FOR METHOD 8240

Compound	µg/L
Chloromethane	10
Bromomethane	10
Vinyl Chloride	10
Chloroethane	10
Methylene Chloride	5
Acetone	10
Carbon Disulfide	5
1,1-Dichloroethene	5
1,1-Dichloroethane	5
1,2-Dichloroethene (total)	5
Chloroform	5
1,2-Dichloroethane	5
2-Butanone	10
1,1,1-Trichloroethane	5
Carbon Tetrachloride	5
Vinyl Acetate	10
Bromodichloromethane	5
1,2-Dichloropropane	5
cis-1,3-Dichloropropene	5
Trichloroethene	5
Dibromochloromethane	5
1,1,2-Trichloroethane	5
Benzene	5
Trans-1,3-Dichloropropene	5
Bromoform	5
4-Methyl-2-Pentanone	10

TABLE 3-2 (CONTINUED)

APPENDIX IX - VOLATILE ORGANIC COMPOUNDS AND PRACTICAL QUANTITATION LIMITS (PQL's) FOR METHOD 8240

Compound	µg/L
2-Hexanone	10
Tetrachloroethene	5
1,1,2,2-Tetrachloroethane	5
Toluene	5
Chlorobenzene	5
Ethylbenzene	5
Styrene	5
Xylenes, Total	5
Dichlorodifluoromethane	5
Trichlorofluoromethane	5
Acrolein	100
Acrylonitrile	25
Iodomethane	5
3-Chloro-1-propene	5
Acetonitrile	50
2-Chloro-1,3-butadiene	5
Propionitrile	100
Methacrylonitrile	100
Isobutanol	100
Dibromomethane	5
1,2-Dibromoethane	5
1,1,1,2-Tetrachloroethane	5
1,4-Dichloro-2-butene	50
1,2,3-Trichloropropane	5
1,2-Dibromo-3-chloropropane	5

2169.02 0000:RTG:sebr1204.t 3-5

Revised Table 3-3[1]

APPENDIX IX - METALS, METHODS OF ANALYSIS AND PRACTICAL QUANTITATION LIMITS (PQL's)

Analyte	PQL in µg/L	SW-846 Method
Antimony	10	7041
Arsenic[2]	3	7060
Barium[2]	50	6010
Cadmium[2]	0.3	7131
Chromium (total)[2]	2	7191
Cobalt	50	6010
Copper	3	7211
Lead[2]	3	7421
Mercury[2]	0.2	7470,7471
Nickel[2]	40	6010
Selenium[2]	3	7740
Silver[2]	1	7761
Tin	500	RMT Lab Internal
Zinc[2]	20	6010
Sulfide (total)	1000	9030

Notes:

(1) Table originally presented in Groundwater Sampling and Analysis Plan (RMT, 1992). Revised based on First Quarter groundwater sampling results.

(2) Compound or element is found in ASF wastestream.

TABLE 3-3

APPENDIX IX - METALS, METHODS OF ANALYSIS AND PRACTICAL QUANTITATION LIMITS (PQL's)

Analyte	PQL in µg/L	SW-846 Method
Antimony	10	7041
Arsenic	3	7060
Barium	50	6010
Beryllium	5	6010
Cadmium	0.3	7131
Chromium (total)	2	7191
Cobalt	50	6010
Copper	3	7211
Lead	3	7421
Mercury	0.2	7470,7471
Nickel	40	6010
Selenium	3	7740
Silver	1	7761
Thallium	3	7841
Tin	200	RMT Lab Internal
Vanadium	50	6010
Zinc	20	6010
Cyanide (total)	10	9012
Sulfide (total)	1000	9030

TABLE 3-5 COMPOUNDS FOUND IN ASF WASTESTREAM	
Arsenic	Lead
Barium	Manganese
Cadmium	Mercury
Chloride	Nickel
Chromium	Phenol
Fluoride	Selenium
Iron	Silver
Sulfate	Zinc

APPENDIX D

ANALYTICAL LABORATORY RESULTS

ANALYTICAL LABO[illegible]RY RESULTS
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES

Parameter	Units	MW-20 (DUP) 14-Sep-94	FIELD BLANK 14-Sep-94	MW-01A 14-Sep-94	MW-04A 14-Sep-94	MW-13 14-Sep-94	MW-14 14-Sep-94
ALKALINITY, CARBONATE	MG/L	290	< 20	< 20	420	< 20	200
ANTIMONY, DISSOLVED	UG/L	< 10	< 10	< 10	< 10	< 10	< 10
ARSENIC, DISSOLVED	UG/L	3.8	< 3	< 3	< 3	< 3	< 3
BARIUM, DISSOLVED	UG/L	< 50	< 50	< 50	< 50	< 50	< 50
CADMIUM, DISSOLVED	UG/L	< 0.3	< 0.3	1.6	< 0.3	0.96	< 0.3
CHLORIDE	MG/L	25	< 2	270	11	78	26
CHLOROFORM	UG/L	< 10	< 10	< 10	< 2	< 10	< 10
CHROMIUM, DISSOLVED	UG/L	< 2	< 2	2.5	< 50	< 2	< 2
COBALT, DISSOLVED	UG/L	< 50	< 50	< 50	< 3	110	< 50
COPPER, DISSOLVED	UG/L	< 3	< 3	34	0.24	< 3	< 3
FLUORIDE	MG/L	0.46	< 0.1	0.92	4900	0.88	0.34
IRON, DISSOLVED	UG/L	18000	< 100	34000	< 3	30000	1900
LEAD, DISSOLVED	UG/L	< 3	< 3	< 3	4000	< 3	< 3
MANGANESE, DISSOLVED	UG/L	7700	< 5	2700	< 0.2	12000	600
MERCURY, DISSOLVED	UG/L	< 0.2	< 0.2	< 0.2	< 40	< 0.2	< 0.2
NICKEL, DISSOLVED	UG/L	< 40	< 40	86	< 0.05	160	< 40
NITROGEN, NITRATE	MG/L	< 0.05	< 0.05	< 0.25	< 0.01	< 0.05	0.052
PHENOLICS, TOTAL RECOVERABLE	MG/L	< 0.01	< 0.01	< 0.01	< 6	< 0.01	0.02
SELENIUM, DISSOLVED	UG/L	< 6	< 6	< 6	< 1	< 6	< 6
SILVER, DISSOLVED	UG/L	< 1	< 1	< 1	32000	< 1	< 1
SODIUM, DISSOLVED	UG/L	110000	< 500	120000	980	42000	38000
SULFATE	MG/L	750	< 10	570	< 1	930	1200
SULFIDE	MG/L	1.2	< 1	< 1	< 500	< 1	< 1
TIN, DISSOLVED	UG/L	< 500	< 500	< 500	18	< 500	< 500
TOTAL ORGANIC CARBON AS NPOC	MG/L	13	< 0.25	17	< 5	24	9.3
TOTAL ORGANIC HALIDES	UG/L	6.8	< 5	17	24	14	62
ZINC, DISSOLVED	UG/L	< 20	< 20	150		240	< 20

ANALYTICAL LABORATORY RESULTS
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES

Parameters	Units	MW-19 14-Sep-94	MW-19P 14-Sep-94	MW-20 14-Sep-94	MW-21 14-Sep-94	MW-21P 14-Sep-94	MW-22 14-Sep-94
ALKALINITY, CARBONATE	MG/L	< 20		290	350	380	< 140
ANTIMONY, DISSOLVED	UG/L	< 10		< 10	< 10	< 10	10
ARSENIC, DISSOLVED	UG/L	< 3		< 3	7.8	< 3	< 3
BARIUM, DISSOLVED	UG/L	< 50		< 50	< 50	140	< 50
CADMIUM, DISSOLVED	UG/L	0.66		0.98	0.35	< 0.3	< 0.3
CHLORIDE	MG/L	4.8		20	60	160	< 33
CHLOROFORM	UG/L	0.4		< 10	< 10	< 10	10
CHROMIUM, DISSOLVED	UG/L	< 2		< 2	< 2	< 2	< 2
COBALT, DISSOLVED	UG/L	< 50		< 50	< 50	< 50	< 50
COPPER, DISSOLVED	UG/L	7.7		< 3	< 3	5.6	< 3
FLUORIDE	MG/L	< 0.1		0.47	0.66	2.9	< 0.6
IRON, DISSOLVED	UG/L	< 100		19000	35000	2300	17000
LEAD, DISSOLVED	UG/L	< 3		< 3	< 3	< 3	3
MANGANESE, DISSOLVED	UG/L	510		8300	10000	69	< 5500
MERCURY, DISSOLVED	UG/L	< 0.2		< 0.2	< 0.2	< 0.2	0.2
NICKEL, DISSOLVED	UG/L	< 40		< 40	< 40	< 40	< 40
NITROGEN, NITRATE	MG/L	1.2		< 0.05	< 0.05	0.55	< 0.05
PHENOLICS, TOTAL RECOVERABLE	MG/L	0.011		0.011	< 0.01	0.015	< 0.012
SELENIUM, DISSOLVED	UG/L	< 6		< 6	< 6	< 6	6
SILVER, DISSOLVED	UG/L	< 1		< 1	< 1	< 1	< 1
SODIUM, DISSOLVED	UG/L	5800		110000	120000	340000	< 41000
SULFATE	MG/L	42		750	1200	470	400
SULFIDE	MG/L	1.3		< 1	4	1.3	1
TIN, DISSOLVED	UG/L	< 500		< 500	< 500	< 500	< 500
TOTAL ORGANIC CARBON AS NPOC	MG/L	26		7.8	7.4	43	< 23
TOTAL ORGANIC HALIDES	UG/L	< 5		5.8	13	59	17
ZINC, DISSOLVED	UG/L	45		21	22	< 20	21

ANALYTICAL LABORATORY RESULTS
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES

Parameters	Units	MW-22P 14-Sep-94	MW-23 14-Sep-94
ALKALINITY, CARBONATE	MG/L	770	34
ANTIMONY, DISSOLVED	UG/L	< 10	< 10
ARSENIC, DISSOLVED	UG/L	< 3	< 3
BARIUM, DISSOLVED	UG/L	140	< 50
CADMIUM, DISSOLVED	UG/L	< 0.3	< 0.3
CHLORIDE	MG/L	63	240
CHLOROFORM	UG/L	< 10	< 10
CHROMIUM, DISSOLVED	UG/L	< 2	< 2
COBALT, DISSOLVED	UG/L	< 50	< 50
COPPER, DISSOLVED	UG/L	< 3	< 3
FLUORIDE	MG/L	9.5	0.11
IRON, DISSOLVED	UG/L	190	30000
LEAD, DISSOLVED	UG/L	< 6	< 3
MANGANESE, DISSOLVED	UG/L	22	3700
MERCURY, DISSOLVED	UG/L	< 0.2	< 0.2
NICKEL, DISSOLVED	UG/L	< 40	< 40
NITROGEN, NITRATE	MG/L	< 0.05	< 0.05
PHENOLICS, TOTAL RECOVERABLE	MG/L	< 0.01	< 0.01
SELENIUM, DISSOLVED	UG/L	< 6	< 6
SILVER, DISSOLVED	UG/L	< 1	< 1
SODIUM, DISSOLVED	UG/L	500000	8800
SULFATE	MG/L	300	170
SULFIDE	MG/L	< 1	< 1
TIN, DISSOLVED	UG/L	< 500	< 500
TOTAL ORGANIC CARBON AS NPOC	MG/L	26	1.2
TOTAL ORGANIC HALIDES	UG/L	7.4	11
ZINC, DISSOLVED	UG/L	35	59

APPENDIX E

STATISTICAL ANALYSIS METHODS AND RESULTS

EPA/530-SW-89-026

PB89-151047

STATISTICAL ANALYSIS OF GROUND-WATER MONITORING DATA AT RCRA FACILITIES

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FEBRUARY 1989

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SPRINGFIELD, VA. 22161

For data sets with more than 30 observations, the parametric analysis of variance performed on the rank values is a good approximation to the Kruskal-Wallis test (Quade, 1966). If the user has access to SAS, the PROC RANK procedure is used to obtain the ranks of the data. The analysis of variance procedure detailed in Section 5.2.1 is then performed on the ranks. Contrasts are tested as in the parametric analysis of variance.

INTERPRETATION

The Kruskal-Wallis test statistic is compared to the tabulated critical value from the chi-squared distribution. If the test statistic does not exceed the tabulated value, there is no statistically significant evidence of contamination and the analysis would stop and report this finding. If the test statistic exceeds the tabulated value, there is significant evidence that the hypothesis of no differences in compliance concentrations from the background level is not true. Consequently, if the test statistic exceeds the critical value, one concludes that there is significant evidence of contamination. One then proceeds to investigate where the differences lie, that is, which wells are indicating contamination.

The multiple comparisons procedure described in steps 5 and 6 compares each compliance well to the background well. This determines which compliance wells show statistically significant evidence of contamination at an experimentwise error rate of 5 percent. In many cases, inspection of the mean or median concentrations will be sufficient to indicate where the problem lies.

5.3 TOLERANCE INTERVALS BASED ON THE NORMAL DISTRIBUTION

An alternate approach to analysis of variance to determine whether there is statistically significant evidence of contamination is to use tolerance intervals. A tolerance interval is constructed from the data on (uncontaminated) background wells. The concentrations from compliance wells are then compared with the tolerance interval. With the exception of pH, if the compliance concentrations do not fall in the tolerance interval, this provides statistically significant evidence of contamination.

Tolerance intervals are most appropriate for use at facilities that do not exhibit high degrees of spatial variation between background wells and compliance wells. Facilities that overlie extensive, homogeneous geologic deposits (for example, thick, homogeneous lacustrine clays) that do not naturally display hydrogeochemical variations may be suitable for this statistical method of analysis.

A tolerance interval establishes a concentration range that is constructed to contain a specified proportion (P%) of the population with a specified confidence coefficient, Y. The proportion of the population included, P, is referred to as the coverage. The probability with which the tolerance interval includes the proportion P% of the population is referred to as the tolerance coefficient.

A coverage of 95% is recommended. If this is used, random observations from the same distribution as the background well data would exceed the upper

tolerance limit less than 5% of the time. Similarly, a tolerance coefficient of 95% is recommended. This means that one has a confidence level of 95% that the upper 95% tolerance limit will contain at least 95% of the distribution of observations from background well data. These values were chosen to be consistent with the performance standards described in Section 2. The use of these values corresponds to the selection of α of 5% in the multiple well testing situation.

The procedure can be applied with as few as three observations from the background distribution. However, doing so would result in a large upper tolerance limit. A sample size of eight or more results is an adequate tolerance interval. The minimum sampling schedule called for in the regulations would result in at least four observations from each background well. Only if a single background well is sampled at a single point in time is the sample size so small as to make use of the procedure questionable.

Tolerance intervals can be constructed assuming that the data or the transformed data are normally distributed. Tolerance intervals can also be constructed assuming other distributions. It is also possible to construct nonparametric tolerance intervals using only the assumption that the data came from some continuous population. However, the nonparametric tolerance intervals require such a large number of observations to provide a reasonable coverage and tolerance coefficient that they are impractical in this application.

The range of the concentration data in the background well samples should be considered in determining whether the tolerance interval approach should be used, and if so, what distribution is appropriate. The background well concentration data should be inspected for outliers and tests of normality applied before selecting the tolerance interval approach. Tests of normality were presented in Section 4.2. Note that in this case, the test of normality would be applied to the background well data that are used to construct the tolerance interval. These data should all be from the same normal distribution.

In this application, unless pH is being monitored, a one-sided tolerance interval or an upper tolerance limit is desired, since contamination is indicated by large concentrations of the hazardous constituents monitored. Thus, for concentrations, the appropriate tolerance interval is (0, TL), with the comparison of importance being the larger limit, TL.

PURPOSE

The purpose of the tolerance interval approach is to define a concentration range from background well data, within which a large proportion of the monitoring observations should fall with high probability. Once this is done, data from compliance wells can be checked for evidence of contamination by simply determining whether they fall in the tolerance interval. If they do not, this is evidence of contamination.

In this case the data are assumed to be approximately normally distributed. Section 4.2 provided methods to check for normality. If the data are

not normal, take the natural logarithm of the data and see if the transformed data are approximately normal. If so, this method can be used on the logarithms of the data. Otherwise, seek the assistance of a professional statistician.

PROCEDURE

Step 1. Calculate the mean, $\bar{X}$, and the standard deviation, S, from the background well data.

Step 2. Construct the one-sided upper tolerance limit as

$$TL = \bar{X} + K\,S,$$

where K is the one-sided normal tolerance factor found in Table 5, Appendix B.

Step 3. Compare each observation from compliance wells to the tolerance limit found in Step 2. If any observation exceeds the tolerance limit, that is statistically significant evidence that the well is contaminated. Note that if the tolerance interval was constructed on the logarithms of the original background observations, the logarithms of the compliance well observations should be compared to the tolerance limit. Alternatively the tolerance limit may be transferred to the original data scale by taking the antilogarithm.

REFERENCE

Lieberman, Gerald J. 1958. "Tables for One-sided Statistical Tolerance Limits." *Industrial Quality Control.* Vol. XIV, No. 10.

EXAMPLE

Table 5-5 contains example data that represent lead concentration levels in parts per million in water samples at a hypothetical facility. The background well data are in columns 1 and 2, while the other four columns represent compliance well data.

Step 1. The mean and standard deviation of the n = 8 observations have been calculated for the background well. The mean is 51.4 and the standard deviation is 16.3.

Step 2. The tolerance factor for a one-sided normal tolerance interval is found from Table 5, Appendix B as 3.188. This is for 95% coverage with probability 95% and for n = 8. The upper tolerance limit is then calculated as 51.4 + (3.188)(16.3) = 103.4.

Step 3. The tolerance limit of 103.3 is compared with the compliance well data. Any value that exceeds the tolerance limit indicates statistically significant evidence of contamination. Two observations from Well 1, two observations from Well 3, and all four observations from Well 4 exceed the tolerance limit. Thus there is statistically significant evidence of contamination at Wells 1, 3, and 4.

be appropriate when the number of detected compounds is quite small relative to the number of compounds analyzed for as might occur in detection monitoring.

PURPOSE

The test of proportions determines whether the proportion of compounds detected in the compliance well data differs significantly from the proportion of compounds detected in the background well data. If there is a significant difference, this is statistically significant evidence of contamination.

PROCEDURE

The procedure uses the normal distribution approximation to the binomial distribution. This assumes that the sample size is reasonably large. Generally, if the proportion of detected values is denoted by P, and the sample size is n, then the normal approximation is adequate, provided that nP and n(1-P) both are greater than or equal to 5.

Step 1. Determine X, the number of background well samples in which the compound was detected. Let n be the total number of background well samples analyzed. Compute the proportion of detects:

$$\hat{P}_u = x/n$$

Step 2. Determine Y, the number of compliance well samples in which the compound was detected. Let M be the total number of compliance well samples analyzed. Compute the proportion of detects:

$$\hat{P}_d = y/m$$

Step 3. Compute the standard error of the difference in proportions:

$$S_D = \{[(x+y)/(n+m)][1 - (x+y)/(n+m)][1/n + 1/m]\}^{1/2}$$

and form the statistic:

$$Z = (\hat{P}_u - \hat{P}_d)/S_D$$

Step 4. Compare the absolute value of Z to the 97.5th percentile from the standard normal distribution, 1.96. If the absolute value of Z exceeds 1.96, this provides statistically significant evidence at the 5% significance level that the proportion of compliance well samples where the compound was detected exceeds the proportion of background well samples where the compound was detected. This would be interpreted as evidence of contamination. (The two-sided test is used to provide information about differences in either direction.)

EXAMPLE

Table 8-2 contains data on cadmium concentrations measured in background well and compliance wells at a facility. In the table, "BDL" is used for below detection limit.

TABLE 8-2. EXAMPLE DATA FOR A TEST OF PROPORTIONS

Cadmium concentration (μg/L) at background well (24 samples)		Cadmium concentration (μg/L) at compliance wells (64 samples)		
0.1	BDL	0.12	BDL	0.024
0.12	BDL	0.08	BDL	BDL
BDL*	BDL	BDL	BDL	BDL
0.26	BDL	0.2	0.11	BDL
BDL		BDL	0.06	BDL
0.1		0.1	BDL	BDL
BDL		BDL	0.23	0.1
0.014		0.012	BDL	0.04
BDL		BDL	0.11	BDL
BDL		BDL	BDL	BDL
BDL		BDL	0.031	0.1
BDL		BDL	BDL	BDL
BDL		BDL	BDL	0.01
0.12		0.12	BDL	BDL
BDL		0.07	BDL	BDL
0.21		BDL	BDL	BDL
BDL		0.19	0.12	BDL
0.12		BDL	0.08	BDL
BDL		0.1	BDL	
BDL		BDL	0.26	
		0.01	BDL	
		BDL	0.02	
		BDL	BDL	

*BDL means below detection limit.

Step 1. Estimate the proportion above detection in the background wells. As shown in Table 8-2, there were 24 samples from background wells analyzed for cadmium, so n= 24. Of these, 16 were below detection and x = 8 were above detection, so P_u = 8/24 = 0.333.

Step 2. Estimate the proportion above detection in the compliance wells. There were 64 samples from compliance wells analyzed for cadmium, with 40 below detection and 24 detected values. This gives m = 64, y = 24, so P_d = 24/64 = 0.375.

Step 3. Calculate the standard error of the difference in proportions.

$$S_D = \{[(8+24)/(24+64)][1-(8+24)/(24+64)](1/24 + 1/64)\}^{1/2} = 0.115$$

Step 4. Form the statistic Z and compare it to the normal distribution.

$$Z = \frac{0.375 - 0.333}{0.115} = 0.37$$

which is less in absolute value than the value from the normal distribution, 1.96. Consequently, there is no statistically significant evidence that the proportion of samples with cadmium levels above the detection limit differs in the background well and compliance well samples.

INTERPRETATION

Since the proportion of water samples with detected amounts of cadmium in the compliance wells was not significantly different from that in the background wells, the data are interpreted to provide no evidence of contamination. Had the proportion of samples with detectable levels of cadmium in the compliance wells been significantly higher than that in the background wells this would have been evidence of contamination. Had the proportion been significantly higher in the background wells, additional study would have been required. This could indicate that contamination was migrating from an off-site source, or it could mean that the hydraulic gradient had been incorrectly estimated or had changed and that contamination was occurring from the facility, but the ground-water flow was not in the direction originally estimated. Mounding of contaminants in the ground water near the background wells could also be a possible explanation of this observance.

8.1.3 Cohen's Method

If a confidence interval or a tolerance interval based upon the normal distribution is being constructed, a technique presented by Cohen (1959) specifies a method to adjust the sample mean and sample standard deviation to account for data below the detection limit. The only requirements for the use of this technique is that the data are normally distributed and that the detection limit be always the same. This technique is demonstrated below.

Table E-1

Calculation of Tolerance Intervals

For Upgradient Shale Wells

TABLE E1
CALCULATION OF TOLERANCE INTERVALS FOR UPGRADIENT SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

Well No.	Date	Parameter	Prefix	Result	Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit
MW01A	17-Dec-93	ALKALINITY, BICARBONATE	<	20	mg/L									
MW01A	15-Mar-94	ALKALINITY, BICARBONATE	<	20	mg/L									
MW01A	16-Jun-94	ALKALINITY, BICARBONATE	<	20	mg/L									
MW14	14-Dec-93	ALKALINITY, BICARBONATE		210	mg/L									
MW14	15-Mar-94	ALKALINITY, BICARBONATE		200	mg/L									
MW14	17-Jun-94	ALKALINITY, BICARBONATE		200	mg/L									
MW19	14-Dec-93	ALKALINITY, BICARBONATE	<	20	mg/L									
MW19	16-Mar-94	ALKALINITY, BICARBONATE	<	20	mg/L									
MW19	16-Jun-94	ALKALINITY, BICARBONATE	<	20	mg/L									
MW19P	14-Dec-93	ALKALINITY, BICARBONATE		530	mg/L									
MW19P	15-Mar-94	ALKALINITY, BICARBONATE	<		mg/L									
MW19P	17-Jun-94	ALKALINITY, BICARBONATE	<	20	mg/L									
						11	8	3	73%					
MW01A	17-Dec-93	ALKALINITY, CARBONATE	<	20	mg/L									
MW01A	15-Mar-94	ALKALINITY, CARBONATE	<	20	mg/L									
MW01A	16-Jun-94	ALKALINITY, CARBONATE	<	20	mg/L									
MW01A	14-Sep-94	ALKALINITY, CARBONATE	<	20	MG/L									
MW14	14-Dec-93	ALKALINITY, CARBONATE	<	20	mg/L									
MW14	15-Mar-94	ALKALINITY, CARBONATE	<	20	mg/L									
MW14	17-Jun-94	ALKALINITY, CARBONATE	<	20	mg/L									
MW14	14-Sep-94	ALKALINITY, CARBONATE		200	MG/L									
MW19	14-Dec-93	ALKALINITY, CARBONATE	<	20	mg/L									
MW19	16-Mar-94	ALKALINITY, CARBONATE	<	20	mg/L									
MW19	16-Jun-94	ALKALINITY, CARBONATE	<	20	mg/L									
MW19	14-Sep-94	ALKALINITY, CARBONATE	<	20	MG/L									
MW19P	17-Dec-93	ALKALINITY, CARBONATE		44	mg/L									
MW19P	15-Mar-94	ALKALINITY, CARBONATE	<		mg/L									
MW19P	17-Jun-94	ALKALINITY, CARBONATE	<	20	mg/L									
						14	13	1	93%					
MW01A	17-Dec-93	ANTIMONY, DISSOLVED	<	10	ug/L									
MW01A	15-Mar-94	ANTIMONY, DISSOLVED	<	10	ug/L									
MW01A	16-Jun-94	ANTIMONY, DISSOLVED	<	10	ug/L									
MW01A	14-Sep-94	ANTIMONY, DISSOLVED	<	10	UG/L									
MW14	14-Dec-93	ANTIMONY, DISSOLVED	<	10	ug/L									
MW14	15-Mar-94	ANTIMONY, DISSOLVED	<	10	ug/L									
MW14	17-Jun-94	ANTIMONY, DISSOLVED	<	10	ug/L									
MW14	14-Sep-94	ANTIMONY, DISSOLVED	<	10	UG/L									
MW19	14-Dec-93	ANTIMONY, DISSOLVED	<	10	ug/L									
MW19	16-Mar-94	ANTIMONY, DISSOLVED	<	10	ug/L									
MW19	16-Jun-94	ANTIMONY, DISSOLVED	<	10	ug/L									
MW19	14-Sep-94	ANTIMONY, DISSOLVED	<	10	UG/L									
MW19P	17-Dec-93	ANTIMONY, DISSOLVED	<	10	ug/L									
MW19P	15-Mar-94	ANTIMONY, DISSOLVED			ug/L									
MW19P	17-Jun-94	ANTIMONY, DISSOLVED	<	10	ug/L									
						14	14	0	100%					
MW01A	17-Dec-93	ARSENIC, DISSOLVED	<	3	ug/L									
MW01A	15-Mar-94	ARSENIC, DISSOLVED	<	3	ug/L									
MW01A	16-Jun-94	ARSENIC, DISSOLVED	<	3	ug/L									
MW01A	14-Sep-94	ARSENIC, DISSOLVED	<	3	UG/L									
MW14	14-Dec-93	ARSENIC, DISSOLVED	<	3	ug/L									
MW14	15-Mar-94	ARSENIC, DISSOLVED	<	3	ug/L									
MW14	17-Jun-94	ARSENIC, DISSOLVED	<	3	ug/L									
MW14	14-Sep-94	ARSENIC, DISSOLVED	<	3	UG/L									
MW19	14-Dec-93	ARSENIC, DISSOLVED	<	3	ug/L									
MW19	16-Mar-94	ARSENIC, DISSOLVED	<	3	ug/L									

TABLE E1
CALCULATION OF TOLERANCE INTERVALS FOR UPGRADIENT SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

Well No.	Date	Parameter	Prefix	Result Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit
MW19	16-Jun-94	ARSENIC, DISSOLVED	<	3 ug/L									
MW19	14-Sep-94	ARSENIC, DISSOLVED	<	3 UG/L									
MW19P	17-Dec-93	ARSENIC, DISSOLVED		12 ug/L									
MW19P	15-Mar-94	ARSENIC, DISSOLVED		ug/L									
MW19P	17-Jun-94	ARSENIC, DISSOLVED	<	3 ug/L									
					14	13	1	93%					
MW01A	17-Dec-93	BARIUM, DISSOLVED	<	50 ug/L									
MW01A	15-Mar-94	BARIUM, DISSOLVED	<	50 ug/L									
MW01A	16-Jun-94	BARIUM, DISSOLVED	<	50 ug/L									
MW01A	14-Sep-94	BARIUM, DISSOLVED	<	50 UG/L									
MW14	14-Dec-93	BARIUM, DISSOLVED	<	50 ug/L									
MW14	15-Mar-94	BARIUM, DISSOLVED	<	50 ug/L									
MW14	17-Jun-94	BARIUM, DISSOLVED	<	50 ug/L									
MW14	14-Sep-94	BARIUM, DISSOLVED	<	50 UG/L									
MW19	14-Dec-93	BARIUM, DISSOLVED	<	50 ug/L									
MW19	16-Mar-94	BARIUM, DISSOLVED	<	50 ug/L									
MW19	16-Jun-94	BARIUM, DISSOLVED	<	50 ug/L									
MW19	14-Sep-94	BARIUM, DISSOLVED	<	50 UG/L									
MW19P	17-Dec-93	BARIUM, DISSOLVED	<	50 ug/L									
MW19P	15-Mar-94	BARIUM, DISSOLVED		ug/L									
MW19P	17-Jun-94	BARIUM, DISSOLVED	<	50 ug/L									
					14	14	0	100%					
MW01A	17-Dec-93	BERYLLIUM, DISSOLVED	<	5 ug/L									
MW14	14-Dec-93	BERYLLIUM, DISSOLVED	<	5 ug/L									
MW19	14-Dec-93	BERYLLIUM, DISSOLVED	<	5 ug/L									
MW19P	17-Dec-93	BERYLLIUM, DISSOLVED	<	5 ug/L									
					4	4	0	100%					
MW01A	17-Dec-93	CADMIUM, DISSOLVED		0.76 ug/L									
MW01A	15-Mar-94	CADMIUM, DISSOLVED		3.2 ug/L									
MW01A	16-Jun-94	CADMIUM, DISSOLVED		2 ug/L									
MW01A	14-Sep-94	CADMIUM, DISSOLVED		1.6 UG/L									
MW14	14-Dec-93	CADMIUM, DISSOLVED	<	0.3 ug/L									
MW14	15-Mar-94	CADMIUM, DISSOLVED	<	0.3 ug/L									
MW14	17-Jun-94	CADMIUM, DISSOLVED	<	0.3 ug/L									
MW14	14-Sep-94	CADMIUM, DISSOLVED	<	0.3 UG/L									
MW19	14-Dec-93	CADMIUM, DISSOLVED	<	0.3 ug/L									
MW19	16-Mar-94	CADMIUM, DISSOLVED		0.89 ug/L									
MW19	16-Jun-94	CADMIUM, DISSOLVED		0.33 ug/L									
MW19	14-Sep-94	CADMIUM, DISSOLVED		0.66 UG/L									
MW19P	17-Dec-93	CADMIUM, DISSOLVED	<	0.3 ug/L									
MW19P	15-Mar-94	CADMIUM, DISSOLVED		ug/L									
MW19P	17-Jun-94	CADMIUM, DISSOLVED		0.33 ug/L									
					14	6	8	43%	0.83	0.84	2.614		3.0
MW01A	17-Dec-93	CHLORIDE		97 mg/L									
MW01A	15-Mar-94	CHLORIDE		310 mg/L									
MW01A	16-Jun-94	CHLORIDE		220 mg/L									
MW01A	14-Sep-94	CHLORIDE		270 MG/L									
MW14	14-Dec-93	CHLORIDE		28 mg/L									
MW14	15-Mar-94	CHLORIDE		32 mg/L									
MW14	17-Jun-94	CHLORIDE		23 mg/L									
MW14	14-Sep-94	CHLORIDE		26 MG/L									
MW19	14-Dec-93	CHLORIDE		16 mg/L									
MW19	16-Mar-94	CHLORIDE		13 mg/L									
MW19	16-Jun-94	CHLORIDE		5.1 mg/L									
MW19	14-Sep-94	CHLORIDE		4.8 MG/L									

TABLE E1
CALCULATION OF TOLERANCE INTERVALS FOR UPGRADIENT SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

Well No.	Date	Parameter	Prefix	Result	Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit
MW19P	17-Dec-93	CHLORIDE		210	mg/L									
MW19P	15-Mar-94	CHLORIDE			mg/L									
MW19P	17-Jun-94	CHLORIDE		5.1	mg/L									
						14	0	14	0%	90.00	107.25	2.614		370
MW01A	14-Sep-94	CHLOROFORM	<	10	UG/L									
MW14	14-Sep-94	CHLOROFORM	<	10	UG/L									
MW19	14-Sep-94	CHLOROFORM		0.4	UG/L									
MW01A	17-Dec-93	CHROMIUM, DISSOLVED	<	2	ug/L									
MW01A	15-Mar-94	CHROMIUM, DISSOLVED	<	2	ug/L									
MW01A	16-Jun-94	CHROMIUM, DISSOLVED		2.9	ug/L									
MW01A	14-Sep-94	CHROMIUM, DISSOLVED		2.5	UG/L									
MW14	14-Dec-93	CHROMIUM, DISSOLVED	<	2	ug/L									
MW14	15-Mar-94	CHROMIUM, DISSOLVED	<	2	ug/L									
MW14	17-Jun-94	CHROMIUM, DISSOLVED	<	2	ug/L									
MW14	14-Sep-94	CHROMIUM, DISSOLVED	<	2	UG/L									
MW19	14-Dec-93	CHROMIUM, DISSOLVED	<	2	ug/L									
MW19	16-Mar-94	CHROMIUM, DISSOLVED	<	2	ug/L									
MW19	16-Jun-94	CHROMIUM, DISSOLVED	<	2	ug/L									
MW19	14-Sep-94	CHROMIUM, DISSOLVED	<	2	UG/L									
MW19P	17-Dec-93	CHROMIUM, DISSOLVED	<	2	ug/L									
MW19P	15-Mar-94	CHROMIUM, DISSOLVED			ug/L									
MW19P	17-Jun-94	CHROMIUM, DISSOLVED	<	2	ug/L									
						14	12	2	86%					
MW01A	17-Dec-93	COBALT, DISSOLVED	<	50	ug/L									
MW01A	15-Mar-94	COBALT, DISSOLVED	<	50	ug/L									
MW01A	16-Jun-94	COBALT, DISSOLVED		50	ug/L									
MW01A	14-Sep-94	COBALT, DISSOLVED	<	50	UG/L									
MW14	14-Dec-93	COBALT, DISSOLVED	<	50	ug/L									
MW14	15-Mar-94	COBALT, DISSOLVED	<	50	ug/L									
MW14	17-Jun-94	COBALT, DISSOLVED	<	50	ug/L									
MW14	14-Sep-94	COBALT, DISSOLVED	<	50	UG/L									
MW19	14-Dec-93	COBALT, DISSOLVED	<	50	ug/L									
MW19	16-Mar-94	COBALT, DISSOLVED	<	50	ug/L									
MW19	16-Jun-94	COBALT, DISSOLVED	<	50	ug/L									
MW19	14-Sep-94	COBALT, DISSOLVED	<	50	UG/L									
MW19P	17-Dec-93	COBALT, DISSOLVED	<	50	ug/L									
MW19P	15-Mar-94	COBALT, DISSOLVED			ug/L									
MW19P	17-Jun-94	COBALT, DISSOLVED	<	50	ug/L									
MW19P	17-Dec-93	CONDUCTANCE, SPECIFIC		100	UMHOS/CM									
MW19	14-Dec-93	CONDUCTANCE, SPECIFIC		170	UMHOS/CM									
MW19	16-Mar-94	CONDUCTANCE, SPECIFIC		119	UMHOS/CM									
MW01A	17-Dec-93	CONDUCTANCE, SPECIFIC		1100	UMHOS/CM									
MW01A	15-Mar-94	CONDUCTANCE, SPECIFIC		1430	UMHOS/CM									
MW01A	16-Jun-94	CONDUCTANCE, SPECIFIC		1640	UMHOS/CM									
MW14	14-Dec-93	CONDUCTANCE, SPECIFIC		2200	UMHOS/CM									
MW14	15-Mar-94	CONDUCTANCE, SPECIFIC		1920	UMHOS/CM									
MW14	17-Jun-94	CONDUCTANCE, SPECIFIC		2050	UMHOS/CM									
MW19	16-Jun-94	CONDUCTANCE, SPECIFIC		1430	UMHOS/CM									
MW19P	15-Mar-94	CONDUCTANCE, SPECIFIC			UMHOS/CM									
MW19P	17-Jun-94	CONDUCTANCE, SPECIFIC		1430	UMHOS/CM									
MW01A	14-Sep-94	CONDUCTANCE, SPECIFIC		1750	UMHOS/CM									
MW14	14-Sep-94	CONDUCTANCE, SPECIFIC		1950	UMHOS/CM									
MW19	14-Sep-94	CONDUCTANCE, SPECIFIC		1575	UMHOS/CM									
						11	0	11	0%	1679.55	313.23	2.815		2561

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CALCULATION OF TOLERANCE INTERVALS FOR UPGRADIENT SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

Well No.	Date	Parameter	Prefix	Result	Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit
MW01A	17-Dec-93	COPPER, DISSOLVED		16	ug/L									
MW01A	15-Mar-94	COPPER, DISSOLVED		11	ug/L									
MW01A	16-Jun-94	COPPER, DISSOLVED		32	ug/L									
MW01A	14-Sep-94	COPPER, DISSOLVED		34	UG/L									
MW14	14-Dec-93	COPPER, DISSOLVED	<	3	ug/L									
MW14	15-Mar-94	COPPER, DISSOLVED	<	3	ug/L									
MW14	17-Jun-94	COPPER, DISSOLVED	<	3	ug/L									
MW14	14-Sep-94	COPPER, DISSOLVED	<	3	UG/L									
MW19	14-Dec-93	COPPER, DISSOLVED	<	3	ug/L									
MW19	16-Mar-94	COPPER, DISSOLVED	<	3	ug/L									
MW19	16-Jun-94	COPPER, DISSOLVED	<	3	ug/L									
MW19	14-Sep-94	COPPER, DISSOLVED		7.7	UG/L									
MW19P	17-Dec-93	COPPER, DISSOLVED		9.9	ug/L									
MW19P	15-Mar-94	COPPER, DISSOLVED	<		ug/L									
MW19P	17-Jun-94	COPPER, DISSOLVED	<	3	ug/L									
						14	9	5	64%					
MW01A	17-Dec-93	CYANIDE, TOTAL	<	0.01	mg/L									
MW14	14-Dec-93	CYANIDE, TOTAL	<	0.01	mg/L									
MW19	14-Dec-93	CYANIDE, TOTAL	<	0.01	mg/L									
MW19P	17-Dec-93	CYANIDE, TOTAL	<	0.01	mg/L									
MW01A	17-Dec-93	FLUORIDE		0.69	mg/L									
MW01A	15-Mar-94	FLUORIDE		0.82	mg/L									
MW01A	16-Jun-94	FLUORIDE		1.4	mg/L									
MW01A	14-Sep-94	FLUORIDE		0.92	MG/L									
MW14	14-Dec-93	FLUORIDE		0.31	mg/L									
MW14	15-Mar-94	FLUORIDE		0.25	mg/L									
MW14	17-Jun-94	FLUORIDE		0.34	mg/L									
MW14	14-Sep-94	FLUORIDE		0.34	MG/L									
MW19	14-Dec-93	FLUORIDE		0.14	mg/L									
MW19	16-Mar-94	FLUORIDE	<	0.1	mg/L									
MW19	16-Jun-94	FLUORIDE	<	0.1	mg/L									
MW19	14-Sep-94	FLUORIDE	<	0.1	MG/L									
MW19P	17-Dec-93	FLUORIDE		2.1	mg/L									
MW19P	15-Mar-94	FLUORIDE	<		mg/L									
MW19P	17-Jun-94	FLUORIDE	<	0.1	mg/L									
						14	5	9	36%	0.55	0.57	2.614		2.0
MW01A	17-Dec-93	IRON, DISSOLVED		11000	ug/L									
MW01A	15-Mar-94	IRON, DISSOLVED		2000	ug/L									
MW01A	16-Jun-94	IRON, DISSOLVED		21000	ug/L									
MW01A	14-Sep-94	IRON, DISSOLVED		34000	UG/L									
MW14	14-Dec-93	IRON, DISSOLVED		1700	ug/L									
MW14	15-Mar-94	IRON, DISSOLVED		1500	ug/L									
MW14	17-Jun-94	IRON, DISSOLVED		1400	ug/L									
MW14	14-Sep-94	IRON, DISSOLVED		1900	UG/L									
MW19	14-Dec-93	IRON, DISSOLVED	<	100	ug/L									
MW19	16-Mar-94	IRON, DISSOLVED	<	100	ug/L									
MW19	16-Jun-94	IRON, DISSOLVED	<	100	ug/L									
MW19	14-Sep-94	IRON, DISSOLVED	<	100	UG/L									
MW19P	17-Dec-93	IRON, DISSOLVED		330	ug/L									
MW19P	15-Mar-94	IRON, DISSOLVED			ug/L									
MW19P	17-Jun-94	IRON, DISSOLVED	<	100	ug/L									
						14	5	9	36%	5381	9738	2.614		30835
MW01A	17-Dec-93	LEAD, DISSOLVED	<	3	ug/L									
MW01A	15-Mar-94	LEAD, DISSOLVED	<	3	ug/L									

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SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

Well No.	Date	Parameter	Prefix	Result	Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit
MW01A	16-Jun-94	LEAD, DISSOLVED	<	3	ug/L									
MW01A	14-Sep-94	LEAD, DISSOLVED	<	3	UG/L									
MW14	14-Dec-93	LEAD, DISSOLVED	<	3	ug/L									
MW14	15-Mar-94	LEAD, DISSOLVED	<	3	ug/L									
MW14	17-Jun-94	LEAD, DISSOLVED	<	3	ug/L									
MW14	14-Sep-94	LEAD, DISSOLVED	<	3	UG/L									
MW19	14-Dec-93	LEAD, DISSOLVED	<	3	ug/L									
MW19	16-Mar-94	LEAD, DISSOLVED	<	3	ug/L									
MW19	16-Jun-94	LEAD, DISSOLVED	<	3	ug/L									
MW19	14-Sep-94	LEAD, DISSOLVED	<	3	UG/L									
MW19P	17-Dec-93	LEAD, DISSOLVED	<	3	ug/L									
MW19P	15-Mar-94	LEAD, DISSOLVED			ug/L									
MW19P	17-Jun-94	LEAD, DISSOLVED	<	3	ug/L									
						14	14	0	100%					
MW01A	17-Dec-93	MANGANESE, DISSOLVED		1200	ug/L									
MW01A	15-Mar-94	MANGANESE, DISSOLVED		1000	ug/L									
MW01A	16-Jun-94	MANGANESE, DISSOLVED		2200	ug/L									
MW01A	14-Sep-94	MANGANESE, DISSOLVED		2700	UG/L									
MW14	14-Dec-93	MANGANESE, DISSOLVED		620	ug/L									
MW14	15-Mar-94	MANGANESE, DISSOLVED		660	ug/L									
MW14	17-Jun-94	MANGANESE, DISSOLVED		670	ug/L									
MW14	14-Sep-94	MANGANESE, DISSOLVED		600	UG/L									
MW19	14-Dec-93	MANGANESE, DISSOLVED		900	ug/L									
MW19	16-Mar-94	MANGANESE, DISSOLVED		59	ug/L									
MW19	16-Jun-94	MANGANESE, DISSOLVED		600	ug/L									
MW19	14-Sep-94	MANGANESE, DISSOLVED		510	UG/L									
MW19P	17-Dec-93	MANGANESE, DISSOLVED	<	5	ug/L									
MW19P	15-Mar-94	MANGANESE, DISSOLVED			ug/L									
MW19P	17-Jun-94	MANGANESE, DISSOLVED		600	ug/L									
						14	1	13	7%	880	714	2.614		2748
MW01A	17-Dec-93	MERCURY, DISSOLVED	<	0.2	ug/L									
MW01A	15-Mar-94	MERCURY, DISSOLVED	<	0.2	ug/L									
MW01A	16-Jun-94	MERCURY, DISSOLVED	<	0.2	ug/L									
MW01A	14-Sep-94	MERCURY, DISSOLVED	<	0.2	UG/L									
MW14	14-Dec-93	MERCURY, DISSOLVED	<	0.2	ug/L									
MW14	15-Mar-94	MERCURY, DISSOLVED	<	0.2	ug/L									
MW14	17-Jun-94	MERCURY, DISSOLVED	<	0.2	ug/L									
MW14	14-Sep-94	MERCURY, DISSOLVED	<	0.2	UG/L									
MW19	14-Dec-93	MERCURY, DISSOLVED	<	0.2	ug/L									
MW19	16-Mar-94	MERCURY, DISSOLVED	<	0.2	ug/L									
MW19	16-Jun-94	MERCURY, DISSOLVED	<	0.2	ug/L									
MW19	14-Sep-94	MERCURY, DISSOLVED	<	0.2	UG/L									
MW19P	17-Dec-93	MERCURY, DISSOLVED	<	0.2	ug/L									
MW19P	15-Mar-94	MERCURY, DISSOLVED			ug/L									
MW19P	17-Jun-94	MERCURY, DISSOLVED	<	0.2	ug/L									
						14	14	0	100%					
MW01A	17-Dec-93	NICKEL, DISSOLVED	<	40	ug/L									
MW01A	15-Mar-94	NICKEL, DISSOLVED	<	40	ug/L									
MW01A	16-Jun-94	NICKEL, DISSOLVED		71	ug/L									
MW01A	14-Sep-94	NICKEL, DISSOLVED		86	UG/L									
MW14	14-Dec-93	NICKEL, DISSOLVED	<	40	ug/L									
MW14	15-Mar-94	NICKEL, DISSOLVED	<	40	ug/L									
MW14	17-Jun-94	NICKEL, DISSOLVED	<	40	ug/L									
MW14	14-Sep-94	NICKEL, DISSOLVED	<	40	UG/L									
MW19	14-Dec-93	NICKEL, DISSOLVED	<	40	ug/L									

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Well No.	Date	Parameter	Prefix	Result	Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit
MW19	16-Mar-94	NICKEL, DISSOLVED	<	40	ug/L									
MW19	16-Jun-94	NICKEL, DISSOLVED	<	40	ug/L									
MW19	14-Sep-94	NICKEL, DISSOLVED	<	40	UG/L									
MW19P	17-Dec-93	NICKEL, DISSOLVED	<	40	ug/L									
MW19P	15-Mar-94	NICKEL, DISSOLVED			ug/L									
MW19P	17-Jun-94	NICKEL, DISSOLVED	<	40	ug/L									
						14	12	2	86%					
MW01A	17-Dec-93	NITROGEN, NITRATE		0.52	mg/L									
MW01A	15-Mar-94	NITROGEN, NITRATE	<	0.48	mg/L									
MW01A	16-Jun-94	NITROGEN, NITRATE	<	0.05	mg/L									
MW01A	14-Sep-94	NITROGEN, NITRATE	<	0.25	MG/L									
MW14	14-Dec-93	NITROGEN, NITRATE	<	0.05	mg/L									
MW14	15-Mar-94	NITROGEN, NITRATE	<	0.05	mg/L									
MW14	17-Jun-94	NITROGEN, NITRATE	<	0.05	mg/L									
MW14	14-Sep-94	NITROGEN, NITRATE		0.052	MG/L									
MW19	14-Dec-93	NITROGEN, NITRATE		1.4	mg/L									
MW19	16-Mar-94	NITROGEN, NITRATE		1.1	mg/L									
MW19	16-Jun-94	NITROGEN, NITRATE		1.6	mg/L									
MW19	14-Sep-94	NITROGEN, NITRATE		1.2	MG/L									
MW19P	17-Dec-93	NITROGEN, NITRATE		0.23	mg/L									
MW19P	15-Mar-94	NITROGEN, NITRATE			mg/L									
MW19P	17-Jun-94	NITROGEN, NITRATE		1.6	mg/L									
						14	6	8	43%	0.62	0.60	2.614		2.2
MW14	14-Dec-93	PHENOLICS, TOTAL RECOVERABLE	<	301	mg/L									
MW01A	17-Dec-93	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L									
MW01A	15-Mar-94	PHENOLICS, TOTAL RECOVERABLE		0.034	mg/L									
MW01A	16-Jun-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L									
MW01A	14-Sep-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	MG/L									
MW14	15-Mar-94	PHENOLICS, TOTAL RECOVERABLE		0.26	mg/L									
MW14	17-Jun-94	PHENOLICS, TOTAL RECOVERABLE		0.012	mg/L									
MW14	14-Sep-94	PHENOLICS, TOTAL RECOVERABLE		0.02	MG/L									
MW19	14-Dec-93	PHENOLICS, TOTAL RECOVERABLE		0.01	mg/L									
MW19	16-Mar-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L									
MW19	16-Jun-94	PHENOLICS, TOTAL RECOVERABLE		0.01	mg/L									
MW19	14-Sep-94	PHENOLICS, TOTAL RECOVERABLE		0.011	MG/L									
MW19P	17-Dec-93	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L									
MW19P	15-Mar-94	PHENOLICS, TOTAL RECOVERABLE			mg/L									
MW19P	17-Jun-94	PHENOLICS, TOTAL RECOVERABLE		0.01	mg/L									
						13	5	8	38%	0.03	0.07	2.67		0.2
MW01A	17-Dec-93	SELENIUM, DISSOLVED	<	3	ug/L									
MW01A	15-Mar-94	SELENIUM, DISSOLVED	<	12	ug/L									
MW01A	16-Jun-94	SELENIUM, DISSOLVED	<	3	ug/L									
MW01A	14-Sep-94	SELENIUM, DISSOLVED	<	6	UG/L									
MW14	14-Dec-93	SELENIUM, DISSOLVED	<	3	ug/L									
MW14	15-Mar-94	SELENIUM, DISSOLVED	<	12	ug/L									
MW14	17-Jun-94	SELENIUM, DISSOLVED	<	3	ug/L									
MW14	14-Sep-94	SELENIUM, DISSOLVED	<	6	UG/L									
MW19	14-Dec-93	SELENIUM, DISSOLVED	<	3	ug/L									
MW19	16-Mar-94	SELENIUM, DISSOLVED	<	12	ug/L									
MW19	16-Jun-94	SELENIUM, DISSOLVED	<	3	ug/L									
MW19	14-Sep-94	SELENIUM, DISSOLVED	<	6	UG/L									
MW19P	17-Dec-93	SELENIUM, DISSOLVED	<	3	ug/L									
MW19P	15-Mar-94	SELENIUM, DISSOLVED			ug/L									
MW19P	17-Jun-94	SELENIUM, DISSOLVED	<	3	ug/L									
						14	14	0	100%					0.00

C:ASFUG1_4.wk3; date 26-Oct-94

TABLE E1
CALCULATION OF TOLERANCE INTERVALS FOR UPGRADIENT SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

Well No.	Date	Parameter	Prefix	Result	Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit
MW01A	17-Dec-93	SILVER, DISSOLVED	<	1	ug/L									
MW01A	15-Mar-94	SILVER, DISSOLVED	<	1	ug/L									
MW01A	16-Jun-94	SILVER, DISSOLVED	<	1	ug/L									
MW01A	15-Sep-94	SILVER, DISSOLVED	<	1	UG/L									
MW14	14-Dec-93	SILVER, DISSOLVED	<	1	ug/L									
MW14	15-Mar-94	SILVER, DISSOLVED	<	1	ug/L									
MW14	17-Jun-94	SILVER, DISSOLVED	<	1	ug/L									
MW14	14-Sep-94	SILVER, DISSOLVED	<	1	UG/L									
MW19	14-Dec-93	SILVER, DISSOLVED	<	1	ug/L									
MW19	16-Mar-94	SILVER, DISSOLVED	<	1	ug/L									
MW19	16-Jun-94	SILVER, DISSOLVED	<	1	ug/L									
MW19	14-Sep-94	SILVER, DISSOLVED	<	1	UG/L									
MW19P	17-Dec-93	SILVER, DISSOLVED	<	1	ug/L									
MW19P	15-Mar-94	SILVER, DISSOLVED			ug/L									
MW19P	17-Jun-94	SILVER, DISSOLVED	<	1	ug/L									
						14	14	0	100%					
MW01A	17-Dec-93	SODIUM, DISSOLVED		61000	ug/L									
MW01A	15-Mar-94	SODIUM, DISSOLVED		140000	ug/L									
MW01A	16-Jun-94	SODIUM, DISSOLVED		110000	ug/L									
MW01A	14-Sep-94	SODIUM, DISSOLVED		120000	UG/L									
MW14	14-Dec-93	SODIUM, DISSOLVED		39000	ug/L									
MW14	15-Mar-94	SODIUM, DISSOLVED		37000	ug/L									
MW14	17-Jun-94	SODIUM, DISSOLVED		39000	ug/L									
MW14	14-Sep-94	SODIUM, DISSOLVED		38000	UG/L									
MW19	14-Dec-93	SODIUM, DISSOLVED	<	7600	ug/L									
MW19	16-Mar-94	SODIUM, DISSOLVED		4800	ug/L									
MW19	16-Jun-94	SODIUM, DISSOLVED		5400	ug/L									
MW19	14-Sep-94	SODIUM, DISSOLVED		5800	UG/L									
MW19P	17-Dec-93	SODIUM, DISSOLVED		200000	ug/L									
MW19P	15-Mar-94	SODIUM, DISSOLVED			ug/L									
MW19P	17-Jun-94	SODIUM, DISSOLVED		5400	ug/L									
						14	1	13	7%	58071	58941	2.614		212143
MW01A	17-Dec-93	SULFATE		240	mg/L									
MW01A	15-Mar-94	SULFATE		540	mg/L									
MW01A	16-Jun-94	SULFATE		460	mg/L									
MW01A	14-Sep-94	SULFATE		570	MG/L									
MW14	14-Dec-93	SULFATE		1100	mg/L									
MW14	15-Mar-94	SULFATE		1100	mg/L									
MW14	17-Jun-94	SULFATE		1000	mg/L									
MW14	14-Sep-94	SULFATE		1200	MG/L									
MW19	14-Dec-93	SULFATE		43	mg/L									
MW19	16-Mar-94	SULFATE		32	mg/L									
MW19	16-Jun-94	SULFATE		36	mg/L									
MW19	14-Sep-94	SULFATE		42	MG/L									
MW19P	17-Dec-93	SULFATE		330	mg/L									
MW19P	15-Mar-94	SULFATE			mg/L									
MW19P	17-Jun-94	SULFATE		36	mg/L									
						14	0	14	0%	480.64	433.23	2.614		1613
MW01A	14-Sep-94	SULFIDE	<	1	MG/L									
MW14	14-Sep-94	SULFIDE	<	1	MG/L									
MW19	14-Sep-94	SULFIDE		1.3	MG/L									
MW01A	17-Dec-93	SULFIDE, TOTAL	<	1	mg/L									
MW01A	15-Mar-94	SULFIDE, TOTAL	<	1	mg/L									
MW01A	16-Jun-94	SULFIDE, TOTAL	<	1	mg/L									
MW14	14-Dec-93	SULFIDE, TOTAL		1.9	mg/L									

TABLE E1
CALCULATION OF TOLERANCE INTERVALS FOR UPGRADIENT SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

Well No.	Date	Parameter	Prefix	Result	Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit
MW14	15-Mar-94	SULFIDE, TOTAL		1.2	mg/L									
MW14	17-Jun-94	SULFIDE, TOTAL		2.5	mg/L									
MW19	14-Dec-93	SULFIDE, TOTAL		1.6	mg/L									
MW19	16-Mar-94	SULFIDE, TOTAL	<	1	mg/L									
MW19	16-Jun-94	SULFIDE, TOTAL		1.2	mg/L									
MW19P	17-Dec-93	SULFIDE, TOTAL		3.3	mg/L									
MW19P	15-Mar-94	SULFIDE, TOTAL			mg/L									
MW19P	17-Jun-94	SULFIDE, TOTAL		1.2	mg/L									
						14	6	8	43%	1.44	0.66	2.614		3.2
MW01A	17-Dec-93	THALLIUM, DISSOLVED	<	3	mg/L									
MW14	14-Dec-93	THALLIUM, DISSOLVED	<	3	mg/L									
MW19	14-Dec-93	THALLIUM, DISSOLVED	<	3	mg/L									
MW19P	17-Dec-93	THALLIUM, DISSOLVED	<	3	mg/L									
MW01A	17-Dec-93	TIN, DISSOLVED	<	500	ug/L									
MW01A	15-Mar-94	TIN, DISSOLVED	<	500	ug/L									
MW01A	16-Jun-94	TIN, DISSOLVED	<	500	ug/L									
MW01A	14-Sep-94	TIN, DISSOLVED	<	500	UG/L									
MW14	14-Dec-93	TIN, DISSOLVED	<	500	ug/L									
MW14	15-Mar-94	TIN, DISSOLVED	<	500	ug/L									
MW14	17-Jun-94	TIN, DISSOLVED	<	500	ug/L									
MW14	14-Sep-94	TIN, DISSOLVED	<	500	UG/L									
MW19	14-Dec-93	TIN, DISSOLVED	<	500	ug/L									
MW19	16-Mar-94	TIN, DISSOLVED	<	500	ug/L									
MW19	16-Jun-94	TIN, DISSOLVED	<	500	ug/L									
MW19	14-Sep-94	TIN, DISSOLVED	<	500	UG/L									
MW19P	17-Dec-93	TIN, DISSOLVED	<	500	ug/L									
MW19P	15-Mar-94	TIN, DISSOLVED			ug/L									
MW19P	17-Jun-94	TIN, DISSOLVED	<	500	ug/L									
						14	14	0	100%					
MW01A	15-Mar-94	TOTAL ORGANIC CARBON AS NPOC		101	mg/L									
MW01A	17-Dec-93	TOTAL ORGANIC CARBON AS NPOC		0.6	mg/L									
MW01A	16-Jun-94	TOTAL ORGANIC CARBON AS NPOC		1.7	mg/L									
MW01A	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC		17	MG/L									
MW14	14-Dec-93	TOTAL ORGANIC CARBON AS NPOC		3.3	mg/L									
MW14	15-Mar-94	TOTAL ORGANIC CARBON AS NPOC		2.2	mg/L									
MW14	17-Jun-94	TOTAL ORGANIC CARBON AS NPOC		1.2	mg/L									
MW14	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC		9.3	MG/L									
MW19	14-Dec-93	TOTAL ORGANIC CARBON AS NPOC		1.9	mg/L									
MW19	16-Mar-94	TOTAL ORGANIC CARBON AS NPOC		1.1	mg/L									
MW19	16-Jun-94	TOTAL ORGANIC CARBON AS NPOC		0.34	mg/L									
MW19	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC		26	MG/L									
MW19P	17-Dec-93	TOTAL ORGANIC CARBON AS NPOC		34	mg/L									
MW19P	15-Mar-94	TOTAL ORGANIC CARBON AS NPOC			mg/L									
MW19P	17-Jun-94	TOTAL ORGANIC CARBON AS NPOC		0.34	mg/L									
						13	0	13	0%	7.61	10.67	2.614		35
MW19P	17-Dec-93	TOTAL ORGANIC HALIDES		130	ug/L									
MW01A	17-Dec-93	TOTAL ORGANIC HALIDES		8	ug/L									
MW01A	15-Mar-94	TOTAL ORGANIC HALIDES		20	ug/L									
MW01A	16-Jun-94	TOTAL ORGANIC HALIDES		14	ug/L									
MW01A	14-Sep-94	TOTAL ORGANIC HALIDES		17	UG/L									
MW14	14-Dec-93	TOTAL ORGANIC HALIDES		7.4	ug/L									
MW14	15-Mar-94	TOTAL ORGANIC HALIDES		10	ug/L									
MW14	17-Jun-94	TOTAL ORGANIC HALIDES		6.8	ug/L									
MW14	14-Sep-94	TOTAL ORGANIC HALIDES		62	UG/L									

TABLE E1
CALCULATION OF TOLERANCE INTERVALS FOR UPGRADIENT SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

Well No.	Date	Parameter	Prefix	Result Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit
MW19	14-Dec-93	TOTAL ORGANIC HALIDES	<	5 ug/L									
MW19	16-Mar-94	TOTAL ORGANIC HALIDES		5 ug/L									
MW19	16-Jun-94	TOTAL ORGANIC HALIDES		7.6 ug/L									
MW19	14-Sep-94	TOTAL ORGANIC HALIDES	<	5 UG/L									
MW19P	15-Mar-94	TOTAL ORGANIC HALIDES		ug/L									
MW19P	17-Jun-94	TOTAL ORGANIC HALIDES		7.6 ug/L									
					13	2	11	15%	13.49	14.72	2.614		52
MW01A	17-Dec-93	VANADIUM, DISSOLVED	<	50 ug/L									
MW14	14-Dec-93	VANADIUM, DISSOLVED		50 ug/L									
MW19	14-Dec-93	VANADIUM, DISSOLVED	<	50 ug/L									
MW19P	17-Dec-93	VANADIUM, DISSOLVED	<	50 ug/L									
MW01A	17-Dec-93	ZINC, DISSOLVED		70 ug/L									
MW01A	15-Mar-94	ZINC, DISSOLVED		56 ug/L									
MW01A	16-Jun-94	ZINC, DISSOLVED		160 ug/L									
MW01A	14-Sep-94	ZINC, DISSOLVED		150 UG/L									
MW14	14-Dec-93	ZINC, DISSOLVED		20 ug/L									
MW14	15-Mar-94	ZINC, DISSOLVED		20 ug/L									
MW14	17-Jun-94	ZINC, DISSOLVED	<	20 ug/L									
MW14	14-Sep-94	ZINC, DISSOLVED	<	20 UG/L									
MW19	14-Dec-93	ZINC, DISSOLVED	<	20 ug/L									
MW19	16-Mar-94	ZINC, DISSOLVED	<	20 ug/L									
MW19	16-Jun-94	ZINC, DISSOLVED	<	20 ug/L									
MW19	14-Sep-94	ZINC, DISSOLVED		45 UG/L									
MW19P	17-Dec-93	ZINC, DISSOLVED	<	20 ug/L									
MW19P	15-Mar-94	ZINC, DISSOLVED		ug/L									
MW19P	17-Jun-94	ZINC, DISSOLVED	<	20 ug/L									
					14	7	7	50%	47.21	46.72	2.614		169
MW01A	17-Dec-93	pH, FIELD		3.5 SU									
MW01A	15-Mar-94	pH, FIELD		3.2 SU									
MW01A	16-Jun-94	pH, FIELD		4.1 SU									
MW01A	14-Sep-94	pH, FIELD		4.3 SU									
MW14	14-Dec-93	pH, FIELD		7.2 SU									
MW14	15-Mar-94	pH, FIELD		6.2 SU									
MW14	17-Jun-94	pH, FIELD		7.1 SU									
MW14	14-Sep-94	pH, FIELD		6.8 SU									
MW19	14-Dec-93	pH, FIELD		6.2 SU									
MW19	16-Mar-94	pH, FIELD		5.4 SU									
MW19	16-Jun-94	pH, FIELD		6.5 SU									
MW19	14-Sep-94	pH, FIELD		5.5 SU									
MW19P	17-Dec-93	pH, FIELD		9 SU									
MW19P	15-Mar-94	pH, FIELD		SU									
MW19P	17-Jun-94	pH, FIELD		6.5 SU									
MW19P	14-Sep-94	pH, FIELD		SU									
					14	0	14	0%	5.82	1.46	2.614	2.0	9.6

Table E-2

Comparison of Downgradient and Upgradient Groundwater Quality - Shale Wells

TABLE E2
COMPARISON OF DOWNGRADIENT AND UPGRADIENT GROUNDWATER QUALITY - SHALE WELLS
AMERICAN STEEL FOUNDRIES
SERING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
MW20	16-Dec-93	ALKALINITY, BICARBONATE		330	mg/L			
MW20	16-Mar-94	ALKALINITY, BICARBONATE		370	mg/L			
MW20	16-Jun-94	ALKALINITY, BICARBONATE	<	20	mg/L			
MW21P	17-Dec-93	ALKALINITY, BICARBONATE		360	mg/L			
MW21P	16-Mar-94	ALKALINITY, BICARBONATE		350	mg/L			
MW21P	16-Jun-94	ALKALINITY, BICARBONATE		370	mg/L			
MW22P	16-Dec-93	ALKALINITY, BICARBONATE		770	mg/L			
MW22P	15-Mar-94	ALKALINITY, BICARBONATE		770	mg/L			
MW22P	16-Jun-94	ALKALINITY, BICARBONATE		770	mg/L			
Proportions Test			1	9				
No. of Background Detects (x)		3						
No. of Background Samples (n)		11						
Proportion of Detects (Pu)		0.27						
No. of Downgradient Detects (y)		8						
No. of Downgradient Samples (m)		9						
Proportion of Detects (Pd)		0.89						
Standard of Error		0.2236						
Z Statistic (Z)		-2.7556						
Absolute value of Z exceeds 1.96, therefore there is a difference between upgradient and downgradient water quality at the 5% significance level								
MW20	16-Dec-93	ALKALINITY, CARBONATE	<	20	mg/L			
MW20	16-Mar-94	ALKALINITY, CARBONATE	<	20	mg/L			
MW20	16-Jun-94	ALKALINITY, CARBONATE	<	20	mg/L			
MW20	14-Sep-94	ALKALINITY, CARBONATE		290	MG/L			
MW21P	17-Dec-93	ALKALINITY, CARBONATE	<	20	mg/L			
MW21P	16-Mar-94	ALKALINITY, CARBONATE	<	20	mg/L			
MW21P	16-Jun-94	ALKALINITY, CARBONATE	<	20	mg/L			
MW21P	14-Sep-94	ALKALINITY, CARBONATE		380	MG/L			
MW22P	16-Dec-93	ALKALINITY, CARBONATE	<	20	mg/L			
MW22P	15-Mar-94	ALKALINITY, CARBONATE	<	20	mg/L			
MW22P	16-Jun-94	ALKALINITY, CARBONATE	<	20	mg/L			
MW22P	14-Sep-94	ALKALINITY, CARBONATE		770	MG/L			
Proportions Test			9	12				
No. of Background Detects (x)		1						
No. of Background Samples (n)		14						
Proportion of Detects (Pu)		0.07						
No. of Downgradient Detects (y)		3						
No. of Downgradient Samples (m)		12						
Proportion of Detects (Pd)		0.25						
Standard of Error		0.1418						
Z Statistic (Z)		-1.2581	No Difference					
MW20	16-Dec-93	ANTIMONY, DISSOLVED	<	10	ug/L			
MW20	16-Mar-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW20	16-Jun-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW20	14-Sep-94	ANTIMONY, DISSOLVED	<	10	UG/L			
MW21P	17-Dec-93	ANTIMONY, DISSOLVED	<	10	ug/L			
MW21P	16-Mar-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW21P	16-Jun-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW21P	14-Sep-94	ANTIMONY, DISSOLVED	<	10	UG/L			
MW22P	16-Dec-93	ANTIMONY, DISSOLVED	<	10	ug/L			
MW22P	15-Mar-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW22P	16-Jun-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW22P	14-Sep-94	ANTIMONY, DISSOLVED	<	10	UG/L			
Proportions Test			12	12				
No. of Background Detects (x)		0						
No. of Background Samples (n)		14						
Proportion of Detects (Pu)		0.00						
No. of Downgradient Detects (y)		0						
No. of Downgradient Samples (m)		12						
Proportion of Detects (Pd)		0.00						
Standard of Error		0.0000						
Z Statistic (Z)		ERR	No Difference					
MW20	16-Dec-93	ARSENIC, DISSOLVED	<	3	ug/L			
MW20	16-Mar-94	ARSENIC, DISSOLVED		3.3	ug/L			
MW20	16-Jun-94	ARSENIC, DISSOLVED	<	3	ug/L			
MW20	14-Sep-94	ARSENIC, DISSOLVED	<	3	UG/L			
MW21P	17-Dec-93	ARSENIC, DISSOLVED	<	3	ug/L			
MW21P	16-Mar-94	ARSENIC, DISSOLVED	<	3	ug/L			
MW21P	16-Jun-94	ARSENIC, DISSOLVED	<	3	ug/L			
MW21P	14-Sep-94	ARSENIC, DISSOLVED	<	3	UG/L			
MW22P	16-Dec-93	ARSENIC, DISSOLVED	<	3	ug/L			
MW22P	15-Mar-94	ARSENIC, DISSOLVED	<	3	ug/L			
MW22P	16-Jun-94	ARSENIC, DISSOLVED	<	3	ug/L			
MW22P	14-Sep-94	ARSENIC, DISSOLVED	<	3	UG/L			
Proportions Test			11	12				
No. of Background Detects (x)		1						
No. of Background Samples (n)		14						
Proportion of Detects (Pu)		0.07						
No. of Downgradient Detects (y)		1						
No. of Downgradient Samples (m)		12						

TABLE E2
COMPARISON OF DOWNGRADIENT AND UPGRADIENT GROUNDWATER QUALITY - SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
Proportion of Detects (Pd)			0.08					
Standard of Error			0.1048					
Z Statistic (Z)			-0.1136 No Difference					
MW20	16-Dec-93	BARIUM, DISSOLVED	<	50	ug/L			
MW20	16-Mar-94	BARIUM, DISSOLVED	<	50	ug/L			
MW20	16-Jun-94	BARIUM, DISSOLVED	<	50	ug/L			
MW20	14-Sep-94	BARIUM, DISSOLVED	<	50	UG/L			
MW21P	17-Dec-93	BARIUM, DISSOLVED		120	ug/L			
MW21P	16-Mar-94	BARIUM, DISSOLVED		240	ug/L			
MW21P	16-Jun-94	BARIUM, DISSOLVED		140	ug/L			
MW21P	14-Sep-94	BARIUM, DISSOLVED		140	UG/L			
MW22P	16-Dec-93	BARIUM, DISSOLVED		200	ug/L			
MW22P	15-Mar-94	BARIUM, DISSOLVED		170	ug/L			
MW22P	16-Jun-94	BARIUM, DISSOLVED		110	ug/L			
MW22P	14-Sep-94	BARIUM, DISSOLVED		140	UG/L			
Proportions Test			4	12				
No. of Background Detects (x)			0					
No. of Background Samples (n)			14					
Proportion of Detects (Pu)			0.00					
No. of Downgradient Detects (y)			8					
No. of Downgradient Samples (m)			12					
Proportion of Detects (Pd)			0.67					
Standard of Error			0.1818					
Z Statistic (Z)			-3.6717					

Absolute value of Z exceeds 1.96, therefore there is a difference between upgradient and downgradient water quality at the 5% significance level

MW20	16-Dec-93	BERYLLIUM, DISSOLVED	<	5	ug/L			
MW21P	17-Dec-93	BERYLLIUM, DISSOLVED	<	5	ug/L			
MW22P	16-Dec-93	BERYLLIUM, DISSOLVED	<	5	ug/L			
MW20	16-Dec-93	CADMIUM, DISSOLVED	<	0.3	ug/L			3.0
MW20	16-Mar-94	CADMIUM, DISSOLVED	<	0.3	ug/L			3.0
MW20	16-Jun-94	CADMIUM, DISSOLVED		0.33	ug/L			3.0
MW20	14-Sep-94	CADMIUM, DISSOLVED		0.98	UG/L			3.0
MW21P	17-Dec-93	CADMIUM, DISSOLVED	<	0.3	ug/L			3.0
MW21P	16-Mar-94	CADMIUM, DISSOLVED		0.65	ug/L			3.0
MW21P	16-Jun-94	CADMIUM, DISSOLVED	<	0.3	ug/L			3.0
MW21P	14-Sep-94	CADMIUM, DISSOLVED	<	0.3	UG/L			3.0
MW22P	16-Dec-93	CADMIUM, DISSOLVED	<	0.3	ug/L			3.0
MW22P	15-Mar-94	CADMIUM, DISSOLVED	<	0.3	ug/L			3.0
MW22P	16-Jun-94	CADMIUM, DISSOLVED	<	0.3	ug/L			3.0
MW22P	14-Sep-94	CADMIUM, DISSOLVED	<	0.3	UG/L			3.0
MW20	16-Dec-93	CHLORIDE		22	mg/L			370
MW20	16-Mar-94	CHLORIDE		27	mg/L			370
MW20	16-Jun-94	CHLORIDE		5.1	mg/L			370
MW20	14-Sep-94	CHLORIDE		20	MG/L			370
MW21P	17-Dec-93	CHLORIDE		39	mg/L			370
MW21P	16-Mar-94	CHLORIDE		42	mg/L			370
MW21P	16-Jun-94	CHLORIDE		35	mg/L			370
MW21P	14-Sep-94	CHLORIDE		150	MG/L			370
MW22P	16-Dec-93	CHLORIDE		60	mg/L			370
MW22P	15-Mar-94	CHLORIDE		62	mg/L			370
MW22P	16-Jun-94	CHLORIDE		57	mg/L			370
MW22P	14-Sep-94	CHLORIDE		63	MG/L			370
MW20	14-Sep-94	CHLOROFORM	<	10	UG/L			
MW21P	14-Sep-94	CHLOROFORM	<	10	UG/L			
MW22P	14-Sep-94	CHLOROFORM	<	10	UG/L			
MW20	16-Dec-93	CHROMIUM, DISSOLVED	<	2	ug/L			
MW20	16-Mar-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW20	16-Jun-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW20	14-Sep-94	CHROMIUM, DISSOLVED	<	2	UG/L			
MW21P	17-Dec-93	CHROMIUM, DISSOLVED	<	2	ug/L			
MW21P	16-Mar-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW21P	16-Jun-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW21P	14-Sep-94	CHROMIUM, DISSOLVED	<	2	UG/L			
MW22P	16-Dec-93	CHROMIUM, DISSOLVED	<	2	ug/L			
MW22P	16-Mar-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW22P	16-Jun-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW22P	14-Sep-94	CHROMIUM, DISSOLVED	<	2	UG/L			
Proportions Test			12	12				
No. of Background Detects (x)			2					
No. of Background Samples (n)			14					
Proportion of Detects (Pu)			0.14					
No. of Downgradient Detects (y)			0					
No. of Downgradient Samples (m)			12					
Proportion of Detects (Pd)			0.00					
Standard of Error			0.1048					

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TABLE E2
COMPARISON OF DOWNGRADIENT AND UPGRADIENT GROUNDWATER QUALITY - SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
Z Statistic (Z)			1.3628					
Difference between upgradient and downgradient, but upgradient has more detects.								
MW20	16-Dec-93	COBALT, DISSOLVED	<	50	ug/L			
MW20	16-Mar-94	COBALT, DISSOLVED	<	50	ug/L			
MW20	16-Jun-94	COBALT, DISSOLVED	<	50	ug/L			
MW20	14-Sep-94	COBALT, DISSOLVED	<	50	UG/L			
MW21P	17-Dec-93	COBALT, DISSOLVED	<	50	ug/L			
MW21P	16-Mar-94	COBALT, DISSOLVED	<	50	ug/L			
MW21P	16-Jun-94	COBALT, DISSOLVED	<	50	ug/L			
MW21P	14-Sep-94	COBALT, DISSOLVED	<	50	UG/L			
MW22P	16-Dec-93	COBALT, DISSOLVED	<	50	ug/L			
MW22P	15-Mar-94	COBALT, DISSOLVED	<	50	ug/L			
MW22P	16-Jun-94	COBALT, DISSOLVED	<	50	ug/L			
MW22P	14-Sep-94	COBALT, DISSOLVED	<	50	UG/L			
Proportions Test			12	12				
No. of Background Detects (x)			1					
No. of Background Samples (n)			14					
Proportion of Detects (Pu)			0.07					
No. of Downgradient Detects (y)			0					
No. of Downgradient Samples (m)			12					
Proportion of Detects (Pd)			0.00					
Standard of Error			0.0767					
Z Statistic (Z)			0.9442	No Difference				
MW20	16-Dec-93	CONDUCTANCE, SPECIFIC		2100	UMHOS/CM	2561		
MW20	16-Mar-94	CONDUCTANCE, SPECIFIC		1850	UMHOS/CM	2561		
MW20	16-Jun-94	CONDUCTANCE, SPECIFIC		1430	UMHOS/CM	2561		
MW21P	17-Dec-93	CONDUCTANCE, SPECIFIC		1800	UMHOS/CM	2561		
MW21P	16-Mar-94	CONDUCTANCE, SPECIFIC		1260	UMHOS/CM	2561		
MW21P	16-Jun-94	CONDUCTANCE, SPECIFIC		1820	UMHOS/CM	2561		
MW22P	16-Dec-93	CONDUCTANCE, SPECIFIC		2300	UMHOS/CM	2561		
MW22P	15-Mar-94	CONDUCTANCE, SPECIFIC		2050	UMHOS/CM	2561		
MW22P	16-Jun-94	CONDUCTANCE, SPECIFIC		2370	UMHOS/CM	2561		
MW20	14-Sep-94	CONDUCTANCE, SPECIFIC		1740	UMHOS/CM	2561		
MW21P	14-Sep-94	CONDUCTANCE, SPECIFIC		1140	UMHOS/CM	2561		
MW22P	14-Sep-94	CONDUCTANCE, SPECIFIC		1340	UMHOS/CM	2561		
MW20	16-Dec-93	COPPER, DISSOLVED	<	3	ug/L			
MW20	16-Mar-94	COPPER, DISSOLVED	<	3	ug/L			
MW20	16-Jun-94	COPPER, DISSOLVED	<	3	ug/L			
MW20	14-Sep-94	COPPER, DISSOLVED	<	3	UG/L			
MW21P	17-Dec-93	COPPER, DISSOLVED	<	3	ug/L			
MW21P	16-Mar-94	COPPER, DISSOLVED	<	3	ug/L			
MW21P	16-Jun-94	COPPER, DISSOLVED	<	3	ug/L			
MW21P	14-Sep-94	COPPER, DISSOLVED		5.6	UG/L			
MW22P	16-Dec-93	COPPER, DISSOLVED	<	3	ug/L			
MW22P	15-Mar-94	COPPER, DISSOLVED	<	3	ug/L			
MW22P	16-Jun-94	COPPER, DISSOLVED	<	3	ug/L			
MW22P	14-Sep-94	COPPER, DISSOLVED	<	3	UG/L			
Proportions Test			11	12				
No. of Background Detects (x)			5					
No. of Background Samples (n)			14					
Proportion of Detects (Pu)			0.36					
No. of Downgradient Detects (y)			1					
No. of Downgradient Samples (m)			12					
Proportion of Detects (Pd)			0.08					
Standard of Error			0.1667					
Z Statistic (Z)			1.6520	No Difference				
MW20	16-Dec-93	CYANIDE, TOTAL	<	0.041	mg/L			
MW21P	17-Dec-93	CYANIDE, TOTAL	<	0.01	mg/L			
MW22P	16-Dec-93	CYANIDE, TOTAL	<	0.01	mg/L			
MW20	16-Dec-93	FLUORIDE		0.48	mg/L	2.0		
MW20	16-Mar-94	FLUORIDE		0.4	mg/L	2.0		
MW20	16-Jun-94	FLUORIDE	<	0.1	mg/L	2.0		
MW20	14-Sep-94	FLUORIDE		0.47	MG/L	2.0		
MW21P	17-Dec-93	FLUORIDE		3.3	mg/L	2.0		YES
MW21P	16-Mar-94	FLUORIDE		3.8	mg/L	2.0		YES
MW21P	16-Jun-94	FLUORIDE		3.1	mg/L	2.0		YES
MW21P	14-Sep-94	FLUORIDE		2.9	MG/L	2.0		YES
MW22P	16-Dec-93	FLUORIDE		9	mg/L	2.0		YES
MW22P	15-Mar-94	FLUORIDE		10	mg/L	2.0		YES
MW22P	16-Jun-94	FLUORIDE		9.5	mg/L	2.0		YES
MW22P	14-Sep-94	FLUORIDE		9.5	MG/L	2.0		YES
MW20	16-Dec-93	IRON, DISSOLVED		12000	ug/L	30835		
MW20	16-Mar-94	IRON, DISSOLVED		19000	ug/L	30835		

TABLE E2
COMPARISON OF DOWNGRADIENT AND UPGRADIENT GROUNDWATER QUALITY - SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
MW20	16-Jun-94	IRON, DISSOLVED	<	100	ug/L	30835		
MW20	14-Sep-94	IRON, DISSOLVED		19000	UG/L	30835		
MW21P	17-Dec-93	IRON, DISSOLVED	<	100	ug/L	30835		
MW21P	16-Mar-94	IRON, DISSOLVED	<	100	ug/L	30835		
MW21P	16-Jun-94	IRON, DISSOLVED	<	100	ug/L	30835		
MW21P	14-Sep-94	IRON, DISSOLVED		2300	UG/L	30835		
MW22P	16-Dec-93	IRON, DISSOLVED		530	ug/L	30835		
MW22P	16-Mar-94	IRON, DISSOLVED	<	100	ug/L	30835		
MW22P	16-Jun-94	IRON, DISSOLVED	<	100	ug/L	30835		
MW22P	14-Sep-94	IRON, DISSOLVED		190	UG/L	30835		
MW20	16-Dec-93	LEAD, DISSOLVED	<	3	ug/L			
MW20	16-Mar-94	LEAD, DISSOLVED	<	3	ug/L			
MW20	16-Jun-94	LEAD, DISSOLVED	<	3	ug/L			
MW20	14-Sep-94	LEAD, DISSOLVED	<	3	UG/L			
MW21P	17-Dec-93	LEAD, DISSOLVED	<	3	ug/L			
MW21P	16-Mar-94	LEAD, DISSOLVED	<	3	ug/L			
MW21P	16-Jun-94	LEAD, DISSOLVED	<	3	ug/L			
MW21P	14-Sep-94	LEAD, DISSOLVED	<	3	UG/L			
MW22P	16-Dec-93	LEAD, DISSOLVED	<	3	ug/L			
MW22P	16-Mar-94	LEAD, DISSOLVED	<	3	ug/L			
MW22P	16-Jun-94	LEAD, DISSOLVED	<	3	ug/L			
MW22P	14-Sep-94	LEAD, DISSOLVED	<	6	UG/L			
Proportions Test			12	12				
No. of Background Detects (x)			0					
No. of Background Samples (n)			14					
Proportion of Detects (Pu)			0.00					
No. of Downgradient Detects (y)			0					
No. of Downgradient Samples (m)			12					
Proportion of Detects (Pd)			0.00					
Standard of Error			0.0000					
Z Statistic (Z)			ERR No Difference					
MW20	16-Dec-93	MANGANESE, DISSOLVED		10000	ug/L	2748		Yes
MW20	16-Mar-94	MANGANESE, DISSOLVED		8200	ug/L	2748		
MW20	16-Jun-94	MANGANESE, DISSOLVED		800	ug/L	2748		
MW20	14-Sep-94	MANGANESE, DISSOLVED		8300	UG/L	2748		Yes
MW21P	17-Dec-93	MANGANESE, DISSOLVED		37	ug/L	2748		
MW21P	16-Mar-94	MANGANESE, DISSOLVED		21	ug/L	2748		
MW21P	16-Jun-94	MANGANESE, DISSOLVED		36	ug/L	2748		
MW21P	14-Sep-94	MANGANESE, DISSOLVED		69	UG/L	2748		
MW22P	16-Dec-93	MANGANESE, DISSOLVED		49	ug/L	2748		
MW22P	16-Mar-94	MANGANESE, DISSOLVED		19	ug/L	2748		
MW22P	16-Jun-94	MANGANESE, DISSOLVED		8.4	ug/L	2748		
MW22P	14-Sep-94	MANGANESE, DISSOLVED		22	UG/L	2748		
MW20	16-Dec-93	MERCURY, DISSOLVED	<	0.2	ug/L			
MW20	16-Mar-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW20	16-Jun-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW20	14-Sep-94	MERCURY, DISSOLVED	<	0.2	UG/L			
MW21P	17-Dec-93	MERCURY, DISSOLVED	<	0.2	ug/L			
MW21P	16-Mar-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW21P	16-Jun-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW21P	14-Sep-94	MERCURY, DISSOLVED	<	0.2	UG/L			
MW22P	16-Dec-93	MERCURY, DISSOLVED	<	0.2	ug/L			
MW22P	16-Mar-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW22P	16-Jun-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW22P	14-Sep-94	MERCURY, DISSOLVED	<	0.2	UG/L			
Proportions Test			12	12				
No. of Background Detects (x)			0					
No. of Background Samples (n)			14					
Proportion of Detects (Pu)			0.00					
No. of Downgradient Detects (y)			0					
No. of Downgradient Samples (m)			12					
Proportion of Detects (Pd)			0.00					
Standard of Error			0.0000					
Z Statistic (Z)			ERR No Difference					
MW20	16-Dec-93	NICKEL, DISSOLVED	<	40	ug/L			
MW20	16-Mar-94	NICKEL, DISSOLVED	<	40	ug/L			
MW20	16-Jun-94	NICKEL, DISSOLVED	<	40	ug/L			
MW20	14-Sep-94	NICKEL, DISSOLVED	<	40	UG/L			
MW21P	17-Dec-93	NICKEL, DISSOLVED	<	40	ug/L			
MW21P	16-Mar-94	NICKEL, DISSOLVED	<	40	ug/L			
MW21P	16-Jun-94	NICKEL, DISSOLVED	<	40	ug/L			
MW21P	14-Sep-94	NICKEL, DISSOLVED	<	40	UG/L			
MW22P	16-Dec-93	NICKEL, DISSOLVED	<	40	ug/L			
MW22P	16-Mar-94	NICKEL, DISSOLVED	<	40	ug/L			
MW22P	16-Jun-94	NICKEL, DISSOLVED	<	40	ug/L			
MW22P	14-Sep-94	NICKEL, DISSOLVED	<	40	UG/L			
Proportions Test			12	12				
No. of Background Detects (x)			2					

TABLE E2
COMPARISON OF DOWNGRADIENT AND UPGRADIENT GROUNDWATER QUALITY - SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
No. of Background Samples (n)			14					
Proportion of Detects (Pu)			0.14					
No. of Downgradient Detects (y)			0					
No. of Downgradient Samples (m)			12					
Proportion of Detects (Pd)			0.00					
Standard of Error			0.1048					
Z Statistic (Z)			1.3828 No Difference					
MW20	16-Dec-93	NITROGEN, NITRATE	<	0.05	mg/L	2.2		
MW20	16-Mar-94	NITROGEN, NITRATE	<	0.05	mg/L	2.2		
MW20	16-Jun-94	NITROGEN, NITRATE		1.6	mg/L	2.2		
MW20	14-Sep-94	NITROGEN, NITRATE	<	0.05	MG/L	2.2		
MW21P	17-Dec-93	NITROGEN, NITRATE	<	0.05	mg/L	2.2		
MW21P	16-Mar-94	NITROGEN, NITRATE	<	0.05	mg/L	2.2		
MW21P	16-Jun-94	NITROGEN, NITRATE		0.2	mg/L	2.2		
MW21P	14-Sep-94	NITROGEN, NITRATE		0.55	MG/L	2.2		
MW22P	16-Dec-93	NITROGEN, NITRATE	<	0.05	mg/L	2.2		
MW22P	16-Mar-94	NITROGEN, NITRATE	<	0.05	mg/L	2.2		
MW22P	16-Jun-94	NITROGEN, NITRATE	<	0.05	mg/L	2.2		
MW22P	14-Sep-94	NITROGEN, NITRATE	<	0.05	MG/L	2.2		
MW20	16-Dec-93	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L	0.2		
MW20	16-Mar-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L	0.2		
MW20	16-Jun-94	PHENOLICS, TOTAL RECOVERABLE		0.01	mg/L	0.2		
MW20	14-Sep-94	PHENOLICS, TOTAL RECOVERABLE		0.011	MG/L	0.2		
MW21P	17-Dec-93	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L	0.2		
MW21P	16-Mar-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L	0.2		
MW21P	16-Jun-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L	0.2		
MW21P	14-Sep-94	PHENOLICS, TOTAL RECOVERABLE		0.015	MG/L	0.2		
MW22P	16-Dec-93	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L	0.2		
MW22P	15-Mar-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L	0.2		
MW22P	16-Jun-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L	0.2		
MW22P	14-Sep-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	MG/L	0.2		
MW20	16-Dec-93	SELENIUM, DISSOLVED	<	3	ug/L			
MW20	16-Mar-94	SELENIUM, DISSOLVED	<	12	ug/L			
MW20	16-Jun-94	SELENIUM, DISSOLVED	<	3	ug/L			
MW20	14-Sep-94	SELENIUM, DISSOLVED	<	6	UG/L			
MW21P	17-Dec-93	SELENIUM, DISSOLVED	<	3	ug/L			
MW21P	16-Mar-94	SELENIUM, DISSOLVED	<	12	ug/L			
MW21P	16-Jun-94	SELENIUM, DISSOLVED	<	3	ug/L			
MW21P	14-Sep-94	SELENIUM, DISSOLVED	<	6	UG/L			
MW22P	16-Dec-93	SELENIUM, DISSOLVED	<	3	ug/L			
MW22P	15-Mar-94	SELENIUM, DISSOLVED	<	12	ug/L			
MW22P	16-Jun-94	SELENIUM, DISSOLVED	<	3	ug/L			
MW22P	14-Sep-94	SELENIUM, DISSOLVED	<	6	UG/L			
Proportions Test			12	12				
No. of Background Detects (x)			0					
No. of Background Samples (n)			14					
Proportion of Detects (Pu)			0.00					
No. of Downgradient Detects (y)			0					
No. of Downgradient Samples (m)			12					
Proportion of Detects (Pd)			0.00					
Standard of Error			0.0000					
Z Statistic (Z)			ERR No Difference					
MW20	16-Dec-93	SILVER, DISSOLVED	<	1	ug/L			
MW20	16-Mar-94	SILVER, DISSOLVED	<	1	ug/L			
MW20	16-Jun-94	SILVER, DISSOLVED	<	1	ug/L			
MW20	14-Sep-94	SILVER, DISSOLVED	<	1	UG/L			
MW21P	17-Dec-93	SILVER, DISSOLVED	<	1	ug/L			
MW21P	16-Mar-94	SILVER, DISSOLVED	<	1	ug/L			
MW21P	16-Jun-94	SILVER, DISSOLVED	<	1	ug/L			
MW21P	14-Sep-94	SILVER, DISSOLVED	<	1	UG/L			
MW22P	16-Dec-93	SILVER, DISSOLVED	<	1	ug/L			
MW22P	15-Mar-94	SILVER, DISSOLVED	<	1	ug/L			
MW22P	16-Jun-94	SILVER, DISSOLVED	<	1	ug/L			
MW22P	14-Sep-94	SILVER, DISSOLVED	<	1	UG/L			
Proportions Test			12	12				
No. of Background Detects (x)			0					
No. of Background Samples (n)			14					
Proportion of Detects (Pu)			0.00					
No. of Downgradient Detects (y)			0					
No. of Downgradient Samples (m)			12					
Proportion of Detects (Pd)			0.00					
Standard of Error			0.0000					
Z Statistic (Z)			ERR					
MW20	16-Dec-93	SODIUM, DISSOLVED		89000	ug/L	212143		
MW20	16-Mar-94	SODIUM, DISSOLVED		89000	ug/L	212143		

TABLE E2
COMPARISON OF DOWNGRADIENT AND UPGRADIENT GROUNDWATER QUALITY - SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
MW20	16-Jun-94	SODIUM, DISSOLVED		5400	ug/L	212143		
MW20	14-Sep-94	SODIUM, DISSOLVED		110000	UG/L	212143		
MW21P	17-Dec-93	SODIUM, DISSOLVED		290000	ug/L	212143		YES
MW21P	16-Mar-94	SODIUM, DISSOLVED		27000	ug/L	212143		
MW21P	16-Jun-94	SODIUM, DISSOLVED		330000	ug/L	212143		YES
MW21P	14-Sep-94	SODIUM, DISSOLVED		340000	UG/L	212143		YES
MW22P	16-Dec-93	SODIUM, DISSOLVED		470000	ug/L	212143		YES
MW22P	16-Mar-94	SODIUM, DISSOLVED		470000	ug/L	212143		YES
MW22P	16-Jun-94	SODIUM, DISSOLVED		580000	ug/L	212143		YES
MW22P	14-Sep-94	SODIUM, DISSOLVED		500000	UG/L	212143		YES
MW20	16-Dec-93	SULFATE		870	mg/L	1613		
MW20	16-Mar-94	SULFATE		790	mg/L	1613		
MW20	16-Jun-94	SULFATE		36	mg/L	1613		
MW20	14-Sep-94	SULFATE		750	MG/L	1613		
MW21P	17-Dec-93	SULFATE		460	mg/L	1613		
MW21P	16-Mar-94	SULFATE		470	mg/L	1613		
MW21P	16-Jun-94	SULFATE		330	mg/L	1613		
MW21P	14-Sep-94	SULFATE		470	MG/L	1613		
MW22P	16-Dec-93	SULFATE		330	mg/L	1613		
MW22P	16-Mar-94	SULFATE		340	mg/L	1613		
MW22P	16-Jun-94	SULFATE		320	mg/L	1613		
MW22P	14-Sep-94	SULFATE		300	MG/L	1613		
MW20	14-Sep-94	SULFIDE	<	1	MG/L	3.2		
MW21P	14-Sep-94	SULFIDE		1.3	MG/L	3.2		
MW22P	14-Sep-94	SULFIDE	<	1	MG/L	3.2		
MW20	16-Dec-93	SULFIDE, TOTAL	<	1	mg/L	3.2		
MW20	16-Mar-94	SULFIDE, TOTAL	<	1	mg/L	3.2		
MW20	16-Jun-94	SULFIDE, TOTAL		1.2	mg/L	3.2		
MW21P	17-Dec-93	SULFIDE, TOTAL	<	1	mg/L	3.2		
MW21P	16-Mar-94	SULFIDE, TOTAL	<	1	mg/L	3.2		
MW21P	16-Jun-94	SULFIDE, TOTAL		2	mg/L	3.2		
MW22P	16-Dec-93	SULFIDE, TOTAL		3.2	mg/L	3.2		
MW22P	16-Mar-94	SULFIDE, TOTAL		1	mg/L	3.2		
MW22P	16-Jun-94	SULFIDE, TOTAL		1.9	mg/L	3.2		
MW20	16-Dec-93	THALLIUM, DISSOLVED	<	3	mg/L			
MW21P	17-Dec-93	THALLIUM, DISSOLVED	<	3	mg/L			
MW22P	16-Dec-93	THALLIUM, DISSOLVED	<	3	mg/L			
MW20	16-Dec-93	TIN, DISSOLVED	<	500	ug/L			
MW20	16-Mar-94	TIN, DISSOLVED	<	500	ug/L			
MW20	16-Jun-94	TIN, DISSOLVED	<	500	ug/L			
MW20	14-Sep-94	TIN, DISSOLVED	<	500	UG/L			
MW21P	17-Dec-93	TIN, DISSOLVED	<	500	ug/L			
MW21P	16-Mar-94	TIN, DISSOLVED	<	500	ug/L			
MW21P	16-Jun-94	TIN, DISSOLVED	<	500	ug/L			
MW21P	14-Sep-94	TIN, DISSOLVED	<	500	UG/L			
MW22P	16-Dec-93	TIN, DISSOLVED	<	500	ug/L			
MW22P	16-Mar-94	TIN, DISSOLVED	<	500	ug/L			
MW22P	16-Jun-94	TIN, DISSOLVED	<	500	ug/L			
MW22P	14-Sep-94	TIN, DISSOLVED	<	500	UG/L			
Proportions Test			12	12				
No. of Background Detects (x)			0					
No. of Background Samples (n)			14					
Proportion of Detects (Pu)			0.00					
No. of Downgradient Detects (y)			0					
No. of Downgradient Samples (m)			12					
Proportion of Detects (Pd)			0.00					
Standard of Error			0.0000					
Z Statistic (Z)			ERR No Difference					
MW20	16-Dec-93	TOTAL ORGANIC CARBON AS NPOC		31	mg/L	36		
MW20	16-Mar-94	TOTAL ORGANIC CARBON AS NPOC		4.4	mg/L	36		
MW20	16-Jun-94	TOTAL ORGANIC CARBON AS NPOC		0.34	mg/L	36		
MW20	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC		7.8	MG/L	36		
MW21P	17-Dec-93	TOTAL ORGANIC CARBON AS NPOC		1.8	mg/L	36		
MW21P	16-Mar-94	TOTAL ORGANIC CARBON AS NPOC		2.3	mg/L	36		
MW21P	16-Jun-94	TOTAL ORGANIC CARBON AS NPOC		2.4	mg/L	36		
MW21P	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC		43	MG/L	36		YES
MW22P	16-Dec-93	TOTAL ORGANIC CARBON AS NPOC		2.8	mg/L	36		
MW22P	16-Mar-94	TOTAL ORGANIC CARBON AS NPOC		2.4	mg/L	36		
MW22P	16-Jun-94	TOTAL ORGANIC CARBON AS NPOC		3.1	mg/L	36		
MW22P	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC		26	MG/L	36		
MW20	16-Dec-93	TOTAL ORGANIC HALIDES		5	ug/L	52		
MW20	16-Mar-94	TOTAL ORGANIC HALIDES		30	ug/L	52		
MW20	16-Jun-94	TOTAL ORGANIC HALIDES		7.6	ug/L	52		

TABLE E2
COMPARISON OF DOWNGRADIENT AND UPGRADIENT GROUNDWATER QUALITY - SHALE WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
MW20	14-Sep-94	TOTAL ORGANIC HALIDES		5.8	UG/L	52		
MW21P	17-Dec-93	TOTAL ORGANIC HALIDES		11	ug/L	52		
MW21P	16-Mar-94	TOTAL ORGANIC HALIDES	<	5	ug/L	52		
MW21P	16-Jun-94	TOTAL ORGANIC HALIDES		8.2	ug/L	52		
MW21P	14-Sep-94	TOTAL ORGANIC HALIDES		59	UG/L	52		YES
MW22P	16-Dec-93	TOTAL ORGANIC HALIDES	<	5	ug/L	52		
MW22P	16-Mar-94	TOTAL ORGANIC HALIDES		17	ug/L	52		
MW22P	16-Jun-94	TOTAL ORGANIC HALIDES		7.2	ug/L	52		
MW22P	14-Sep-94	TOTAL ORGANIC HALIDES		7.4	UG/L	52		
MW20	16-Dec-93	VANADIUM, DISSOLVED	<	50	ug/L			
MW21P	17-Dec-93	VANADIUM, DISSOLVED	<	50	ug/L			
MW22P	16-Dec-93	VANADIUM, DISSOLVED	<	50	ug/L			
MW20	16-Dec-93	ZINC, DISSOLVED	<	20	ug/L	169		
MW20	16-Mar-94	ZINC, DISSOLVED	<	20	ug/L	169		
MW20	16-Jun-94	ZINC, DISSOLVED	<	20	ug/L	169		
MW20	14-Sep-94	ZINC, DISSOLVED		21	UG/L	169		
MW21P	17-Dec-93	ZINC, DISSOLVED	<	20	ug/L	169		
MW21P	16-Mar-94	ZINC, DISSOLVED	<	20	ug/L	169		
MW21P	16-Jun-94	ZINC, DISSOLVED	<	20	ug/L	169		
MW21P	14-Sep-94	ZINC, DISSOLVED	<	20	UG/L	169		
MW22P	16-Dec-93	ZINC, DISSOLVED	<	20	ug/L	169		
MW22P	16-Mar-94	ZINC, DISSOLVED	<	20	ug/L	169		
MW22P	16-Jun-94	ZINC, DISSOLVED	<	20	ug/L	169		
MW22P	14-Sep-94	ZINC, DISSOLVED		35	UG/L	169		
MW20	16-Dec-93	pH, FIELD		6.5	SU	9.7	2.0	
MW20	16-Mar-94	pH, FIELD		6.7	SU	9.7	2.0	
MW20	16-Jun-94	pH, FIELD		6.6	SU	9.7	2.0	
MW21P	17-Dec-93	pH, FIELD		7.8	SU	9.7	2.0	
MW21P	16-Mar-94	pH, FIELD		7	SU	9.7	2.0	
MW21P	16-Jun-94	pH, FIELD		7.5	SU	9.7	2.0	
MW22P	16-Dec-93	pH, FIELD		8.2	SU	9.7	2.0	
MW22P	16-Mar-94	pH, FIELD		7.3	SU	9.7	2.0	
MW22P	16-Jun-94	pH, FIELD		8.1	SU	9.7	2.0	
MW20	14-Sep-94	pH, FIELD		6.5	SU	9.7	2.0	
MW21P	14-Sep-94	pH, FIELD		6.4	SU	9.7	2.0	
MW22P	14-Sep-94	pH, FIELD		8.1	SU	9.7	2.0	

Table E-3

Calculation of Tolerance Intervals

For Sidegradient Well MW-23

TABLE E3
CALCULATION OF TOLERANCE INTERVALS FOR SIDEGRADIENT SPOILS WELL MW-23
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

Well No.	Date	Parameter	Prefix	Result Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence	Upper 95% Confidence
MW23	15-Dec-93	ALKALINITY, BICARBONATE		160 mg/L									
MW23	16-Mar-94	ALKALINITY, BICARBONATE		66 mg/L									
MW23	16-Jun-94	ALKALINITY, BICARBONATE		76 mg/L									
					3	0	3	0%	100.67	42.15	7.655		423
MW23	15-Dec-93	ALKALINITY, CARBONATE	<	20 mg/L									
MW23	16-Mar-94	ALKALINITY, CARBONATE	<	20 mg/L									
MW23	16-Jun-94	ALKALINITY, CARBONATE	<	20 mg/L									
MW23	14-Sep-94	ALKALINITY, CARBONATE		34 MG/L									
					4	3	1	75%	23.50	6.06	5.145		55
MW23	15-Dec-93	ANTIMONY, DISSOLVED	<	10 ug/L									
MW23	16-Mar-94	ANTIMONY, DISSOLVED	<	10 ug/L									
MW23	16-Jun-94	ANTIMONY, DISSOLVED	<	10 ug/L									
MW23	14-Sep-94	ANTIMONY, DISSOLVED	<	10 UG/L									
MW23	15-Dec-93	ARSENIC, DISSOLVED	<	3 ug/L									
MW23	16-Mar-94	ARSENIC, DISSOLVED	<	3 ug/L									
MW23	16-Jun-94	ARSENIC, DISSOLVED	<	3 ug/L									
MW23	14-Sep-94	ARSENIC, DISSOLVED	<	3 UG/L									
MW23	15-Dec-93	BARIUM, DISSOLVED	<	50 ug/L									
MW23	16-Mar-94	BARIUM, DISSOLVED	<	50 ug/L									
MW23	16-Jun-94	BARIUM, DISSOLVED	<	50 ug/L									
MW23	14-Sep-94	BARIUM, DISSOLVED	<	50 UG/L									
MW23	15-Dec-93	BERYLLIUM, DISSOLVED	<	5 ug/L									
MW23	15-Dec-93	CADMIUM, DISSOLVED		0.7 ug/L									
MW23	16-Mar-94	CADMIUM, DISSOLVED		4.6 ug/L									
MW23	16-Jun-94	CADMIUM, DISSOLVED	<	0.3 ug/L									
MW23	14-Sep-94	CADMIUM, DISSOLVED	<	0.3 UG/L									
					4	2	2	50%	1.48	1.81	5.145		10.8
MW23	15-Dec-93	CHLORIDE		26 mg/L									
MW23	16-Mar-94	CHLORIDE		240 mg/L									
MW23	16-Jun-94	CHLORIDE		87 mg/L									
MW23	14-Sep-94	CHLORIDE		240 MG/L									
					4	0	4	0%	148.25	94.25	5.145		633
MW23	14-Sep-94	CHLOROFORM	<	10 UG/L									
MW23	15-Dec-93	CHROMIUM, DISSOLVED	<	2 ug/L									
MW23	16-Mar-94	CHROMIUM, DISSOLVED	<	2 ug/L									
MW23	16-Jun-94	CHROMIUM, DISSOLVED	<	2 ug/L									
MW23	14-Sep-94	CHROMIUM, DISSOLVED	<	2 UG/L									
MW23	15-Dec-93	COBALT, DISSOLVED	<	50 ug/L									
MW23	16-Mar-94	COBALT, DISSOLVED	<	50 ug/L									
MW23	16-Jun-94	COBALT, DISSOLVED	<	50 ug/L									
MW23	14-Sep-94	COBALT, DISSOLVED	<	50 UG/L									
MW23	15-Dec-93	CONDUCTANCE, SPECIFIC		2100 UMHOS/CM									
MW23	16-Mar-94	CONDUCTANCE, SPECIFIC		1300 UMHOS/CM									
MW23	16-Jun-94	CONDUCTANCE, SPECIFIC		1580 UMHOS/CM									
MW23	14-Sep-94	CONDUCTANCE, SPECIFIC		1071 UMHOS/CM									
					4	0	4	0%	1512.75	383.99	5.145		3488
MW23	15-Dec-93	COPPER, DISSOLVED	<	3 ug/L									
MW23	16-Mar-94	COPPER, DISSOLVED	<	3 ug/L									

TABLE E3
CALCULATION OF TOLERANCE INTERVALS FOR SIDEGRADIENT SPOILS WELL MW-23
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

Well No.	Date	Parameter	Prefix	Result Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence	Upper 95% Confidence
MW23	16-Jun-94	COPPER, DISSOLVED	<	3 ug/L									
MW23	14-Sep-94	COPPER, DISSOLVED	<	3 UG/L									
MW23	15-Dec-93	CYANIDE, TOTAL		0.01 mg/L									
MW23	15-Dec-93	FLUORIDE		0.22 mg/L									
MW23	16-Mar-94	FLUORIDE		0.12 mg/L									
MW23	16-Jun-94	FLUORIDE		0.15 mg/L									
MW23	14-Sep-94	FLUORIDE		0.11 MG/L	4	0	4	0%	0.15	0.04	5.145		0.37
MW23	15-Dec-93	IRON, DISSOLVED		11000 ug/L									
MW23	16-Mar-94	IRON, DISSOLVED		120 ug/L									
MW23	16-Jun-94	IRON, DISSOLVED		17000 ug/L									
MW23	14-Sep-94	IRON, DISSOLVED		30000 UG/L	4	0	4	0%	14530.00	10788.08	5.145		70035
MW23	15-Dec-93	LEAD, DISSOLVED	<	3 ug/L									
MW23	16-Mar-94	LEAD, DISSOLVED	<	3 ug/L									
MW23	16-Jun-94	LEAD, DISSOLVED	<	3 ug/L									
MW23	14-Sep-94	LEAD, DISSOLVED	<	3 UG/L									
MW23	15-Dec-93	MANGANESE, DISSOLVED		5200 ug/L									
MW23	16-Mar-94	MANGANESE, DISSOLVED		4400 ug/L									
MW23	16-Jun-94	MANGANESE, DISSOLVED		4000 ug/L									
MW23	14-Sep-94	MANGANESE, DISSOLVED		3700 UG/L	4	0	4	0%	4325.00	562.92	5.145		7221
MW23	15-Dec-93	MERCURY, DISSOLVED	<	0.2 ug/L									
MW23	16-Mar-94	MERCURY, DISSOLVED	<	0.2 ug/L									
MW23	16-Jun-94	MERCURY, DISSOLVED	<	0.2 ug/L									
MW23	14-Sep-94	MERCURY, DISSOLVED	<	0.2 UG/L									
MW23	15-Dec-93	NICKEL, DISSOLVED	<	40 ug/L									
MW23	16-Mar-94	NICKEL, DISSOLVED	<	40 ug/L									
MW23	16-Jun-94	NICKEL, DISSOLVED	<	40 ug/L									
MW23	14-Sep-94	NICKEL, DISSOLVED	<	40 UG/L									
MW23	15-Dec-93	NITROGEN, NITRATE	<	0.05 mg/L									
MW23	16-Mar-94	NITROGEN, NITRATE		0.22 mg/L									
MW23	16-Jun-94	NITROGEN, NITRATE	<	0.05 mg/L									
MW23	14-Sep-94	NITROGEN, NITRATE	<	0.05 MG/L									
MW23	15-Dec-93	PHENOLICS, TOTAL RECOVERABLE	<	0.01 mg/L									
MW23	16-Mar-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01 mg/L									
MW23	16-Jun-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01 mg/L									
MW23	14-Sep-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01 MG/L									
MW23	15-Dec-93	SELENIUM, DISSOLVED	<	3 ug/L									
MW23	16-Mar-94	SELENIUM, DISSOLVED	<	12 ug/L									
MW23	16-Jun-94	SELENIUM, DISSOLVED	<	3 ug/L									
MW23	14-Sep-94	SELENIUM, DISSOLVED	<	6 UG/L									
MW23	15-Dec-93	SILVER, DISSOLVED	<	1 ug/L									
MW23	16-Mar-94	SILVER, DISSOLVED	<	1 ug/L									
MW23	16-Jun-94	SILVER, DISSOLVED	<	1 ug/L									
MW23	14-Sep-94	SILVER, DISSOLVED	<	1 UG/L									

TABLE E3
CALCULATION OF TOLERANCE INTERVALS FOR SIDEGRADIENT SPOILS WELL MW-23
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

Well No.	Date	Parameter	Prefix	Result Units	Number of Results	Number of Non-detects	Number of Detects	Percentage of Non-detects	Mean	Standard Deviation	T-Value	Lower 95% Confidence	Upper 95% Confidence
MW23	15-Dec-93	SODIUM, DISSOLVED		41000 ug/L									
MW23	16-Mar-94	SODIUM, DISSOLVED		12000 ug/L									
MW23	16-Jun-94	SODIUM, DISSOLVED		17000 ug/L									
MW23	14-Sep-94	SODIUM, DISSOLVED		8800 UG/L	4	0	4	0%	19700.00	12640.02	5.145		84733
MW23	15-Dec-93	SULFATE		1200 mg/L									
MW23	16-Mar-94	SULFATE		280 mg/L									
MW23	16-Jun-94	SULFATE		750 mg/L									
MW23	14-Sep-94	SULFATE		170 MG/L	4	0	4	0%	600.00	409.21	5.145		2705
MW23	14-Sep-94	SULFIDE	<	1 MG/L									
MW23	15-Dec-93	SULFIDE, TOTAL	<	1 mg/L									
MW23	16-Mar-94	SULFIDE, TOTAL	<	1 mg/L									
MW23	16-Jun-94	SULFIDE, TOTAL	<	1 mg/L									
MW23	15-Dec-93	THALLIUM, DISSOLVED	<	3 mg/L									
MW23	15-Dec-93	TIN, DISSOLVED	<	500 ug/L									
MW23	16-Mar-94	TIN, DISSOLVED	<	500 ug/L									
MW23	16-Jun-94	TIN, DISSOLVED	<	500 ug/L									
MW23	14-Sep-94	TIN, DISSOLVED	<	500 UG/L									
MW23	15-Dec-93	TOTAL ORGANIC CARBON AS NPOC		1.1 mg/L									
MW23	16-Mar-94	TOTAL ORGANIC CARBON AS NPOC		0.66 mg/L									
MW23	16-Jun-94	TOTAL ORGANIC CARBON AS NPOC		0.77 mg/L									
MW23	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC		1.2 MG/L	4	0	4	0%	0.93	0.22	5.145		2.1
MW23	15-Dec-93	TOTAL ORGANIC HALIDES	<	5 ug/L									
MW23	16-Mar-94	TOTAL ORGANIC HALIDES	<	5 ug/L									
MW23	16-Jun-94	TOTAL ORGANIC HALIDES		8.3 ug/L									
MW23	14-Sep-94	TOTAL ORGANIC HALIDES		11 UG/L									
MW23	15-Dec-93	VANADIUM, DISSOLVED	<	50 ug/L									
MW23	15-Dec-93	ZINC, DISSOLVED	<	20 ug/L									
MW23	16-Mar-94	ZINC, DISSOLVED		21 ug/L									
MW23	16-Jun-94	ZINC, DISSOLVED		46 ug/L									
MW23	14-Sep-94	ZINC, DISSOLVED		59 UG/L	4	1	3	25%	36.50	16.65	5.145		122
MW23	15-Dec-93	pH, FIELD		6.9 SU									
MW23	16-Mar-94	pH, FIELD		3 SU									
MW23	16-Jun-94	pH, FIELD		6.4 SU									
MW23	14-Sep-94	pH, FIELD		6.3 SU	4	0	4	0%	5.65	1.55	5.145	-2.30814	13.6

Table E-4

Comparison of Downgradient and

Sidegradient Groundwater Quality - Spoils Wells

TABLE E4
COMPARISON OF DOWNGRADIENT AND SIDEGRADIENT GROUNDWATER QUALITY - SPOILS WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
MW04A	16-Dec-93	ALKALINITY, BICARBONATE		350	mg/L	423		
MW04A	15-Mar-94	ALKALINITY, BICARBONATE		480	mg/L	423		YES
MW04A	16-Jun-94	ALKALINITY, BICARBONATE		450	mg/L	423		YES
MW13	15-Dec-93	ALKALINITY, BICARBONATE		76	mg/L	423		
MW13	15-Mar-94	ALKALINITY, BICARBONATE		44	mg/L	423		
MW13	15-Jun-94	ALKALINITY, BICARBONATE		42	mg/L	423		
MW21	16-Dec-93	ALKALINITY, BICARBONATE		360	mg/L	423		
MW21	15-Mar-94	ALKALINITY, BICARBONATE		360	mg/L	423		
MW21	17-Jun-94	ALKALINITY, BICARBONATE		360	mg/L	423		
MW22	15-Dec-93	ALKALINITY, BICARBONATE		150	mg/L	423		
MW22	15-Mar-94	ALKALINITY, BICARBONATE		130	mg/L	423		
MW22	16-Jun-94	ALKALINITY, BICARBONATE		160	mg/L	423		
MW04A	16-Dec-93	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW04A	15-Mar-94	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW04A	16-Jun-94	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW04A	14-Sep-94	ALKALINITY, CARBONATE		420	MG/L	55		YES
MW13	15-Dec-93	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW13	15-Mar-94	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW13	15-Jun-94	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW13	14-Sep-94	ALKALINITY, CARBONATE	<	20	MG/L	55		
MW21	16-Dec-93	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW21	15-Mar-94	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW21	17-Jun-94	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW21	14-Sep-94	ALKALINITY, CARBONATE		350	MG/L	55		YES
MW22	15-Dec-93	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW22	15-Mar-94	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW22	15-Jun-94	ALKALINITY, CARBONATE	<	20	mg/L	55		
MW22	14-Sep-94	ALKALINITY, CARBONATE		140	MG/L	55		YES
Proportions Test			13	16				
No. of Background Detects (x)			1					
No. of Background Samples (n)			4					
Proportion of Detects (Pu)			0.25					
No. of Downgradient Detects (y)			3					
No. of Downgradient Samples (m)			16					
Proportion of Detects (Pd)			0.19					
Standard of Error			0.2236					
Z Statistic (Z)			0.2795	No Difference				
MW04A	16-Dec-93	ANTIMONY, DISSOLVED		14	ug/L			
MW04A	15-Mar-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW04A	16-Jun-94	ANTIMONY, DISSOLVED		11	ug/L			
MW04A	14-Sep-94	ANTIMONY, DISSOLVED	<	10	UG/L			
MW13	15-Dec-93	ANTIMONY, DISSOLVED	<	3	ug/L			
MW13	15-Mar-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW13	15-Jun-94	ANTIMONY, DISSOLVED		12	ug/L			
MW13	14-Sep-94	ANTIMONY, DISSOLVED	<	10	UG/L			
MW21	16-Dec-93	ANTIMONY, DISSOLVED	<	10	ug/L			
MW21	15-Mar-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW21	17-Jun-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW21	14-Sep-94	ANTIMONY, DISSOLVED	<	10	UG/L			
MW22	15-Dec-93	ANTIMONY, DISSOLVED	<	10	ug/L			
MW22	15-Mar-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW22	15-Jun-94	ANTIMONY, DISSOLVED	<	10	ug/L			
MW22	14-Sep-94	ANTIMONY, DISSOLVED	<	10	UG/L			
MW04A	16-Dec-93	ARSENIC, DISSOLVED		3.5	ug/L			
MW04A	15-Mar-94	ARSENIC, DISSOLVED	<	3	ug/L			
MW04A	16-Jun-94	ARSENIC, DISSOLVED	<	3	ug/L			
MW04A	14-Sep-94	ARSENIC, DISSOLVED	<	3	UG/L			
MW13	15-Dec-93	ARSENIC, DISSOLVED	<	10	ug/L			
MW13	15-Mar-94	ARSENIC, DISSOLVED	<	3	ug/L			
MW13	15-Jun-94	ARSENIC, DISSOLVED	<	3	ug/L			
MW13	14-Sep-94	ARSENIC, DISSOLVED	<	3	UG/L			
MW21	16-Dec-93	ARSENIC, DISSOLVED		4.5	ug/L			
MW21	15-Mar-94	ARSENIC, DISSOLVED		6.8	ug/L			
MW21	17-Jun-94	ARSENIC, DISSOLVED		5.9	ug/L			
MW21	14-Sep-94	ARSENIC, DISSOLVED		7.8	UG/L			
MW22	15-Dec-93	ARSENIC, DISSOLVED	<	3	ug/L			
MW22	15-Mar-94	ARSENIC, DISSOLVED		5.5	ug/L			
MW22	15-Jun-94	ARSENIC, DISSOLVED	<	3	ug/L			
MW22	14-Sep-94	ARSENIC, DISSOLVED	<	3	UG/L			
MW04A	16-Dec-93	BARIUM, DISSOLVED	<	50	ug/L			
MW04A	15-Mar-94	BARIUM, DISSOLVED	<	50	ug/L			
MW04A	16-Jun-94	BARIUM, DISSOLVED	<	50	ug/L			

TABLE E4
COMPARISON OF DOWNGRADIENT AND SIDEGRADIENT GROUNDWATER QUALITY - SPOILS WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
MW04A	14-Sep-94	BARIUM, DISSOLVED	<	50	UG/L			
MW13	15-Dec-93	BARIUM, DISSOLVED	<	50	ug/L			
MW13	15-Mar-94	BARIUM, DISSOLVED	<	50	ug/L			
MW13	15-Jun-94	BARIUM, DISSOLVED	<	50	ug/L			
MW13	14-Sep-94	BARIUM, DISSOLVED	<	50	UG/L			
MW21	16-Dec-93	BARIUM, DISSOLVED	<	50	ug/L			
MW21	15-Mar-94	BARIUM, DISSOLVED	<	50	ug/L			
MW21	17-Jun-94	BARIUM, DISSOLVED	<	50	ug/L			
MW21	14-Sep-94	BARIUM, DISSOLVED	<	50	UG/L			
MW22	15-Dec-93	BARIUM, DISSOLVED	<	50	ug/L			
MW22	15-Mar-94	BARIUM, DISSOLVED	<	50	ug/L			
MW22	15-Jun-94	BARIUM, DISSOLVED	<	50	ug/L			
MW22	14-Sep-94	BARIUM, DISSOLVED	<	50	UG/L			
MW04A	16-Dec-93	BERYLLIUM, DISSOLVED	<	5	ug/L			
MW13	15-Dec-93	BERYLLIUM, DISSOLVED	<	5	ug/L			
MW21	16-Dec-93	BERYLLIUM, DISSOLVED	<	5	ug/L			
MW22	15-Dec-93	BERYLLIUM, DISSOLVED	<	5	ug/L			
MW04A	16-Dec-93	CADMIUM, DISSOLVED	<	0.3	ug/L	10.8		
MW04A	15-Mar-94	CADMIUM, DISSOLVED		0.67	ug/L	10.8		
MW04A	16-Jun-94	CADMIUM, DISSOLVED	<	0.3	ug/L	10.8		
MW04A	14-Sep-94	CADMIUM, DISSOLVED	<	0.3	UG/L	10.8		
MW13	15-Dec-93	CADMIUM, DISSOLVED		0.96	ug/L	10.8		
MW13	15-Mar-94	CADMIUM, DISSOLVED		4.3	ug/L	10.8		
MW13	15-Jun-94	CADMIUM, DISSOLVED		2.3	ug/L	10.8		
MW13	14-Sep-94	CADMIUM, DISSOLVED		0.96	UG/L	10.8		
MW21	16-Dec-93	CADMIUM, DISSOLVED		0.32	ug/L	10.8		
MW21	15-Mar-94	CADMIUM, DISSOLVED	<	0.3	ug/L	10.8		
MW21	17-Jun-94	CADMIUM, DISSOLVED	<	0.3	ug/L	10.8		
MW21	14-Sep-94	CADMIUM, DISSOLVED		0.35	UG/L	10.8		
MW22	15-Dec-93	CADMIUM, DISSOLVED	<	0.3	ug/L	10.8		
MW22	15-Mar-94	CADMIUM, DISSOLVED	<	0.3	ug/L	10.8		
MW22	15-Jun-94	CADMIUM, DISSOLVED	<	0.3	ug/L	10.8		
MW22	14-Sep-94	CADMIUM, DISSOLVED	<	0.3	UG/L	10.8		
MW04A	16-Dec-93	CHLORIDE		5.6	mg/L	633		
MW04A	15-Mar-94	CHLORIDE		15	mg/L	633		
MW04A	16-Jun-94	CHLORIDE		8.5	mg/L	633		
MW04A	14-Sep-94	CHLORIDE		11	MG/L	633		
MW13	15-Dec-93	CHLORIDE		50	mg/L	633		
MW13	15-Mar-94	CHLORIDE		45	mg/L	633		
MW13	15-Jun-94	CHLORIDE		69	mg/L	633		
MW13	14-Sep-94	CHLORIDE		78	MG/L	633		
MW21	16-Dec-93	CHLORIDE		52	mg/L	633		
MW21	15-Mar-94	CHLORIDE		54	mg/L	633		
MW21	17-Jun-94	CHLORIDE		42	mg/L	633		
MW21	14-Sep-94	CHLORIDE		60	MG/L	633		
MW22	15-Dec-93	CHLORIDE		34	mg/L	633		
MW22	15-Mar-94	CHLORIDE		44	mg/L	633		
MW22	15-Jun-94	CHLORIDE		42	mg/L	633		
MW22	14-Sep-94	CHLORIDE		33	MG/L	633		
MW13	14-Sep-94	CHLOROFORM	<	10	UG/L			
MW21	14-Sep-94	CHLOROFORM	<	10	UG/L			
MW22	14-Sep-94	CHLOROFORM	<	10	UG/L			
MW04A	16-Dec-93	CHROMIUM, DISSOLVED	<	2	ug/L			
MW04A	15-Mar-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW04A	16-Jun-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW04A	14-Sep-94	CHROMIUM, DISSOLVED	<	2	UG/L			
MW13	15-Dec-93	CHROMIUM, DISSOLVED	<	2	ug/L			
MW13	15-Mar-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW13	15-Jun-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW13	14-Sep-94	CHROMIUM, DISSOLVED	<	2	UG/L			
MW21	16-Dec-93	CHROMIUM, DISSOLVED	<	2	ug/L			
MW21	15-Mar-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW21	17-Jun-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW21	14-Sep-94	CHROMIUM, DISSOLVED	<	2	UG/L			
MW22	15-Dec-93	CHROMIUM, DISSOLVED	<	2	ug/L			
MW22	15-Mar-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW22	15-Jun-94	CHROMIUM, DISSOLVED	<	2	ug/L			
MW22	14-Sep-94	CHROMIUM, DISSOLVED	<	2	UG/L			
MW04A	16-Dec-93	COBALT, DISSOLVED		66	ug/L			
MW04A	15-Mar-94	COBALT, DISSOLVED		72	ug/L			
MW04A	16-Jun-94	COBALT, DISSOLVED		63	ug/L			

TABLE E4
COMPARISON OF DOWNGRADIENT AND SIDEGRADIENT GROUNDWATER QUALITY - SPOILS WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
MW04A	14-Sep-94	COBALT, DISSOLVED	<	50	UG/L			
MW13	15-Dec-93	COBALT, DISSOLVED		120	ug/L			
MW13	15-Mar-94	COBALT, DISSOLVED		100	ug/L			
MW13	15-Jun-94	COBALT, DISSOLVED		130	ug/L			
MW13	14-Sep-94	COBALT, DISSOLVED		110	UG/L			
MW21	16-Dec-93	COBALT, DISSOLVED	<	50	ug/L			
MW21	15-Mar-94	COBALT, DISSOLVED	<	50	ug/L			
MW21	17-Jun-94	COBALT, DISSOLVED	<	50	ug/L			
MW21	14-Sep-94	COBALT, DISSOLVED	<	50	UG/L			
MW22	15-Dec-93	COBALT, DISSOLVED	<	50	ug/L			
MW22	15-Mar-94	COBALT, DISSOLVED	<	50	ug/L			
MW22	15-Jun-94	COBALT, DISSOLVED	<	50	ug/L			
MW22	14-Sep-94	COBALT, DISSOLVED	<	50	UG/L			
MW04A	16-Dec-93	CONDUCTANCE, SPECIFIC		2100	UMHOS/CM	3488		
MW04A	15-Mar-94	CONDUCTANCE, SPECIFIC		1690	UMHOS/CM	3488		
MW04A	16-Jun-94	CONDUCTANCE, SPECIFIC		1890	UMHOS/CM	3488		
MW13	15-Dec-93	CONDUCTANCE, SPECIFIC		2000	UMHOS/CM	3488		
MW13	15-Mar-94	CONDUCTANCE, SPECIFIC		1790	UMHOS/CM	3488		
MW13	15-Jun-94	CONDUCTANCE, SPECIFIC		2050	UMHOS/CM	3488		
MW21	16-Dec-93	CONDUCTANCE, SPECIFIC		2700	UMHOS/CM	3488		
MW21	15-Mar-94	CONDUCTANCE, SPECIFIC		2620	UMHOS/CM	3488		
MW21	17-Jun-94	CONDUCTANCE, SPECIFIC		2600	UMHOS/CM	3488		
MW22	15-Dec-93	CONDUCTANCE, SPECIFIC		1500	UMHOS/CM	3488		
MW22	15-Mar-94	CONDUCTANCE, SPECIFIC		1060	UMHOS/CM	3488		
MW22	15-Jun-94	CONDUCTANCE, SPECIFIC		1340	UMHOS/CM	3488		
MW04A	16-Dec-93	COPPER, DISSOLVED		4.4	ug/L			
MW04A	15-Mar-94	COPPER, DISSOLVED	<	3	ug/L			
MW04A	16-Jun-94	COPPER, DISSOLVED	<	3	ug/L			
MW04A	14-Sep-94	COPPER, DISSOLVED	<	3	UG/L			
MW13	15-Dec-93	COPPER, DISSOLVED	<	3	ug/L			
MW13	15-Mar-94	COPPER, DISSOLVED	<	3	ug/L			
MW13	15-Jun-94	COPPER, DISSOLVED	<	3	ug/L			
MW13	14-Sep-94	COPPER, DISSOLVED	<	3	UG/L			
MW21	16-Dec-93	COPPER, DISSOLVED	<	3	ug/L			
MW21	15-Mar-94	COPPER, DISSOLVED	<	3	ug/L			
MW21	17-Jun-94	COPPER, DISSOLVED	<	3	ug/L			
MW21	14-Sep-94	COPPER, DISSOLVED	<	3	UG/L			
MW22	15-Dec-93	COPPER, DISSOLVED	<	3	ug/L			
MW22	15-Mar-94	COPPER, DISSOLVED	<	6.3	ug/L			
MW22	15-Jun-94	COPPER, DISSOLVED	<	3	ug/L			
MW22	14-Sep-94	COPPER, DISSOLVED	<	3	UG/L			
MW04A	16-Dec-93	CYANIDE, TOTAL	<	0.01	mg/L			
MW13	15-Dec-93	CYANIDE, TOTAL	<	0.01	mg/L			
MW21	16-Dec-93	CYANIDE, TOTAL	<	0.01	mg/L			
MW22	15-Dec-93	CYANIDE, TOTAL	<	0.01	mg/L			
MW04A	16-Dec-93	FLUORIDE		0.17	mg/L	0.37		
MW04A	15-Mar-94	FLUORIDE		0.17	mg/L	0.37		
MW04A	16-Jun-94	FLUORIDE		0.2	mg/L	0.37		
MW04A	14-Sep-94	FLUORIDE		0.24	MG/L	0.37		
MW13	15-Dec-93	FLUORIDE		0.36	mg/L	0.37		
MW13	15-Mar-94	FLUORIDE		0.38	mg/L	0.37		YES
MW13	15-Jun-94	FLUORIDE		0.84	mg/L	0.37		YES
MW13	14-Sep-94	FLUORIDE		0.88	MG/L	0.37		YES
MW21	16-Dec-93	FLUORIDE		0.49	mg/L	0.37		YES
MW21	15-Mar-94	FLUORIDE		0.55	mg/L	0.37		YES
MW21	17-Jun-94	FLUORIDE		0.85	mg/L	0.37		YES
MW21	14-Sep-94	FLUORIDE		0.66	MG/L	0.37		YES
MW22	15-Dec-93	FLUORIDE		0.45	mg/L	0.37		YES
MW22	15-Mar-94	FLUORIDE		0.66	mg/L	0.37		YES
MW22	15-Jun-94	FLUORIDE		0.5	mg/L	0.37		YES
MW22	14-Sep-94	FLUORIDE		0.6	MG/L	0.37		YES
MW04A	16-Dec-93	IRON, DISSOLVED		39000	ug/L	70035		
MW04A	15-Mar-94	IRON, DISSOLVED		14000	ug/L	70035		
MW04A	16-Jun-94	IRON, DISSOLVED		18000	ug/L	70035		
MW04A	14-Sep-94	IRON, DISSOLVED		4900	UG/L	70035		
MW13	15-Dec-93	IRON, DISSOLVED		32000	ug/L	70035		
MW13	15-Mar-94	IRON, DISSOLVED		27000	ug/L	70035		
MW13	15-Jun-94	IRON, DISSOLVED		24000	ug/L	70035		
MW13	14-Sep-94	IRON, DISSOLVED		30000	UG/L	70035		
MW21	16-Dec-93	IRON, DISSOLVED		35000	ug/L	70035		
MW21	15-Mar-94	IRON, DISSOLVED		34000	ug/L	70035		
MW21	17-Jun-94	IRON, DISSOLVED		35000	ug/L	70035		

TABLE E4
COMPARISON OF DOWNGRADIENT AND SIDEGRADIENT GROUNDWATER QUALITY - SPOILS WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
MW21	14-Sep-94	IRON, DISSOLVED		35000	UG/L	70035		
MW22	15-Dec-93	IRON, DISSOLVED		16000	ug/L	70035		
MW22	15-Mar-94	IRON, DISSOLVED		15000	ug/L	70035		
MW22	15-Jun-94	IRON, DISSOLVED		17000	ug/L	70035		
MW22	14-Sep-94	IRON, DISSOLVED		17000	UG/L	70035		
MW04A	16-Dec-93	LEAD, DISSOLVED	<	3	ug/L			
MW04A	15-Mar-94	LEAD, DISSOLVED	<	3	ug/L			
MW04A	16-Jun-94	LEAD, DISSOLVED	<	3	ug/L			
MW04A	14-Sep-94	LEAD, DISSOLVED	<	3	UG/L			
MW13	15-Dec-93	LEAD, DISSOLVED	<	3	ug/L			
MW13	15-Mar-94	LEAD, DISSOLVED	<	3	ug/L			
MW13	15-Jun-94	LEAD, DISSOLVED	<	3	ug/L			
MW13	14-Sep-94	LEAD, DISSOLVED	<	3	UG/L			
MW21	16-Dec-93	LEAD, DISSOLVED	<	3	ug/L			
MW21	15-Mar-94	LEAD, DISSOLVED	<	3	ug/L			
MW21	17-Jun-94	LEAD, DISSOLVED	<	3	ug/L			
MW21	14-Sep-94	LEAD, DISSOLVED	<	3	UG/L			
MW22	15-Dec-93	LEAD, DISSOLVED	<	3	ug/L			
MW22	15-Mar-94	LEAD, DISSOLVED	<	3	ug/L			
MW22	15-Jun-94	LEAD, DISSOLVED	<	3	ug/L			
MW22	14-Sep-94	LEAD, DISSOLVED	<	3	UG/L			
MW04A	16-Dec-93	MANGANESE, DISSOLVED		7800	ug/L	7221		YES
MW04A	15-Mar-94	MANGANESE, DISSOLVED		6200	ug/L	7221		
MW04A	16-Jun-94	MANGANESE, DISSOLVED		5500	ug/L	7221		
MW04A	14-Sep-94	MANGANESE, DISSOLVED		4000	UG/L	7221		
MW13	15-Dec-93	MANGANESE, DISSOLVED		13000	ug/L	7221		YES
MW13	15-Mar-94	MANGANESE, DISSOLVED		11000	ug/L	7221		YES
MW13	15-Jun-94	MANGANESE, DISSOLVED		15000	ug/L	7221		YES
MW13	14-Sep-94	MANGANESE, DISSOLVED		12000	UG/L	7221		YES
MW21	16-Dec-93	MANGANESE, DISSOLVED		13000	ug/L	7221		YES
W21	15-Mar-94	MANGANESE, DISSOLVED		11000	ug/L	7221		YES
/21	17-Jun-94	MANGANESE, DISSOLVED		14000	ug/L	7221		YES
.W21	14-Sep-94	MANGANESE, DISSOLVED		10000	UG/L	7221		YES
MW22	15-Dec-93	MANGANESE, DISSOLVED		8000	ug/L	7221		YES
MW22	15-Mar-94	MANGANESE, DISSOLVED		5900	ug/L	7221		
MW22	15-Jun-94	MANGANESE, DISSOLVED		6000	ug/L	7221		
MW22	14-Sep-94	MANGANESE, DISSOLVED		5500	UG/L	7221		
MW04A	16-Dec-93	MERCURY, DISSOLVED	<	0.2	ug/L			
MW04A	15-Mar-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW04A	16-Jun-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW04A	14-Sep-94	MERCURY, DISSOLVED	<	0.2	UG/L			
MW13	15-Dec-93	MERCURY, DISSOLVED	<	0.2	ug/L			
MW13	15-Mar-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW13	15-Jun-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW13	14-Sep-94	MERCURY, DISSOLVED	<	0.2	UG/L			
MW21	16-Dec-93	MERCURY, DISSOLVED	<	0.2	ug/L			
MW21	15-Mar-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW21	17-Jun-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW21	14-Sep-94	MERCURY, DISSOLVED	<	0.2	UG/L			
MW22	15-Dec-93	MERCURY, DISSOLVED	<	0.2	ug/L			
MW22	15-Mar-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW22	15-Jun-94	MERCURY, DISSOLVED	<	0.2	ug/L			
MW22	14-Sep-94	MERCURY, DISSOLVED	<	0.2	UG/L			
MW04A	16-Dec-93	NICKEL, DISSOLVED		82	ug/L			
MW04A	15-Mar-94	NICKEL, DISSOLVED		79	ug/L			
MW04A	16-Jun-94	NICKEL, DISSOLVED		59	ug/L			
MW04A	14-Sep-94	NICKEL, DISSOLVED	<	40	UG/L			
MW13	15-Dec-93	NICKEL, DISSOLVED		160	ug/L			
MW13	15-Mar-94	NICKEL, DISSOLVED		150	ug/L			
MW13	15-Jun-94	NICKEL, DISSOLVED		210	ug/L			
MW13	14-Sep-94	NICKEL, DISSOLVED		160	UG/L			
MW21	16-Dec-93	NICKEL, DISSOLVED	<	40	ug/L			
MW21	15-Mar-94	NICKEL, DISSOLVED	<	40	ug/L			
MW21	17-Jun-94	NICKEL, DISSOLVED	<	40	ug/L			
MW21	14-Sep-94	NICKEL, DISSOLVED	<	40	UG/L			
MW22	15-Dec-93	NICKEL, DISSOLVED		44	ug/L			
MW22	15-Mar-94	NICKEL, DISSOLVED	<	40	ug/L			
V22	15-Jun-94	NICKEL, DISSOLVED	<	40	ug/L			
/22	14-Sep-94	NICKEL, DISSOLVED	<	40	UG/L			
MW04A	16-Dec-93	NITROGEN, NITRATE	<	0.05	mg/L			
MW04A	15-Mar-94	NITROGEN, NITRATE	<	0.5	mg/L			
MW04A	16-Jun-94	NITROGEN, NITRATE	<	0.05	mg/L			

TABLE E4
COMPARISON OF DOWNGRADIENT AND SIDEGRADIENT GROUNDWATER QUALITY - SPOILS WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
MW04A	14-Sep-94	NITROGEN, NITRATE	<	0.05	MG/L			
MW13	15-Dec-93	NITROGEN, NITRATE	<	0.05	mg/L			
MW13	15-Mar-94	NITROGEN, NITRATE	<	0.05	mg/L			
MW13	15-Jun-94	NITROGEN, NITRATE	<	0.05	mg/L			
MW13	14-Sep-94	NITROGEN, NITRATE	<	0.05	MG/L			
MW21	16-Dec-93	NITROGEN, NITRATE	<	0.05	mg/L			
MW21	15-Mar-94	NITROGEN, NITRATE	<	0.05	mg/L			
MW21	17-Jun-94	NITROGEN, NITRATE	<	0.05	mg/L			
MW21	14-Sep-94	NITROGEN, NITRATE	<	0.05	MG/L			
MW22	15-Dec-93	NITROGEN, NITRATE	<	0.05	mg/L			
MW22	15-Mar-94	NITROGEN, NITRATE	<	0.05	mg/L			
MW22	15-Jun-94	NITROGEN, NITRATE	<	0.05	mg/L			
MW22	14-Sep-94	NITROGEN, NITRATE	<	0.05	MG/L			
MW04A	16-Dec-93	PHENOLICS, TOTAL RECOVERABLE		0.013	mg/L			
MW04A	15-Mar-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L			
MW04A	16-Jun-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L			
MW04A	14-Sep-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	MG/L			
MW13	15-Dec-93	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L			
MW13	15-Mar-94	PHENOLICS, TOTAL RECOVERABLE		0.012	mg/L			
MW13	15-Jun-94	PHENOLICS, TOTAL RECOVERABLE		0.02	mg/L			
MW13	14-Sep-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	MG/L			
MW21	16-Dec-93	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L			
MW21	15-Mar-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L			
MW21	17-Jun-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L			
MW21	14-Sep-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	MG/L			
MW22	15-Dec-93	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L			
MW22	15-Mar-94	PHENOLICS, TOTAL RECOVERABLE	<	0.01	mg/L			
MW22	15-Jun-94	PHENOLICS, TOTAL RECOVERABLE		0.011	mg/L			
MW22	14-Sep-94	PHENOLICS, TOTAL RECOVERABLE		0.012	MG/L			
MW04A	16-Dec-93	SELENIUM, DISSOLVED	<	3	ug/L			
MW04A	15-Mar-94	SELENIUM, DISSOLVED	<	12	ug/L			
MW04A	16-Jun-94	SELENIUM, DISSOLVED	<	3	ug/L			
MW04A	14-Sep-94	SELENIUM, DISSOLVED	<	6	UG/L			
MW13	15-Dec-93	SELENIUM, DISSOLVED	<	3	ug/L			
MW13	15-Mar-94	SELENIUM, DISSOLVED	<	12	ug/L			
MW13	15-Jun-94	SELENIUM, DISSOLVED	<	6	ug/L			
MW13	14-Sep-94	SELENIUM, DISSOLVED	<	6	UG/L			
MW21	16-Dec-93	SELENIUM, DISSOLVED	<	3	ug/L			
MW21	15-Mar-94	SELENIUM, DISSOLVED	<	12	ug/L			
MW21	17-Jun-94	SELENIUM, DISSOLVED	<	3	ug/L			
MW21	14-Sep-94	SELENIUM, DISSOLVED	<	6	UG/L			
MW22	15-Dec-93	SELENIUM, DISSOLVED	<	3	ug/L			
MW22	15-Mar-94	SELENIUM, DISSOLVED	<	12	ug/L			
MW22	15-Jun-94	SELENIUM, DISSOLVED	<	6	ug/L			
MW22	14-Sep-94	SELENIUM, DISSOLVED	<	6	UG/L			
MW04A	16-Dec-93	SILVER, DISSOLVED	<	1	ug/L			
MW04A	15-Mar-94	SILVER, DISSOLVED	<	1	ug/L			
MW04A	16-Jun-94	SILVER, DISSOLVED	<	1	ug/L			
MW04A	14-Sep-94	SILVER, DISSOLVED	<	1	UG/L			
MW13	15-Dec-93	SILVER, DISSOLVED	<	1	ug/L			
MW13	15-Mar-94	SILVER, DISSOLVED	<	1	ug/L			
MW13	15-Jun-94	SILVER, DISSOLVED	<	1	ug/L			
MW13	14-Sep-94	SILVER, DISSOLVED	<	1	UG/L			
MW21	16-Dec-93	SILVER, DISSOLVED	<	1	ug/L			
MW21	15-Mar-94	SILVER, DISSOLVED	<	1	ug/L			
MW21	17-Jun-94	SILVER, DISSOLVED	<	1	ug/L			
MW21	14-Sep-94	SILVER, DISSOLVED	<	1	UG/L			
MW22	15-Dec-93	SILVER, DISSOLVED	<	1	ug/L			
MW22	15-Mar-94	SILVER, DISSOLVED	<	1	ug/L			
MW22	15-Jun-94	SILVER, DISSOLVED	<	1	ug/L			
MW22	14-Sep-94	SILVER, DISSOLVED	<	1	UG/L			
MW04A	16-Dec-93	SODIUM, DISSOLVED		31000	ug/L	84733		
MW04A	15-Mar-94	SODIUM, DISSOLVED		31000	ug/L	84733		
MW04A	16-Jun-94	SODIUM, DISSOLVED		30000	ug/L	84733		
MW04A	14-Sep-94	SODIUM, DISSOLVED		32000	UG/L	84733		
MW13	15-Dec-93	SODIUM, DISSOLVED		37000	ug/L	84733		
MW13	15-Mar-94	SODIUM, DISSOLVED		33000	ug/L	84733		
MW13	15-Jun-94	SODIUM, DISSOLVED		40000	ug/L	84733		
MW13	14-Sep-94	SODIUM, DISSOLVED		42000	UG/L	84733		
MW21	16-Dec-93	SODIUM, DISSOLVED		130000	ug/L	84733		YES
MW21	15-Mar-94	SODIUM, DISSOLVED		130000	ug/L	84733		YES
MW21	17-Jun-94	SODIUM, DISSOLVED		130000	ug/L	84733		YES
MW21	14-Sep-94	SODIUM, DISSOLVED		120000	UG/L	84733		YES

TABLE E4
COMPARISON OF DOWNGRADIENT AND SIDEGRADIENT GROUNDWATER QUALITY - SPOILS WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	* LOWER 95% CONFIDENCE LIMIT EXCEEDANCE?
MW22	15-Dec-93	SODIUM, DISSOLVED		40000	ug/L	84733	
MW22	15-Mar-94	SODIUM, DISSOLVED		39000	ug/L	84733	
MW22	15-Jun-94	SODIUM, DISSOLVED		43000	ug/L	84733	
MW22	14-Sep-94	SODIUM, DISSOLVED		41000	UG/L	84733	
MW04A	16-Dec-93	SULFATE		870	mg/L	2705	
MW04A	15-Mar-94	SULFATE		600	mg/L	2705	
MW04A	16-Jun-94	SULFATE		620	mg/L	2705	
MW04A	14-Sep-94	SULFATE		980	MG/L	2705	
MW13	15-Dec-93	SULFATE		1100	mg/L	2705	
MW13	15-Mar-94	SULFATE		970	mg/L	2705	
MW13	15-Jun-94	SULFATE		1100	mg/L	2705	
MW13	14-Sep-94	SULFATE		930	MG/L	2705	
MW21	16-Dec-93	SULFATE		1300	mg/L	2705	
MW21	15-Mar-94	SULFATE		1200	mg/L	2705	
MW21	17-Jun-94	SULFATE		1200	mg/L	2705	
MW21	14-Sep-94	SULFATE		1200	MG/L	2705	
MW22	15-Dec-93	SULFATE		500	mg/L	2705	
MW22	15-Mar-94	SULFATE		420	mg/L	2705	
MW22	15-Jun-94	SULFATE		500	mg/L	2705	
MW22	14-Sep-94	SULFATE		400	MG/L	2705	
MW04A	14-Sep-94	SULFIDE	<	1	MG/L		
MW13	14-Sep-94	SULFIDE	<	1	MG/L		
MW21	14-Sep-94	SULFIDE		4	MG/L		
MW22	14-Sep-94	SULFIDE	<	1	MG/L		
MW04A	16-Dec-93	SULFIDE, TOTAL	<	1	mg/L		
MW04A	15-Mar-94	SULFIDE, TOTAL		1.7	mg/L		
MW04A	16-Jun-94	SULFIDE, TOTAL		2.1	mg/L		
MW13	15-Dec-93	SULFIDE, TOTAL		2	mg/L		
MW13	15-Mar-94	SULFIDE, TOTAL	<	1	mg/L		
MW13	15-Jun-94	SULFIDE, TOTAL	<	1	mg/L		
MW21	16-Dec-93	SULFIDE, TOTAL		3.1	mg/L		
MW21	15-Mar-94	SULFIDE, TOTAL	<	1	mg/L		
MW21	17-Jun-94	SULFIDE, TOTAL	<	1	mg/L		
MW22	15-Dec-93	SULFIDE, TOTAL		1.1	mg/L		
MW22	15-Mar-94	SULFIDE, TOTAL	<	1	mg/L		
MW22	15-Jun-94	SULFIDE, TOTAL	<	1	mg/L		
MW04A	16-Dec-93	THALLIUM, DISSOLVED	<	3	mg/L		
MW13	15-Dec-93	THALLIUM, DISSOLVED	<	3	mg/L		
MW21	16-Dec-93	THALLIUM, DISSOLVED	<	3	mg/L		
MW22	15-Dec-93	THALLIUM, DISSOLVED	<	3	mg/L		
MW04A	16-Dec-93	TIN, DISSOLVED	<	500	ug/L		
MW04A	15-Mar-94	TIN, DISSOLVED	<	500	ug/L		
MW04A	16-Jun-94	TIN, DISSOLVED	<	500	ug/L		
MW04A	14-Sep-94	TIN, DISSOLVED	<	500	UG/L		
MW13	15-Dec-93	TIN, DISSOLVED	<	500	ug/L		
MW13	15-Mar-94	TIN, DISSOLVED	<	500	ug/L		
MW13	15-Jun-94	TIN, DISSOLVED	<	500	ug/L		
MW13	14-Sep-94	TIN, DISSOLVED	<	500	UG/L		
MW21	16-Dec-93	TIN, DISSOLVED	<	500	ug/L		
MW21	15-Mar-94	TIN, DISSOLVED	<	500	ug/L		
MW21	17-Jun-94	TIN, DISSOLVED	<	500	ug/L		
MW21	14-Sep-94	TIN, DISSOLVED	<	500	UG/L		
MW22	15-Dec-93	TIN, DISSOLVED	<	500	ug/L		
MW22	15-Mar-94	TIN, DISSOLVED	<	500	ug/L		
MW22	15-Jun-94	TIN, DISSOLVED	<	500	ug/L		
MW22	14-Sep-94	TIN, DISSOLVED	<	500	UG/L		
MW04A	16-Dec-93	TOTAL ORGANIC CARBON AS NPOC		7	mg/L	2.1	YES
MW04A	15-Mar-94	TOTAL ORGANIC CARBON AS NPOC		13	mg/L	2.1	YES
MW04A	16-Jun-94	TOTAL ORGANIC CARBON AS NPOC		2.4	mg/L	2.1	YES
MW04A	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC		18	MG/L	2.1	YES
MW13	15-Dec-93	TOTAL ORGANIC CARBON AS NPOC		8.2	mg/L	2.1	YES
MW13	15-Mar-94	TOTAL ORGANIC CARBON AS NPOC		4.3	mg/L	2.1	YES
MW13	15-Jun-94	TOTAL ORGANIC CARBON AS NPOC		3.3	mg/L	2.1	YES
MW13	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC		24	MG/L	2.1	YES
MW21	16-Dec-93	TOTAL ORGANIC CARBON AS NPOC		15	mg/L	2.1	YES
MW21	15-Mar-94	TOTAL ORGANIC CARBON AS NPOC		5.5	mg/L	2.1	YES
MW21	17-Jun-94	TOTAL ORGANIC CARBON AS NPOC		16	mg/L	2.1	YES
MW21	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC		7.4	MG/L	2.1	YES
MW22	15-Dec-93	TOTAL ORGANIC CARBON AS NPOC		27	mg/L	2.1	YES
MW22	15-Mar-94	TOTAL ORGANIC CARBON AS NPOC		3.6	mg/L	2.1	YES
MW22	15-Jun-94	TOTAL ORGANIC CARBON AS NPOC		4	mg/L	2.1	YES
MW22	14-Sep-94	TOTAL ORGANIC CARBON AS NPOC		23	MG/L	2.1	YES

TABLE E4
COMPARISON OF DOWNGRADIENT AND SIDEGRADIENT GROUNDWATER QUALITY - SPOILS WELLS
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
DATA FROM FIRST FOUR QUARTERS

WELL ID.	DATE	PARAMETER	PREFIX	RESULT	UNITS	UPPER 95% CONFIDENCE LIMIT	LOWER 95% CONFIDENCE LIMIT	EXCEEDANCE?
MW04A	16-Dec-93	TOTAL ORGANIC HALIDES	<	5	ug/L			
MW04A	15-Mar-94	TOTAL ORGANIC HALIDES	<	5	ug/L			
MW04A	16-Jun-94	TOTAL ORGANIC HALIDES		5.9	ug/L			
MW04A	14-Sep-94	TOTAL ORGANIC HALIDES	<	5	UG/L			
MW13	15-Dec-93	TOTAL ORGANIC HALIDES		8.6	ug/L			
MW13	15-Mar-94	TOTAL ORGANIC HALIDES	<	5	ug/L			
MW13	15-Jun-94	TOTAL ORGANIC HALIDES		6.2	ug/L			
MW13	14-Sep-94	TOTAL ORGANIC HALIDES		14	UG/L			
MW21	16-Dec-93	TOTAL ORGANIC HALIDES		13	ug/L			
MW21	15-Mar-94	TOTAL ORGANIC HALIDES		25	ug/L			
MW21	17-Jun-94	TOTAL ORGANIC HALIDES		10	ug/L			
MW21	14-Sep-94	TOTAL ORGANIC HALIDES		13	UG/L			
MW22	15-Dec-93	TOTAL ORGANIC HALIDES		15	ug/L			
MW22	15-Mar-94	TOTAL ORGANIC HALIDES		9.6	ug/L			
MW22	15-Jun-94	TOTAL ORGANIC HALIDES		12	ug/L			
MW22	14-Sep-94	TOTAL ORGANIC HALIDES		17	UG/L			
MW04A	16-Dec-93	VANADIUM, DISSOLVED	<	50	ug/L			
MW13	15-Dec-93	VANADIUM, DISSOLVED	<	50	ug/L			
MW21	16-Dec-93	VANADIUM, DISSOLVED	<	50	ug/L			
MW22	15-Dec-93	VANADIUM, DISSOLVED	<	50	ug/L			
MW04A	16-Dec-93	ZINC, DISSOLVED		66	ug/L	122		
MW04A	15-Mar-94	ZINC, DISSOLVED		91	ug/L	122		
MW04A	16-Jun-94	ZINC, DISSOLVED		61	ug/L	122		
MW04A	14-Sep-94	ZINC, DISSOLVED		24	UG/L	122		
MW13	15-Dec-93	ZINC, DISSOLVED		250	ug/L	122		YES
MW13	15-Mar-94	ZINC, DISSOLVED		230	ug/L	122		YES
MW13	16-Jun-94	ZINC, DISSOLVED		370	ug/L	122		YES
MW13	14-Sep-94	ZINC, DISSOLVED		240	UG/L	122		YES
MW21	16-Dec-93	ZINC, DISSOLVED		32	ug/L	122		
W21	15-Mar-94	ZINC, DISSOLVED	<	20	ug/L	122		
W21	17-Jun-94	ZINC, DISSOLVED		24	ug/L	122		
MW21	14-Sep-94	ZINC, DISSOLVED		22	UG/L	122		
MW22	15-Dec-93	ZINC, DISSOLVED		40	ug/L	122		
MW22	15-Mar-94	ZINC, DISSOLVED	<	20	ug/L	122		
MW22	15-Jun-94	ZINC, DISSOLVED		25	ug/L	122		
MW22	14-Sep-94	ZINC, DISSOLVED		21	UG/L	122		
MW04A	16-Dec-93	pH, FIELD		6.4	SU	13.6		
MW04A	15-Mar-94	pH, FIELD		6	SU	13.6		
MW04A	16-Jun-94	pH, FIELD		6.2	SU	13.6		
MW13	15-Dec-93	pH, FIELD		5	SU	13.6		
MW13	15-Mar-94	pH, FIELD		5.1	SU	13.6		
MW13	15-Jun-94	pH, FIELD		5.4	SU	13.6		
MW21	16-Dec-93	pH, FIELD		6.4	SU	13.6		
MW21	15-Mar-94	pH, FIELD		6.2	SU	13.6		
MW21	17-Jun-94	pH, FIELD		6.4	SU	13.6		
MW22	15-Dec-93	pH, FIELD		6.3	SU	13.6		
MW22	15-Mar-94	pH, FIELD		5.9	SU	13.6		
MW22	15-Jun-94	pH, FIELD		6.3	SU	13.6		

APPENDIX F

GROUNDWATER SAMPLING AND ANALYSIS PLAN

GROUNDWATER SAMPLING AND ANALYSIS PLAN

SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

REVISED DECEMBER 1994

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Section 1
INTRODUCTION

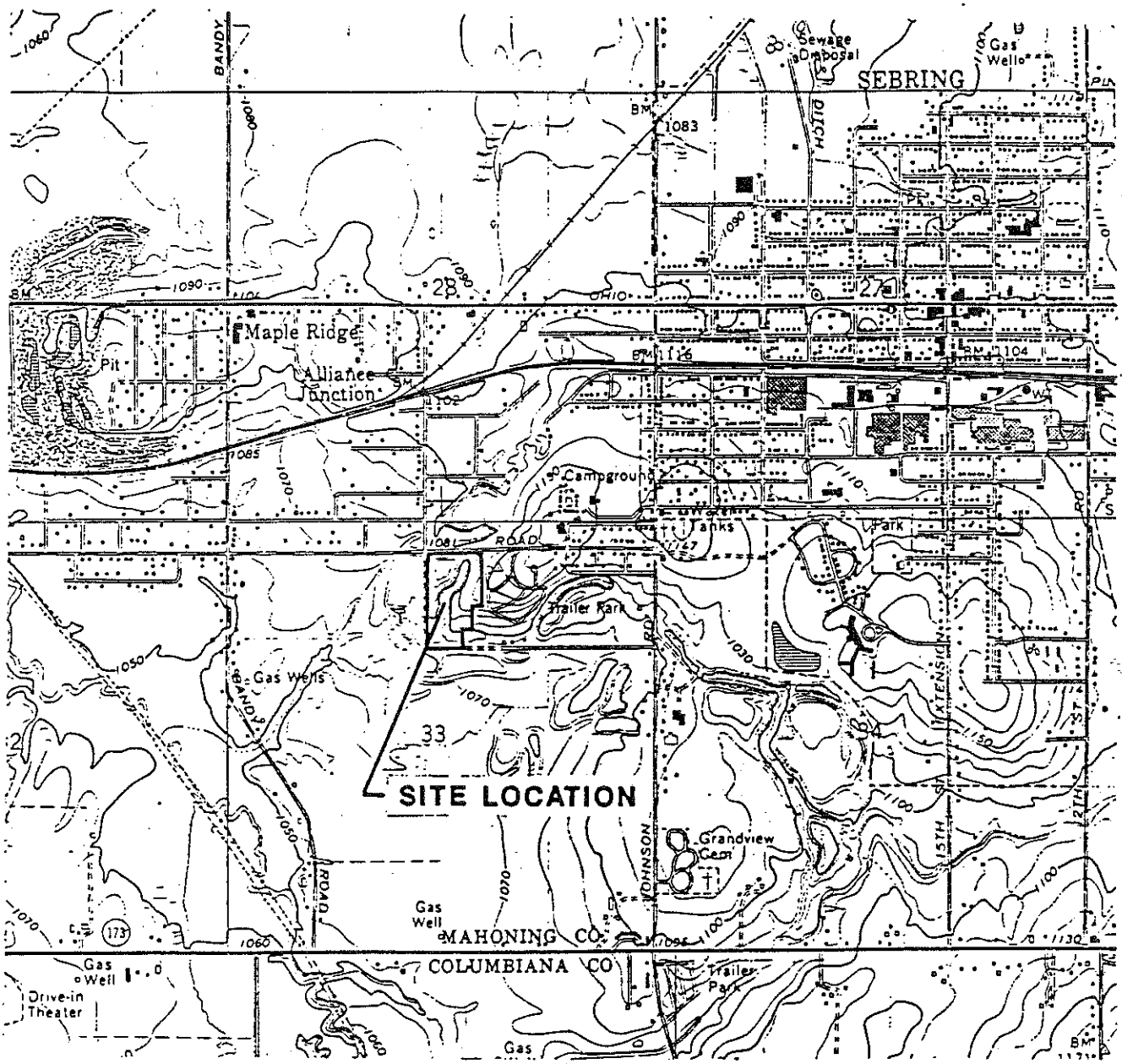
1.1 Background

The landfill, shown on Figure 1-1, has been in operation for over 20 years as a disposal site for typical foundry wastes from the Sebring facility, including foundry sand, refractories, slag material, and sludge from the sand washers and wet dust collectors.

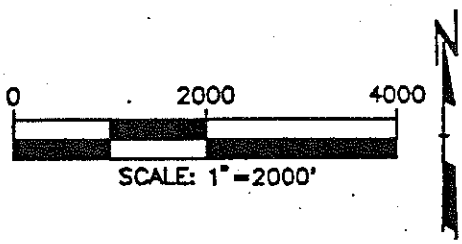
The possibility exists that, during the past 20 years, hazardous electric arc furnace baghouse dust was intermixed with typical foundry waste and deposited in the landfill. To assess the possibility that hazardous materials were placed in the landfill and may have impacted the groundwater quality, ASF has agreed, as part of a consent decree, to perform a groundwater quality assessment of the site under RCRA 40 CFR Part 265 Subpart F, and Ohio Administrative Code (OAC) 3745-65, et seq.

1.2 Purpose and Scope

The purpose of this plan is to describe the groundwater sampling and analysis that Amsted Industries will conduct as part of the routine groundwater quality assessment of the Sebring facility. This plan replaces the Groundwater Sampling and Analysis, Plan dated March, 1992 which described the initial one year (four quarters) of groundwater quality assessment. All sampling and analysis procedures performed will conform to procedures contained in USEPA publication "Test Methods for Evaluation of Solid Waste, SW-846."



STATE LOCATION



SOURCE:

BASEMAP FROM A USGS 7.5 MINUTE QUADRANGLE MAP, "ALLIANCE", OHIO DATED 1966. (PHOTO REVISED 1971 & 1978)

SITE LOCATION MAP
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

RMT INC.

DWN. BY:	EAS
DATE:	DECEMBER, 1991
PROJ.#	2169.02
FILE #	

FIGURE 1-1

This plan will be kept at the Alliance facility and includes the following:

- General Sebring facility description
- Monitoring well locations and depths
- Well installation methods and materials
- Sampling equipment and sample collection methods
- Sampling frequency and schedule
- Sample handling, preservation, shipment, and chain-of-custody procedures
- Decontamination methods
- Analytical parameters, methods, and detection limits
- QA/QC measures
- Statistical evaluation criteria

Section 2

GENERAL FACILITY INFORMATION

2.1 Facility Name, Location, Contact, and Standard Industrial Code

Name: Amsted Industries, Inc. d.b.a.
American Steel Foundries
Sebring Facility

Location: Lake Park Boulevard and Heacock Road
Smith Township, Mahoning County, Ohio

Contact: Mr. Terry Bradway
Safety and Environmental Manager
American Steel Foundries
1001 East Broadway
Alliance, Ohio 44601
(216) 823-6150 ext. 206

Standard
Industrial Code: 3325

2.2 Site Description

The Sebring facility comprises a total of approximately 14.7 acres. The facility is fenced; access is from Lake Park Boulevard along Heacock Road as shown on Figure 2-1, which also shows the approximate limits of waste placement. Wastes have been placed over an area of about 8 acres and range in thickness from a few feet to more than 45 feet near the southcentral part of the landfill.

Soils adjacent to the facility generally consist of lean clay and clayey sand. Shale and siltstone outcrop on the west side of the facility and underlie the facility as well. The area immediately west and south of the site is the location of the abandoned municipal landfill for the village of Sebring. The depth to the water table varies from about 6 feet at the southwest end of the site to about 50 feet on the north and east sides of the site. Groundwater flows in a westerly direction.

Section 3

GROUNDWATER MONITORING PROGRAM

3.1 Objective of the Program

The objective of the groundwater monitoring program is to routinely evaluate whether hazardous waste or hazardous waste constituents have entered the groundwater, and if so, to determine their concentration, and rate and extent of migration in the groundwater. In particular, this program is intended to assess the quality of groundwater at the water table and in the uppermost part of the bedrock aquifer in the area immediately downgradient of the landfill to determine if it has been affected by foundry waste materials disposed on-site.

3.2 Monitoring Program

The groundwater monitoring program is summarized on Table 3-1. The program was developed based on the four quarters of groundwater monitoring conducted pursuant to the Groundwater Quality Assessment Plan (RMT, 1992) and the rationale for the program is described in detail in the Groundwater Quality Assessment Report (RMT, 1994). In summary, the groundwater quality assessment consisted of sampling site monitoring wells on a quarterly basis for one year for the following constituents:

- Major constituents and constituents of concern found in ASF foundry waste stream as determined by ASF testing programs conducted for various purposes.
- Constituents previous detected in surface and groundwater at the Sebring facility.
- Typical foundry waste landfill contaminants.
- Known or suspected adjacent sources of contamination (Tecumseh Pond and Village of Sebring municipal landfill).
- Inorganic indicator parameters useful in understanding groundwater.

Table 3-1

PROPOSED GROUNDWATER MONITORING PROGRAM
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

Monitoring Wells	
Upgradient	**Downgradient**
MW-1A MW-14 MW-19 MW-19P MW-23 (sidegradient)	MW-4A MW-12P* MW-13 MW-13P* MW-21 MW-21P MW-22 MW-22P MW-24* MW-25*

Parameters to be Analyzed	
Semiannually	**Annually**
Specific Conductance** pH** Temperature** Manganese Arsenic Cadmium Cobalt Zinc Nickel Phenols Iron Fluoride Barium	Chromium Lead Mercury Selenium Silver

* Proposed Monitoring Well

** Specific conductance, temperature, and pH will be measured in the field. Water levels will also be measured at each well in the program on a semiannual basis.

Provisions were made in the Groundwater Quality Assessment Plan to reduce the parameter list if certain parameters were not detected above the Practical Quantitation Limit (PQL) during the first quarter of monitoring. The parameter list was reduced subsequent to the first quarter. In addition, based on the entire four quarters of monitoring, the parameter list was modified further and the analysis frequency was modified (changed from quarterly to semiannual with annual analysis for some parameters). The parameter list was reduced to constituents of concern (metals) and field indicator parameters, (pH, specific conductance, and temperature).

Groundwater levels will be monitored on a semiannual basis. At the same time that water levels are measured the well will be inspected to confirm that well integrity is acceptable.

A statistical and qualitative evaluation of groundwater quality will be performed on a semiannual basis and a report submitted to the Ohio EPA. The statistical procedure is described in Section 3.5. Groundwater elevation data and analytical data will be appended to the report.

3.3 Monitoring Well Locations and Installation

In July 1985, four groundwater monitoring wells and one boring were installed near the landfill under the direction of Bowser-Morner, Inc., Dayton, Ohio. In August 1991, an additional four borings and five monitoring wells were installed under the direction of RMT, Inc., to further define the on-site geology and groundwater flow. Six borings were installed in May 1991 to obtain geologic information. Monitoring wells MW-19, MW-19P, MW-20, MW-21, MW-21P, MW-22 and MW-22P were installed under the supervision of RMT in November 1993. The locations of all the monitoring wells are shown on Figure 2-1. These wells are all constructed with PVC.

The monitoring well network is designed to evaluate, on a routine basis, whether chemical constituents of concern have migrated from the landfill into the groundwater and to determine the concentration of chemicals and rate and extent of migration. Table 3-2 summarizes the function of each well in the proposed monitoring system. Five wells will be used for determining background water quality, upgradient or sidegradient of the landfill, and ten wells will be used to indicate water quality downgradient of the landfill. Proposed well locations are also shown on Figure 2-1 and groundwater flow direction is Shown on Figure 3-1.

Proposed well depths range from approximately 35 to 60 feet below ground surface. Each well will be constructed such that the screen is in the shale (uppermost aquifer). Some of the existing wells will be used to monitor water levels only as noted in Table 3-2, which summarizes the function of each existing and proposed well in the monitoring system.

Table 3-2

MONITORING WELL SYSTEM
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

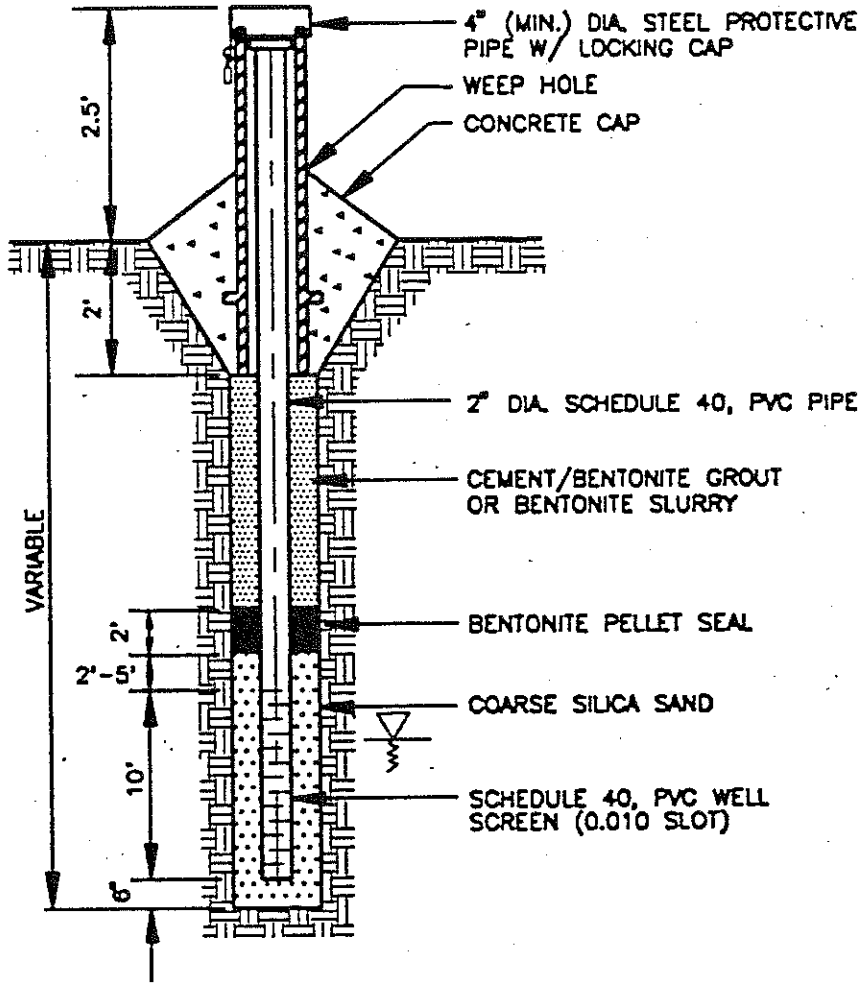
Well Designation (Existing and Proposed)	Up Gradient	Down Gradient	Water Quality	Water Level	Screen Length		Depth in feet (approximately)	Geologic Material
					5 feet	10 feet		
MW-1	x			x	x		55	Shale
MW-1A	x		x			x	42	Shale
MW-2		x		x	x		35	Shale
MW-3		x		x	x		26	Spoils
MW-4		x		x	x		32	Spoils
MW-4A		x	x	x		x	15	Spoils
MW-12		x		x		x	36	Sand & Spoils
MW-12P		x	x	x	x		50*	Shale
MW-13		x	x	x		x	38	Spoils
MW-13P		x	x	x	x		60*	Shale
MW-14	x		x	x		x	62	Shale
MW-19	x		x	x		x	55	Bedrock
MW-19P	x		x	x	x		105	Bedrock
MW-20		x	x	x		x	30	Bedrock
MW-21		x	x	x		x	30	Spoils
MW-21P		x	x	x	x		65	Bedrock
MW-22		x	x	x		x	20	Spoils
MW-22P		x	x	x	x		35	Spoils
MW-23	Side		x	x		x	35	Spoils
MW-24		x	x	x	x		35*	Shale
MW-25		x	x	x	x		55*	Shale

NOTES:
* The well screen will be placed in the permeable zone or layer encountered within the shalely bedrock formation at these approximated depths.

The proposed wells will be constructed with 2-inch diameter, Schedule 80, PVC risers and 5-foot-long screens. The casing and screens will be joined with threaded flush joints. All pipe and screens will be factory-cleaned, and delivered individually wrapped, to the site.

The borings for the wells will be drilled using hollow-stemmed augers and clear water rotary drilling techniques to the approximate depths listed in Table 3-2. Proposed well construction details are shown on Figure 3-2 and 3-3. Wells MW-24 and MW-25 will be constructed as shown on Figure 3-2. Wells MW-12P and MW-13P will be constructed as shown on Figure 3-3. Sand (washed silica or equivalent) will be backfilled around the screen and extended approximately 2 feet above the top of the well screen. A bentonite pellet seal will be installed directly above the sand layer. The remaining borehole annulus will be filled with cement/bentonite grout. A sloping concrete pad will be installed to anchor the protective casing and to direct surface run-off away from the well. Four-inch (minimum diameter) steel protective casings equipped with locks will be installed at each well. A 2-foot length of the casing will be below ground, and about 2.5 feet will be above ground.

The borehole for the monitoring wells will be sampled at 2.5-foot intervals using split-barrel sampling procedures in soil and soft bedrock, and continuous rock coring (NX or larger) in the competent bedrock. A geologist or hydrogeologist will be on-site to log and describe the samples according to the Unified Soil Classification System. The installation methods and materials will be reported on a well diagram. A sample well construction diagram is included in Appendix A.



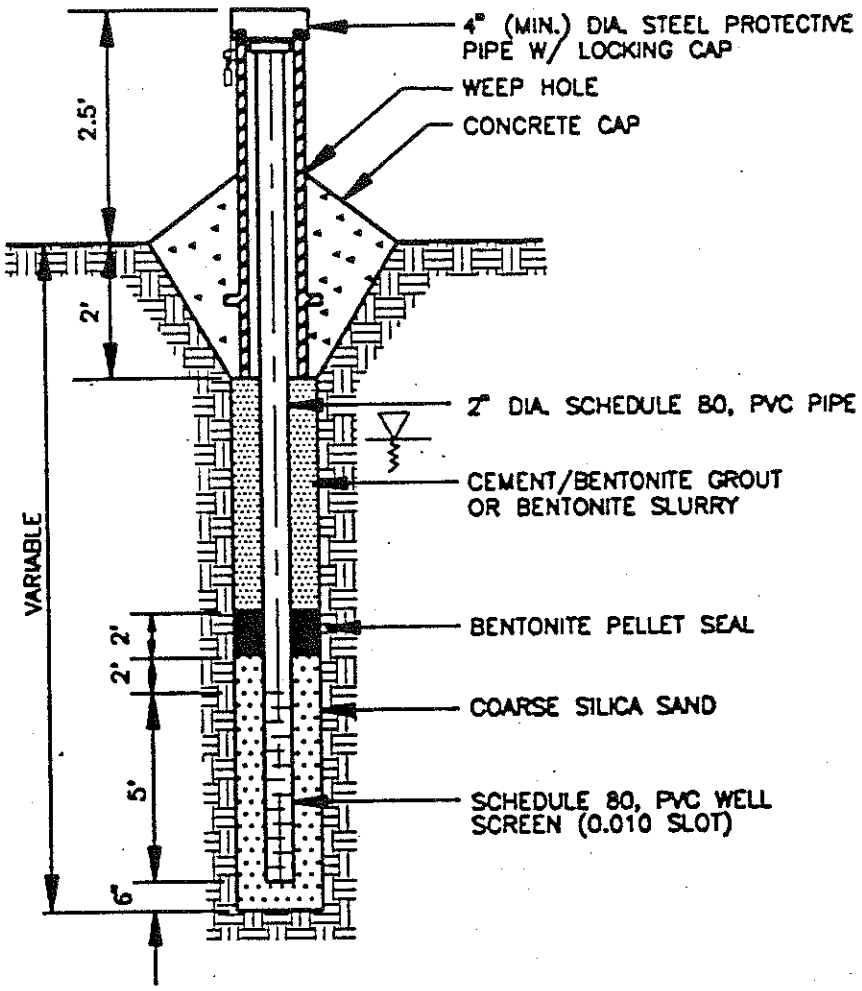
SHALLOW (WATER TABLE) WELL DETAIL

(NOT TO SCALE)

SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

RMT INC.

DWN. BY:	EAS
DATE:	DECEMBER, 1991
PROJ. #	2169.02
FILE #	21690208



DEEP WELL DETAIL

(NOT TO SCALE)

SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

RMT INC.

DWN. BY:	EAS
DATE:	DECEMBER, 1991
PROJ.#	2169.02
FILE #	21690207

The following cleaning procedures will be used prior to starting and between wells:

- Augers, drill rods, and other tools and drilling equipment will be cleaned using a steam-cleaner prior to use at each boring location. Water from a city potable water supply system will be used for steam-cleaning and for all drilling procedures.
- While on-site, the augers or other down-hole equipment will not be allowed to come into contact with surrounding soils prior to use.
- Decontamination will be conducted in a central location in the landfill and decontamination water will be contained in the landfill and allowed to infiltrate.
- The soil cuttings will be collected and placed in the landfill.

The wells will be developed by surging and bailing with a PVC hand bailer until pH and conductivity stabilize within ± 0.1 pH units and ±100 µmhos/cm. Development will be documented on the well construction diagrams (Appendix A).

The locations of the wells will be surveyed to an accuracy of 0.01 feet for top of casing elevations and 0.1 feet for horizontal locations. Locations will be referenced to the on-site coordinate system.

After development, in-field hydraulic conductivity tests (baildown tests) will be conducted on all new wells. Hydraulic conductivity values will be calculated using the Bouwer and Rice (1976) or Cooper, et al. (1967), technique, as appropriate.

3.4 Groundwater Monitoring Parameters

The groundwater samples will be sent to a qualified analytical laboratory. The parameters, analytical methods, and Practical Quantitation Limits are presented in Table 3-3. The groundwater level at each monitoring well will be measured prior to well purging each time a sample is obtained. Groundwater sampling and analysis procedures are described in Section 4.

Table 3-3
PARAMETERS, METHODS OF ANALYSIS AND PRACTICAL QUANTITATION LIMITS

SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

Parameters	SW-846 Analytical Method	Practical Quantitation Limits
pH	9040/9041	0.1 pH unit
Iron-ICP	6010	0.10 mg/L
Fluoride	EPA 340.2	0.1 mg/L
Manganese- ICP	6010	0.005 mg/L
Phenols (colorimetric)	9066	0.01 mg/L
Specific Conductance	9050	10 μmhos/cm
Arsenic	7060	3
Barium	6010	50
Cadmium	7131	0.3
Chromium (total)	7191	2
Cobalt	6010	50
Lead	7421	3
Mercury	7470/7471	0.2
Nickel	6010	40
Selenium	7740	3
Silver	7761	1
Zinc	6010	20

NOTES:
Practical Quantitation Limits are for RMT Laboratories.
ICP-Inductively Coupled Plasma Emission Spectrophotometry.

3.5 Statistical Data Analysis and Reporting

A tolerance interval approach was used to compare 1994 background monitoring well data to 1994 downgradient monitoring well data. The following paragraphs describe the tolerance interval method. An alternate statistical method may be used to evaluate data collected in the future. If an alternate method is contemplated, the OEPA will be notified prior to conducting the analysis.

A tolerance interval is constructed from the data collected from unaffected upgradient background wells. The tolerance interval is constructed by first calculating the mean upgradient concentration of each parameter using all available upgradient data points. Then an interval above and below the mean is created based on the variability of the background data. A more detailed description of the statistical procedure and calculations is presented in Appendix E.

In the case of several parameters, the measured parameter concentration may be below the detection limit. For parameters where the percentage of non-detects is between 0% and 50%, the tolerance interval approach will be used and the detection limit will be substituted for non-detect values.

In the case of all parameters except pH, an upper tolerance interval will be calculated and compared to the actual value for a specific downgradient well. For pH, and upper and lower tolerance interval will be calculated.

For parameters where the percentage of the non-detects exceeds 50%, the tolerance interval approach is not appropriate and a test of proportions will be used. The test of proportions is a method to determine whether a difference in the proportion of detected values in the background well data compared to the downgradient well data provides statistically significant evidence of impact.

Each of the statistical methods used here is described in the U.S. EPA Publication " Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities" (U.S. EPA, 1989).

The results of these comparisons will provide specific information regarding hazardous wastes and/or hazardous waste constituents, if any, that may have been released from the landfill and entered the groundwater.

3.6 Schedule

Sampling will be carried out on a semiannual basis. A report containing the sample results and an evaluation of those results will be submitted to the USEPA and OEPA within 30 days of the receipt of the analytical data for each sampling round.

In the event that the sampling and analysis reveals that hazardous waste or hazardous constituents have entered the groundwater, the USEPA and Ohio EPA will be notified in writing within 10 days. Groundwater monitoring will continue to be conducted in accordance with the requirements of 40 CFR §265.93(d)(7), OAC 3745-65-93(d)(7), and the Groundwater Quality Assessment Report.

Section 4

GROUNDWATER SAMPLING AND ANALYSIS

4.1 Field Procedures

4.1.1 Measuring Static Water Level

Static water levels will be measured in each well prior to purging or sampling. All groundwater level measurements will be made using a surveyed reference point established on the well casing. The reference point will be the highest point of the PVC well casing.

A battery-operated water level indicator will be the primary device for water level measurements. The indicator is a self-contained transistorized instrument equipped with a cable and sensor which activates a buzzer and a light when it comes in contact with the water. The depth to water is read from permanent increment markings on the cable.

In case of instrument failure, depth to groundwater will be measured by a plopper tape which is a bell- or cup-shaped weight attached to a measuring tape. When lowered into the well, a "plopping" sound is made when the weight strikes the surface of the water. An accurate reading can be determined by lifting and lowering the weight in short strokes, and reading the tape when the weight just strikes the water. Depth to water will be recorded to the nearest 0.01 foot.

In order to prevent cross-contamination, the water level measuring device will be decontaminated between wells by rinsing first with a mild detergent solution such as Alconox and then with Type II reagent grade water.

4.1.2 Purging Wells

The monitoring wells will be purged to remove stagnant water to ensure that the samples collected are fresh formation water. Before purging each well, five well volumes will be calculated. The steps to calculate the purging volumes are as follows:

1. Measure depth to water and depth to the bottom of the well.
2. Subtract depth to water from the depth to bottom.
3. For a 2-inch well, multiply the result obtained in Step 2 by 0.163 gallon/foot, and multiply that by 5.

Purging wells will be accomplished by the following steps:

1. Place a plastic dropcloth around the well to minimize possible contamination of sampling equipment with soil.

2. Remove the calculated amount of water necessary to obtain a sample of fresh water from the formation. If the well bails dry, the sample will be collected as soon as there is a sufficient volume recharged to the well to fill all sample bottles.

3. Use a separate pre-cleaned bailer to remove water from each well. A Teflon®-coated, stainless-steel cable will be attached to the bailer; new polypropylene rope will also be attached to the cable.

4. Measure water removed in gallons, to ensure that sufficient volume is purged to remove stagnant water not representative of *in-situ* conditions from the well.

5. Bail in such a manner as to prevent excessive amounts of agitation.

6. Record observations of odor, color, and degree of turbidity.

7. Contain purge water and dispose of appropriately in accordance with applicable regulations. If analysis of previous groundwater samples indicates that water quality at an individual well meets applicable water quality standards, the water may be discharged to the ground.

4.1.3 Sample and Data Collection at Each Well

Samples will be collected immediately after purging. Some wells (e.g., well MW-19P) may recover slowly from purging. These wells will be purged several days prior to sampling. Procedures for the sampling of the monitoring wells are as follows:

1. Set up filtering equipment and prepare pH and specific conductance meters.

2. Label bottles by writing the well number, project name, date, the sampler's name, and the time of day in the sampler section.

3. Collect samples using the dedicated bailer and a bottom-emptying device to prevent excessive amounts of agitation and aeration.

4. Fill bottles for unfiltered samples first.

5. After filling bottles for unfiltered samples, collect a sample for filtering and performing field measurements.

The instruments used in the field and their calibration procedures are described below.

Temperature - Each field thermometer will be inspected before each field trip to see that it is not cracked and that there are no air spaces or bubbles in the mercury. Before using a thermometer in the field, field personnel will make a visual observation to ensure that it has not been damaged. The temperature of the groundwater sample will be recorded to the nearest 0.5°C immediately after the sample is removed from the well.

Specific Conductance - The specific conductance of the liquid will be measured in the same groundwater sample used for the temperature measurement. A portable specific conductance meter will be used to measure the specific conductance of the groundwater sample. Each meter will be checked before each field trip and daily while in the field. Batteries will be checked, and conductivity cells will be cleaned and checked against a known standard (0.01M KCl which reads 1413 μmhos @ 25°C).

YSI 33 S-C-T Meter - Specifications

Range: 0-500, 0-5,000, 0-50,000 μmhos/cm.

Meter Accuracy: ± 2.5% maximum error at 500, 5,000, and 50,000 plus probe error.
± 3.0% maximum error at 250, 2,500, and 25,000 plus probe error.

Probe Accuracy: ± 2% of reading

Readability: 2.5 μmhos/cm on 500 μmhos/cm range
25 μmhos/cm on 5,000 μmhos/cm range
250 μmhos/cm on 50,000 μmhos/cm range

pH - The pH measurements will be made electrometrically using a combination electrode and portable pH meter. The measurements will be recorded to the nearest 0.1 pH unit. Portable meters with provisions for temperature compensation will be used. The meter will be checked before each field trip and daily while in the field for any mechanical or electrical failures, weak batteries, and cracked or fouled electrodes. The meter and electrode also will be checked against at least two standard buffer solutions of known pH values (e.g., 4, 7, and 10). While in the field, the meter will be checked several times per day with fresh buffers. In case of an apparent discrepancy in a pH measurement, the electrode will be checked with pH 7.0 buffer and recelebrated to the closest reference buffer to the pH of the sample. The sample will then be reanalyzed. Duplicate analyses will be made until they agree within 0.1 pH unit. The buffer solution containers will be refilled each day from fresh stock solution. Decontamination of the pH probe will be done by rinsing with distilled water. A separate, clean beaker will be used at each well for conductivity and pH measurements to eliminate the possibility of cross-contamination.

Orion Research Analysis pH Meter - Specifications

pH Range: 0 to 14 with ± 0.01 pH repeatability and ± 0.05% accuracy.
mV Range: -999 to 999 mV, with ± 1.0 mV repeatability and ±5% mV accuracy.

Examples of field data sheets, meter calibration logs, and procedures to complete the field notes are given in Appendix B. A log of meter calibrations and checks will be maintained during each sampling event. The calibration and checks will be performed a minimum of four times a day following the procedures specified in the meter manuals.

4.1.4 Field Filtering

Filtering in the field will be required for all of the inorganic parameters (except sulfide) to prevent changes due to chemical precipitation or biological activity and to collect a more representative sample of the water moving through the ground. In many cases, there may be a small amount of silt or clay in the water after purging the well. This sediment is not representative of constituents transported in groundwater flow systems in porous media. The filtering is performed in the field immediately after sample collection because even short delays may significantly change the water chemistry.

An in-line filtering system, consisting of a disposable filter, bailer, and small hand pump, will be used to collect and filter the samples for inorganics analysis. The pump forces water out of the bailer and through the filter. The possibility of cross-contamination is minimized as both the bailer and filter are disposable and are not reused from one well to another.

4.1.5 Equipment Cleaning Procedures Between Sampling Events

All equipment used for sampling that is not dedicated (purging bailers, water level measuring devices, etc.) is decontaminated after the sampling event using the following methods:

1. Prepare a soapy water bath using laboratory-grade detergent.
2. The inside and outside of filtering equipment are to be washed with a fine-bristle brush.
3. Water level measuring devices are unwound and soaked in soapy water and wiped clean with a cloth.
4. All equipment is rinsed with tap water.
5. All equipment, except water level measuring devices, is rinsed inside and outside with dilute 1:1 nitric acid.
6. Rinse all equipment with Type II reagent water.
7. Dry all equipment, except water level measuring devices, in oven at 105°C, and seal in polypropylene plastic to prevent contamination.

4.1.6 Equipment Cleaning Procedures Between Monitoring Wells

The procedures to be followed for cleaning equipment in the field between wells are as follows:

1. Rinse all equipment with fresh soapy water.
2. Rinse all equipment with Type II reagent grade water.
3. Rinsate will be disposed on the ground surface near each well sampled.

4.2 Sample Preservation Methods

The preservation methods for the parameters to be analyzed are listed in Table 4-1.

4.3 Chain-Of-Custody Guidelines

A Chain-of-Custody Form is intended to be a written record of sample possession and transference and is considered to be a legal document. The guidelines for the Chain-of-Custody Form to be used by sampling and laboratory personnel to ensure proper tracking are outlined below. An example of a Chain-of-Custody Form is included in Appendix C. While filling out the Chain-of-Custody Form, it is important to use only black ink and to write legibly. Errors are to be corrected by drawing a single line through the incorrect information and entering the correct information. All corrections are to be initialed and dated by the person making the correction.

A checklist of information that must be included on the Chain-of-Custody Form (see Appendix C) is as follows:

1. ***Bottles prepared by*** - The laboratory providing the bottles must sign their name here.
2. ***Date / Time*** - To be filled out by the person preparing the bottles.
3. ***Office code*** - To be filled out by the person preparing the bottles.
4. ***Project no.*** - To be completed by the laboratory.
5. ***Client*** - To be completed by the laboratory.
6. ***Sampler*** - The person/persons collecting the samples must sign their name and print their name under their signature. The date and time the sampler relinquishes the samples to either the laboratory or shipper must also be recorded.
7. ***Laboratory no.*** - This number is a unique identification number assigned by the laboratory.
8. ***Year / Date*** - The year and date the samples are collected.

Table 4-1

SAMPLE TREATMENT
SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

Parameter	Bottle Material	Preservative	Holding Time
Appendix IX Metals			
Arsenic	Polyethylene	HNO_3	6 months
Barium	Polyethylene	HNO_3	6 months
Cadmium	Polyethylene	HNO_3	6 months
Chromium (Total)	Polyethylene	HNO_3	6 months
Cobalt	Polyethylene	HNO_3	6 months
Lead	Polyethylene	HNO_3	6 months
Mercury	Polyethylene	HNO_3	6 months
Nickel	Polyethylene	HNO_3	6 months
Selenium	Polyethylene	HNO_3	6 months
Silver	Polyethylene	HNO_3	6 months
Zinc	Polyethylene	HNO_3	6 months
Other Parameters			
Fluoride	Polyethylene	None	28 days
Iron	Polyethylene	HNO_3	6 months
Manganese	Polyethylene	HNO_3	6 months
Phenol	Glass	Sulfuric Acid	28 days
pH	Analysis Performed in Field	Analysis Performed in Field	--
Temperature	Analysis Performed in Field	Analysis Performed in Field	--
Specific Conductance	Analysis Performed in Field	Analysis Performed in Field	

NOTES: All samples are kept cool. (4°C) during transport and storage, regardless of parameter.

9. ***Time*** - The time the sample is collected. This time **MUST** also be noted on the sample bottle.

10. ***Sample station ID*** - The location the sample was collected from, e.g., Pit 1, Tank 17, etc.

11. ***Total number of containers*** - Add up all of the bottles filled, and write total here.

12. ***Sample type*** - Circle sample type listed on Chain-of-Custody Form.

13. ***Container inventory*** - To be completed by laboratory providing the bottles.

14. ***Filtered*** - Place Y (yes) or N (no) to indicate whether the sample in a particular bottle is filtered or not.

15. ***Preserved*** - To be completed by laboratory.

16. ***Refrigerated*** - To be completed by laboratory.

17. ***Comments*** - Sampler may provide additional information about a sample, e.g., if an odor is present.

18. ***Relinquished by / Received by*** - This part of the form is a record of the individuals who actually had the samples in their custody. The spaces must be used in chronological order as the Chain-of-Custody Form is transferred with the samples.

    (1) Sampler signs when relinquishing custody.
    (2) Person accepting custody of samples from sampler signs.
    (3) Person in (2) must sign when relinquishing custody.
    (4)-(6) These are completed as necessary in the same manner as above.

    Note: If commercial carriers are used, the name of the carrier, any airbill number, and date and time of relinquishing is written in by sample entry or field personnel, and the airbill is attached to the Chain-of-Custody Form.

    The final signature is that of the person receiving the samples at the laboratory.

19. ***Seal #*** - Not applicable.

20. ***Seal #*** - Not applicable.

21. ***Hazards associated with samples*** - This section is for field use. It can include any known <u>or</u> suspected hazard associated with the samples. Sample entry personnel may add information to this section based on project manager or supervisor communication to the laboratory after samples are received. Laboratory group supervisors will use any hazard information to update and revise their analysis before work is started.

4.4 Sample Shipment Methods

4.4.1 Time Period

At the completion of the sampling event, samples will be transported to the contracted laboratory immediately to ensure that holding times of the analyses (Table 4-1) are met.

4.4.2 Handling

1. Method of Transport - The method of transport used should be one that will ensure that the samples will be delivered to the laboratory overnight, such as Federal Express.

2. Transport Container and Packing - The samples will be transported in 48-quart coolers.

- Sample packaging procedures will include the following:
- Place several layers of cushioning (bubble pack) in the bottom of the cooler.
- Place cushioning material around all glass bottles.
- Fill a plastic garbage bag with ice, and place on top of samples. Place completed chain-of-custody in Ziploc® bag and tape to inside cover of cooler.
- Tape the drain on cooler shut, and wrap the cooler completely with tape in two locations.
- Place "This Side Up" and "Fragile" labels on cooler.

3. Labels for the transport containers will be addressed to the contracted laboratory.

4.4.3 Sample Bottle Labels

Each sample bottle will be labeled so that the analytical laboratory has the following information:

- Site identification
- Sampling date and time
- Sample identification or location
- Sampling crew
- Type of analysis to which the groundwater will be subjected

All labels are color coded to indicate the type of preservative in the bottle (e.g., Red - Nitric acid, Yellow - Sulfuric acid, Black - No preservative).

4.5 Quality Assurance and Quality Control

4.5.1 Field QA/QC Procedures

A field (equipment rinsate) blank will be collected during each sampling round and submitted to the laboratory to assess the quality of the analytical data. This sample will be taken near the monitoring well with the highest specific conductance.

The intent of the field blank is to ensure that the nondedicated filtering equipment has been effectively cleaned and will consist of Type II reagent water which has been subjected to the same field methods as the samples from the monitoring wells. The field blank will be analyzed for the same parameters as the groundwater samples. The procedures for the collection of the field blank are as follows:

1. Decontaminate the filtering equipment using the specified procedure in Subsection 4.1.6 on cleaning procedures between monitoring wells.
2. Pour a portion of deionized water into the decontaminated filtering equipment, and filter it as though it were a groundwater sample.
3. Pour the filtered sample into the appropriate bottles, and place bottles on ice.
4. Perform pH, conductivity, and temperature.

One field duplicate will be collected per sampling event and analyzed for the same parameters as the other groundwater samples.

4.5.2 Laboratory QA/QC Procedures

Samples will be analyzed by a qualified laboratory in accordance with QA/QC procedures outlined in that laboratory's quality assurance manual. The quality assurance manual is an in-house document which discusses all of the analytical procedures to be followed by the contracted laboratory in order to meet data quality objectives as well as to meet pertinent regulatory requirements. The laboratory's quality assurance manual will be provided to the agency along with the results of the first sampling event for 1995. Control samples will be analyzed as appropriate for the SW 846 analytical method.

Section 5

REFERENCES

Bouwer, H. and R.C. Rice. 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Water Resources Research. Vol. 12, no. 3. pp. 423-428.

Cooper, H.H., J.D. Bredehoeft, and S.S. Papadopulos. 1967. Response of a finite-diameter well to an instantaneous charge of water. Water Resources Research. Vol. 3, no. 1. pp. 263-269.

RMT, Inc. 1992. Groundwater Quality Assessment Plan For Sebring Facility, American Steel Foundries, Alliance, Ohio. January 1992.

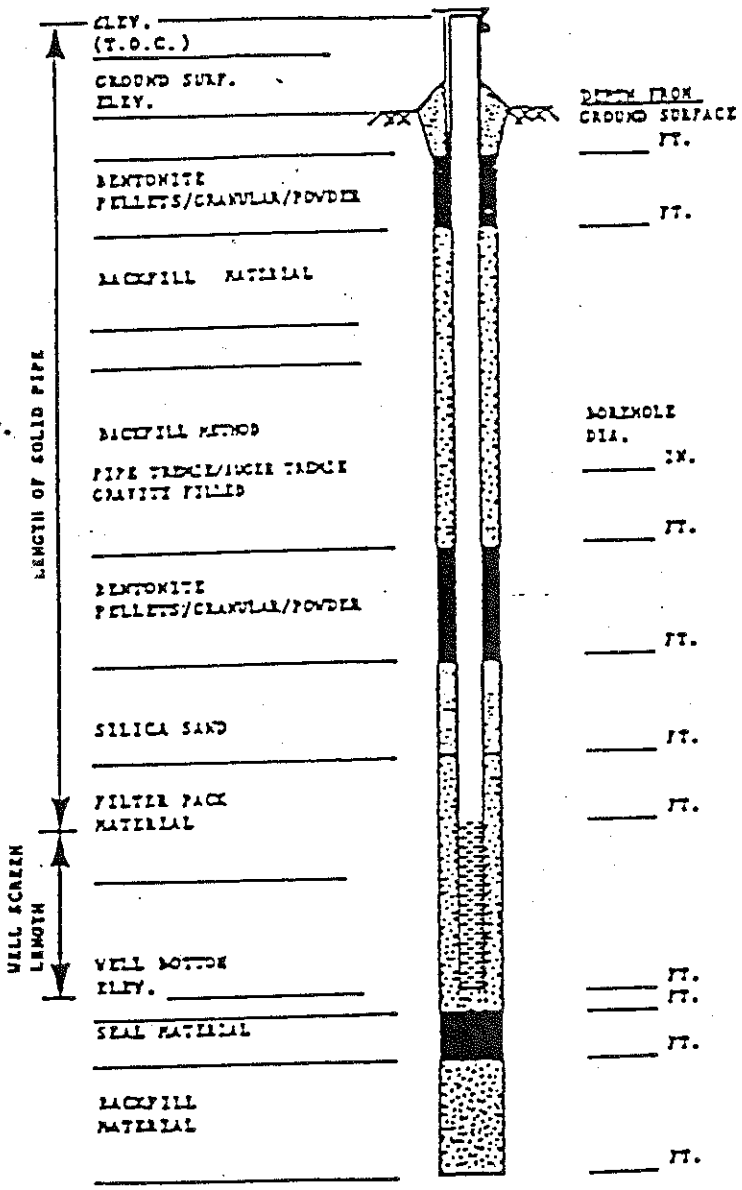
RMT, Inc. 1994. Groundwater Quality Assessment For Sebring Facility, American Steel Foundries, Alliance, Ohio. November 1994.

APPENDIX A
MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT NAME: _____ NO. _____

WELL NO. _____

DATE INSTALLED _____



1) CASING DETAILS

A) TYPE OF PIPE:

PVC, STAINLESS, TEFLON, OTHER _____

PIPE SCHEDULE _____

B) TYPE OF PIPE JOINTS:

COUPLINGS, THREADED (W/TAPE?), OTHER _____

C) WAS SOLVENT USED? YES OR NO

D) TYPE OF WELL SCREEN:

PVC, STAINLESS, TEFLON, OTHER _____

E) WELL SCREEN SLOT SIZE _____

F) PIPE DIA: ID IN. _____ OD IN. _____

G) INSTALLED PROTECTOR PIPE W/LOCK? YES OR NO

PROTECTOR PIPE DIA. ____ IN.

2) WELL DEVELOPMENT

A) METHOD

BAILING, PUMPING, SURGING, COMPRESSED AIR

OTHER _____

(NOTE ADDITIONAL COMMENTS BELOW)

B) TIME SPENT FOR DEVELOPMENT? _____

C) APPROXIMATE WATER VOLUME: REMOVED _____

ADDED _____

D) WATER CLARITY BEFORE DEVELOPMENT?

CLEAR, TURBID, OPAQUE

E) WATER CLARITY AFTER DEVELOPMENT?

CLEAR, SLIGHTLY TURBID, TURBID, OPAQUE

F) ODOR? YES OR NO

3) WATER LEVEL SUMMARY

A) DEPTH FROM TOP OF CASING AFTER DEVELOPMENT?

_____ FT. OR DRY

B) OTHER MEASUREMENTS (T.O.C.):

DATE/TIME _____ FT.

DATE/TIME _____ FT.

DATE/TIME _____ FT.

ADDITIONAL COMMENTS: _____

APPENDIX B
GUIDELINES FOR FIELD NOTES

APPENDIX B

GUIDELINES FOR FIELD NOTES

The importance of recording accurate, complete, and informative field notes cannot be overstated. The quality of the field persons' work is reflected directly in their field record. The field notes are the only reliable record of information gathered in the field. Information gathered in the field should be recorded in the field on standard field book note paper. Notes should be permanent, legible, complete, and capable of only one interpretation. Notes should be recorded with an All-Weather pen with black ink. Field book paper which is resistant to water and that can be marked when wet is available and should be used.

Field notes are to be recorded immediately in the field. Records made on scratch paper and copied later, or other information recorded from memory, are not considered field notes. If these are entered as field notes at some time other than when actual field records are made, then doubt is cast on all of the data.

The two foremost goals of good field notes are as follows:

1. To provide adequate and complete information that is useful and understandable to someone other than the note-taker.

2. To provide documentation of work done or data gathered that is of a quality to withstand the test of legal testimony in a court of law.

Note-takers should always keep the goal of the field assignment and the intended use of the notes foremost in their mind. The notes should be complete and understandable enough so that someone not associated with the actual field job can use them for the intended purpose without the need to question the note-taker or other members of the field crew about the correct interpretation of the notes. There should also be an awareness of what the notes or information might possibly be used for besides the primary purpose of the field investigations. Field staff should make a point of questioning the project manager or technical coordinator if they are unclear on this issue.

If field notes are to be useful, they must be legible. For this reason, they should be lettered instead of written. The lettering should be of a size which is easily readable yet which allows a reasonable amount of data to be entered on the page without crowding. Explanatory remarks are always necessary to clarify the field procedures and provide all of the details.

Field sketches are also very useful and should be used freely. Erasures should not be used, as they always cast doubt on the reliability of the records. If a correction needs to be made to the notes, draw a SINGLE line through the mistake, and date and initial it. All additions, revisions, reductions, or comments added to field notes in the office should be done in ink (usually red) to indicate that such information is not part of the original field record.

A checklist of information that must be included in the field notes for sampling is as follows:

1. Client - Generally this is the project name. Do not use abbreviations.

2. Job number - Be sure this is the correct number. It should be obtained from the trip coordinator or the project manager.

3. Sample no. and type - Name of sample location, e.g., MW-1/water, Production Well-2/water, sludge basin/waste, Johnson/Private well, etc.

4. Date - Date work was performed.

5. Name(s) of sampler - Do not use initials.

6. Well Diameter - Inside diameter of well.

7. Time - Time work at sample location was started. State A.M. or P.M.

8. Depth to water and ref. point - This measurement should always be taken from the top of the well, not from the protective casing. Measurements recorded should be as follows: 10.21 feet + 0.00 feet T/PVC if an electric water level indicator is used, and 10.21 feet + 0.17 feet T/PVC if a plopper tape is used. Lengths of ploppers vary, so you must measure it before each field trip. If the well is PVC and the pipe is cut on a slant, the measurement should be taken from the highest point.

9. Depth to bottom of well - This measurement should be taken in the same manner as depth to water. A nylon-coated steel tape with plopper will be used to measure depth to bottom. The lead and plopper length must be added to all depth to bottom measurements.

10. Water elevation - The depth to water and plopper length should be added together, and the calculated water elevation should be written here in red. This should be done when summarizing notes after the field trip.

11. Total Volume removed - Record the actual amount of water purged from the well in gallons. A pail calibrated in gallons and quarts will be used. Please note: This is the ACTUAL volume removed not the calculated volume.

12. Method - Note the device used to purge, i.e., bailer, submersible pump. If a well goes dry, it should be noted as follows: Bailed dry at 3.5 gal.

13. Color - Note actual color of purged water.

14. Turbidity - Comment on degree of turbidity and report as slight, moderate, or very.

15. Comments - Use this space to record such things as sheens on water, unusual amounts of sediment present, and/or other out-of-the-ordinary observations.

16. Date - The date recorded should be the date the sample was collected. Since it is our policy to sample immediately after purging, this date will be the same as the purging date. The exception would be extremely slow recovering wells that might take longer than 24 hours.

17. Time - Time sample collection started. Please note A.M. or P.M. Please note that the sample must be collected immediately after purging unless the well goes dry.

18. Color - Use same procedure as in Step 13.

19. Turbidity - Use same procedure as in Step 14.

20. Comments - Use same procedure as in Step 15.

21. pH - This measurement must be performed immediately after sample is collected. pH should be recorded to nearest 0.1 pH unit. Four readings should be taken as follows:

    a) Place electrode in sample.

    b) Let meter stabilize and take reading.

    c) Shut meter off, and remove electrode from sample.

    d) Rinse electrode.

    e) Repeat A through D until 4 readings have been recorded.

22. Specific conductance - This measurement must also be performed immediately after sample is collected but before pH. Meter should be read to the nearest 5 μmhos. Four readings should be obtained using the same procedures as noted for pH in Step 21.

23. Temperature - Temperature of the sample must also be taken immediately after the sample is collected and should be recorded to the nearest 0.5°. A Celsius thermometer should be used.

24. Average - These numbers are calculated after the fieldwork has been completed and should be written in red. pH is the average of four readings, and specific conductance is also the average of four readings, converted to 25°C and reported to the nearest 10 μmhos.

25. Time - The time the filtration procedure is started should be recorded here. Note A.M. or P.M.

26. Color - Same procedure as in Step 13.

27. Turbidity - Same procedure as in Step 14.

28. Comments - Notes relating to filtration difficulty. If a sample takes an unusually long time to filter, the length of time should be noted here. Also, any observations made, other than odor, color, and turbidity, should be noted here.

29. Bottles Filled - This section is intended to serve as an inventory of the bottles filled. It should be filled out completely and accurately after the bottles have been filled and before being placed in cooler. Abbreviations should not be used.

30. Chain-of-custody number - This number is found in the upper right-hand corner of the chain-of-custody form.

31. Date shipped - Record the date the samples are shipped to the laboratory. If they are not shipped, record the date on which they are given to the laboratory.

32. Method - Record the name of the shipping used e.g., Fed Ex., Airborne. If the samples are not shipped and you transport them via vehicle, please note this.

33. Airbill number - Record the airbill number found on the shipping form. If the samples are not shipped, place a line here.

34. Signed - The signature should be of the sampler or the field QA/QC design.

35. Date - The date the log is signed should be recorded here.

36. QC'd by - The signature of the sampling QC/QA officer should be recorded here.

37. Date - The date on which the sampling QA/QC officer signs the logs should be recorded here.

38. Page - When all of the field notes are assembled, number the pages.

A title page for all field jobs should be attached to the field notes. It should consist of the project name and number, the location of the project, the dates on which the fieldwork was performed, the purpose of the fieldwork, name of person performing the fieldwork, and a short description of the weather conditions.

In summary, the field notes should

- show all data with sufficient explanation to prevent misinterpretation and with answers to all questions;
- be relative to the immediate purpose of the field assignment and should also anticipate reasonable future uses of the notes;
- be legible; and
- be recorded as if the eventual user of the notes was not present when the fieldwork was performed.

The original field notes often afford the only possible means of accomplishing the desired ends, and, unless sufficiently complete, they may be worthless. These same guidelines apply to notes taken during other field activities.

APPENDIX C

SAMPLE CHAIN-OF-CUSTODY FORM

LABORATO
744 Heartland Trail
Phone (608) 831-4444
FAX (608) 831-7530
Nashville, TN
Schaumburg, IL

F-268 (R2/88)
(Use Black Ink Only)

CHAIN OF CUSTODY RECORD

Sample Type: (GW, WW, SW, Soil, Other)

№ 021838

Bottles Prepared by:	Date/Time	Office Code: (State)

Project No.	Client:

Container Inventory: Filtered (Yes/No); Preserved (Code); Refrigerated (Yes/No)

Code: A - None
B - HNO_3
C - H_2SO_4
D - NaOH
E - _____

RMT Lab NO.	Yr. ___ Date	Time	Sample Station ID	Total Number Of Containers								Comments:

SAMPLER Relinquished by (Sig.)	Date/Time	Received by (Sig.)	Date/Time
①		② Shipper Name & #	
Relinquished by (Sig.) ③	Date/Time	Received by (Sig.) ④ Shipper Name & #	Date/Time
Relinquished by (Sig.) ⑤	Date/Time	Received by (Sig.) ⑥ Shipper Name & #	Date/Time

HAZARDS ASSOCIATED WITH SAMPLES

(For Lab Use Only)

Receipt Temp _____ Receipt pH _____

Client P.O. Number _____

Subsequent Analysis: _____ (Check)

Date Resubmitted _____

Seal # at'chd by ◯ Recvd. intact by ◯ Seal # at'chd by ◯ Recvd. intact by ◯

APPENDIX D

STATISTICAL EVALUATION METHODS

EPA/530-SW-89-026

PB89-151047

STATISTICAL ANALYSIS OF GROUND-WATER MONITORING DATA AT RCRA FACILITIES

RMT
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INTERIM FINAL GUIDANCE

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OFFICE OF SOLID WASTE
WASTE MANAGEMENT DIVISION
U.S. ENVIRONMENTAL PROTECTION AGENCY
401 M STREET, S.W.
WASHINGTON, D.C. 20460

FEBRUARY 1989

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

For data sets with more than 30 observations, the parametric analysis of variance performed on the rank values is a good approximation to the Kruskal-Wallis test (Quade, 1966). If the user has access to SAS, the PROC RANK procedure is used to obtain the ranks of the data. The analysis of variance procedure detailed in Section 5.2.1 is then performed on the ranks. Contrasts are tested as in the parametric analysis of variance.

INTERPRETATION

The Kruskal-Wallis test statistic is compared to the tabulated critical value from the chi-squared distribution. If the test statistic does not exceed the tabulated value, there is no statistically significant evidence of contamination and the analysis would stop and report this finding. If the test statistic exceeds the tabulated value, there is significant evidence that the hypothesis of no differences in compliance concentrations from the background level is not true. Consequently, if the test statistic exceeds the critical value, one concludes that there is significant evidence of contamination. One then proceeds to investigate where the differences lie, that is, which wells are indicating contamination.

The multiple comparisons procedure described in steps 5 and 6 compares each compliance well to the background well. This determines which compliance wells show statistically significant evidence of contamination at an experimentwise error rate of 5 percent. In many cases, inspection of the mean or median concentrations will be sufficient to indicate where the problem lies.

5.3 TOLERANCE INTERVALS BASED ON THE NORMAL DISTRIBUTION

An alternate approach to analysis of variance to determine whether there is statistically significant evidence of contamination is to use tolerance intervals. A tolerance interval is constructed from the data on (uncontaminated) background wells. The concentrations from compliance wells are then compared with the tolerance interval. With the exception of pH, if the compliance concentrations do not fall in the tolerance interval, this provides statistically significant evidence of contamination.

Tolerance intervals are most appropriate for use at facilities that do not exhibit high degrees of spatial variation between background wells and compliance wells. Facilities that overlie extensive, homogeneous geologic deposits (for example, thick, homogeneous lacustrine clays) that do not naturally display hydrogeochemical variations may be suitable for this statistical method of analysis.

A tolerance interval establishes a concentration range that is constructed to contain a specified proportion (P%) of the population with a specified confidence coefficient, Y. The proportion of the population included, P, is referred to as the coverage. The probability with which the tolerance interval includes the proportion P% of the population is referred to as the tolerance coefficient.

A coverage of 95% is recommended. If this is used, random observations on the same distribution as the background well data would exceed the upper

tolerance limit less than 5% of the time. Similarly, a tolerance coefficient of 95% is recommended. This means that one has a confidence level of 95% that the upper 95% tolerance limit will contain at least 95% of the distribution of observations from background well data. These values were chosen to be consistent with the performance standards described in Section 2. The use of these values corresponds to the selection of α of 5% in the multiple well testing situation.

The procedure can be applied with as few as three observations from the background distribution. However, doing so would result in a large upper tolerance limit. A sample size of eight or more results is an adequate tolerance interval. The minimum sampling schedule called for in the regulations would result in at least four observations from each background well. Only if a single background well is sampled at a single point in time is the sample size so small as to make use of the procedure questionable.

Tolerance intervals can be constructed assuming that the data or the transformed data are normally distributed. Tolerance intervals can also be constructed assuming other distributions. It is also possible to construct nonparametric tolerance intervals using only the assumption that the data came from some continuous population. However, the nonparametric tolerance intervals require such a large number of observations to provide a reasonable coverage and tolerance coefficient that they are impractical in this application.

The range of the concentration data in the background well samples should be considered in determining whether the tolerance interval approach should be used, and if so, what distribution is appropriate. The background well concentration data should be inspected for outliers and tests of normality applied before selecting the tolerance interval approach. Tests of normality were presented in Section 4.2. Note that in this case, the test of normality would be applied to the background well data that are used to construct the tolerance interval. These data should all be from the same normal distribution.

In this application, unless pH is being monitored, a one-sided tolerance interval or an upper tolerance limit is desired, since contamination is indicated by large concentrations of the hazardous constituents monitored. Thus, for concentrations, the appropriate tolerance interval is (0, TL), with the comparison of importance being the larger limit, TL.

PURPOSE

The purpose of the tolerance interval approach is to define a concentration range from background well data, within which a large proportion of the monitoring observations should fall with high probability. Once this is done, data from compliance wells can be checked for evidence of contamination by simply determining whether they fall in the tolerance interval. If they do not, this is evidence of contamination.

In this case the data are assumed to be approximately normally distributed. Section 4.2 provided methods to check for normality. If the data are

ot normal, take the natural logarithm of the data and see if the transformed data are approximately normal. If so, this method can be used on the logarithms of the data. Otherwise, seek the assistance of a professional statistician.

PROCEDURE

Step 1. Calculate the mean, $\bar{X}$, and the standard deviation, S, from the background well data.

Step 2. Construct the one-sided upper tolerance limit as

$$TL = \bar{X} + K\,S,$$

where K is the one-sided normal tolerance factor found in Table 5, Appendix B.

Step 3. Compare each observation from compliance wells to the tolerance limit found in Step 2. If any observation exceeds the tolerance limit, that is statistically significant evidence that the well is contaminated. Note that if the tolerance interval was constructed on the logarithms of the original background observations, the logarithms of the compliance well observations should be compared to the tolerance limit. Alternatively the tolerance limit may be transferred to the original data scale by taking the antilogarithm.

REFERENCE

Lieberman, Gerald J. 1958. "Tables for One-sided Statistical Tolerance Limits." *Industrial Quality Control*. Vol. XIV, No. 10.

EXAMPLE

Table 5-5 contains example data that represent lead concentration levels in parts per million in water samples at a hypothetical facility. The background well data are in columns 1 and 2, while the other four columns represent compliance well data.

Step 1. The mean and standard deviation of the n = 8 observations have been calculated for the background well. The mean is 51.4 and the standard deviation is 16.3.

Step 2. The tolerance factor for a one-sided normal tolerance interval is found from Table 5, Appendix B as 3.188. This is for 95% coverage with probability 95% and for n = 8. The upper tolerance limit is then calculated as 51.4 + (3.188)(16.3) = 103.4.

Step 3. The tolerance limit of 103.3 is compared with the compliance well data. Any value that exceeds the tolerance limit indicates statistically significant evidence of contamination. Two observations from Well 1, two observations from Well 3, and all four observations from Well 4 exceed the tolerance limit. Thus there is statistically significant evidence of contamination at Wells 1, 3, and 4.

TABLE 5-5. EXAMPLE DATA FOR NORMAL TOLERANCE INTERVAL

Lead concentrations (ppm)

Date	Background well A	Background well B	Compliance wells Well 1	Compliance wells Well 2	Compliance wells Well 3	Compliance wells Well 4
Jan 1	58.0	46.1	273.1*	34.1	49.9	225.9*
Feb 1	54.1	76.7	170.7*	93.7	73.0	183.1*
Mar 1	30.0	32.1	32.1	70.8	244.7*	198.3*
Apr 1	46.1	68.0	53.0	83.1	202.4*	160.8*

n = 8
Mean = 51.4
SD = 16.3

The upper 95% coverage tolerance limit with tolerance coefficient of 95% is 51.4 + (3.188)(16.3) = 103.4

* Indicates contamination

INTERPRETATION

A tolerance limit with 95% coverage gives an upper bound below which 95% of the observations of the distribution should fall. The tolerance coefficient used here is 95%, implying that at least 95% of the observations should fall below the tolerance limit with probability 95%, if the compliance well data come from the same distribution as the background data. In other words, in this example, we are 95% certain that 95% of the background lead concentrations are below 104 ppm. If observations exceed the tolerance limit, this is evidence that the compliance well data are not from the same distribution, but rather are from a distribution with higher concentrations. This is interpreted as statistically significant evidence of contamination.

5.4 PREDICTION INTERVALS

A prediction interval is a statistical interval calculated to include one or more future observations from the same population with a specified confidence. This approach is algebraically equivalent to the average replicate (AR) test that is presented in the Technical Enforcement Guidance Document (TEGD), September 1986. In ground-water monitoring, a prediction interval approach may be used to make comparisons between background and compliance well data. This method of analysis is similar to that for calculating a tolerance limit, and familiarity with prediction intervals or personal preference would be the only reason for selecting them over the method for tolerance limits. The concentrations of a hazardous constituent in the background wells are used to establish an interval within which K future observations from the same population are expected to lie with a specified confidence. Then each of K future observations of compliance well concentrations is compared to the prediction interval. The interval is constructed to contain all of K future

It should be noted that the nonparametric methods presented earlier automatically deal with values below detection by regarding them as all tied at a level below any quantitated results. The nonparametric methods may be used if there is a moderate amount of data below detection. If the proportion of nonquantified values in the data exceeds 25%, these methods should be used with caution. They should probably not be used if less than half of the data consists of quantified concentrations.

8.1.1 The DL/2 Method

The amount of data that are below detection plays an important role in selecting the method to deal with the limit of detection problem. If a small proportion of the observations are not detected, these may be replaced with a small number, usually the method detection limit divided by 2 (MDL/2), and the usual analysis performed. This is the recommended method for use with the analysis of various procedure of Section 5:2.1. Seek professional help if in doubt about dealing with values below detection limit. The results of the analysis are generally not sensitive to the specific choice of the replacement number.

As a guideline, if 15% or fewer of the values are not detected, replace them with the method detection limit divided by two and proceed with the appropriate analysis using these modified values. Practical quantitation limits (PQL) for Appendix IX compounds were published by EPA in the Federal Register (Vol 52, No 131, July 9, 1987, pp 25947-25952). These give practical quantitation limits by compound and analytical method that may be used in replacing a small amount of nondetected data with the quantitation limit divided by 2. If approved by the Regional Administrator, site specific PQL's may be used in this procedure. If more than 15% of the values are reported as not detected, it is preferable to use a nonparametric method or a test of proportions.

8.1.2. Test of Proportions

If more than 50% of the data are below detection but at least 10% of the observations are quantified, a test of proportions may be used to compare the background well data with the compliance well data. Clearly, if none of the background well observations were above the detection limit, but all of the compliance well observations were above the detection limit, one would suspect contamination. In general the difference may not be as obvious. However, a higher proportion of quantitated values in compliance wells could provide evidence of contamination. The test of proportions is a method to determine whether a difference in proportion of detected values in the background well observations and compliance well observations provides statistically significant evidence of contamination.

The test of proportions should be used when the proportion of quantified values is small to moderate (i.e., between 10% and 50%). If very few quantified values are found, a method based on the Poisson distribution may be used as an alternative approach. A method based on a tolerance limit for the number of detected compounds and the maximum concentration found for any detected compound has been proposed by Gibbons (1988). This alternative would

be appropriate when the number of detected compounds is quite small relative to the number of compounds analyzed for as might occur in detection monitoring.

PURPOSE

The test of proportions determines whether the proportion of compounds detected in the compliance well data differs significantly from the proportion of compounds detected in the background well data. If there is a significant difference, this is statistically significant evidence of contamination.

PROCEDURE

The procedure uses the normal distribution approximation to the binomial distribution. This assumes that the sample size is reasonably large. Generally, if the proportion of detected values is denoted by P, and the sample size is n, then the normal approximation is adequate, provided that nP and n(1-P) both are greater than or equal to 5.

Step 1. Determine X, the number of background well samples in which the compound was detected. Let n be the total number of background well samples analyzed. Compute the proportion of detects:

$$\hat{P}_u = x/n$$

Step 2. Determine Y, the number of compliance well samples in which the compound was detected. Let M be the total number of compliance well samples analyzed. Compute the proportion of detects:

$$\hat{P}_d = y/m$$

Step 3. Compute the standard error of the difference in proportions:

$$S_D = [[(x+y)/(n+m)][1 - (x+y)/(n+m)][1/n + 1/m]]^{1/2}$$

and form the statistic:

$$Z = (\hat{P}_u - \hat{P}_d)/S_D$$

Step 4. Compare the absolute value of Z to the 97.5th percentile from the standard normal distribution, 1.96. If the absolute value of Z exceeds 1.96, this provides statistically significant evidence at the 5% significance level that the proportion of compliance well samples where the compound was detected exceeds the proportion of background well samples where the compound was detected. This would be interpreted as evidence of contamination. (The two-sided test is used to provide information about differences in either direction.)

EXAMPLE

Table 8-2 contains data on cadmium concentrations measured in background well and compliance wells at a facility. In the table, "BDL" is used for below detection limit.

TABLE 8-2. EXAMPLE DATA FOR A TEST OF PROPORTIONS

Cadmium concentration (μg/L) at background well (24 samples)		Cadmium concentration (μg/L) at compliance wells (64 samples)		
0.1	BDL	0.12	BDL	0.024
0.12	BDL	0.08	BDL	BDL
BDL*	BDL	BDL	BDL	BDL
0.26	BDL	0.2	0.11	BDL
BDL		BDL	0.06	BDL
0.1		0.1	BDL	BDL
BDL		BDL	0.23	0.1
0.014		0.012	BDL	0.04
BDL		BDL	0.11	BDL
BDL		BDL	BDL	BDL
BDL		BDL	0.031	0.1
BDL		BDL	BDL	BDL
BDL		BDL	BDL	0.01
0.12		0.12	BDL	BDL
BDL		0.07	BDL	BDL
0.21		BDL	BDL	BDL
BDL		0.19	0.12	BDL
0.12		BDL	0.08	BDL
BDL		0.1	BDL	
BDL		BDL	0.26	
		0.01	BDL	
		BDL	0.02	
		BDL	BDL	

*BDL means below detection limit.

Step 1. Estimate the proportion above detection in the background wells. As shown in Table 8-2, there were 24 samples from background wells analyzed for cadmium, so n= 24. Of these, 16 were below detection and x = 8 were above detection, so $P_u = 8/24 = 0.333$.

Step 2. Estimate the proportion above detection in the compliance wells. There were 64 samples from compliance wells analyzed for cadmium, with 40 below detection and 24 detected values. This gives m = 64, y = 24, so $P_d = 24/64 = 0.375$.

Step 3. Calculate the standard error of the difference in proportions.

$$S_D = [[(8+24)/(24+64)][1-(8+24)/(24+64)](1/24 + 1/64)]^{1/2} = 0.115$$

Step 4. Form the statistic Z and compare it to the normal distribution.

$$Z = \frac{0.375 - 0.333}{0.115} = 0.37$$

which is less in absolute value than the value from the normal distribution, 1.96. Consequently, there is no statistically significant evidence that the proportion of samples with cadmium levels above the detection limit differs in the background well and compliance well samples.

INTERPRETATION

Since the proportion of water samples with detected amounts of cadmium in the compliance wells was not significantly different from that in the background wells, the data are interpreted to provide no evidence of contamination. Had the proportion of samples with detectable levels of cadmium in the compliance wells been significantly higher than that in the background wells this would have been evidence of contamination. Had the proportion been significantly higher in the background wells, additional study would have been required. This could indicate that contamination was migrating from an off-site source, or it could mean that the hydraulic gradient had been incorrectly estimated or had changed and that contamination was occurring from the facility, but the ground-water flow was not in the direction originally estimated. Mounding of contaminants in the ground water near the background wells could also be a possible explanation of this observance.

8.1.3 Cohen's Method

If a confidence interval or a tolerance interval based upon the normal distribution is being constructed, a technique presented by Cohen (1959) specifies a method to adjust the sample mean and sample standard deviation to account for data below the detection limit. The only requirements for the use of this technique is that the data are normally distributed and that the detection limit be always the same. This technique is demonstrated below.

APPENDIX K

GEOTECHNICAL ANALYSIS

SLOPE STABILITY ANALYSIS

SLOPE STABILITY ANALYSIS

Table of Contents

- Purpose/Approach/Methodologies/Assumptions/Results and Recommendations/References
- PC STABL4 Outputs
- Shear Strength Parameters
- Figures

SLOPE STABILITY ANALYSIS

Purpose:

The purpose of the slope stability analysis is to determine if the final cover will be stable for the post-closure conditions. The conditions that were analyzed included short-term stability, long-term stability, and stability under earthquake loads.

Approach:

The slope stability analysis was performed using the following approach:

STEP 1 Identify the critical slope stability profile.

- The southwest corner of the landfill cover was determined to be the critical slope. The final cover is on a 4H:1V slope for a height of 18 feet (Elevation 1078 to Elevation 1096). The profile is estimated from the boring logs for MW-4A and B-9.

STEP 2 Determine shear strength parameters.

The shear strength parameters for the materials that will be affected by the final cover placement and fill are shown in Table 4-1 of the report and are discussed in the attached section entitled "Shear Strength Parameters." The materials considered are as follows:

- Fine-grained foundry waste
- Foundry sand
- Final cover

No laboratory shear strength tests were performed on these materials; therefore shear strength parameters were determined using empirical relationships based on Atterberg limits and Standard Penetration test results. The relationships between empirical formulas and shear strengths are based on extensive testing on soil. The shear strength of the waste was assumed to behave similarly to soil because the waste materials should have similar characteristics as the soil. If, during placement of the fill, equipment operations become difficult, further testing of the waste will be required. The basis for the values is presented in the section entitled "Shear Strength Parameters."

STEP 3 Perform calculations using computer program PCSTABL4.

Methodologies:

The slope stability analysis was performed using a computer software program to evaluate the three conditions. The computer program, PCSTABL4, developed at Purdue University, was used to perform the iterative task of identifying the worst-case failure surface for each condition. PCSTABL4 uses a two-dimensional static limit equilibrium method to determine a factor of safety against failure. The program utilizes the Modified Bishops Method for circular-shaped failures. The earthquake loading used in the program is described in the following paragraph from the users' manual.

The use of earthquake coefficients allows for a pseudo-static representation of earthquake effects within the limiting equilibrium model. This method is applicable for use in low-seismic areas, such as the Alliance site. A direct relationship is assumed to exist between the pseudo-static earthquake force acting on the sliding mass and the weight of the sliding mass. Specified horizontal and vertical coefficients are used to scale the horizontal and vertical components of the earthquake force relative to the weight of the sliding mass. Positive horizontal and vertical earthquake coefficients indicate that the horizontal and vertical components of the earthquake force are directed leftward and upward, respectively. Negative coefficients are allowed.

Assumptions:

Failure Mode - The failure mode considered for the stability analysis was a rotational failure of the soil subgrade, natural formations, and various wastes.

Profile - The cross section selected to be analyzed represented a worst-case profile with regard to slope stability.

The cross section examined was for the southwestern corner of the landfill. The slope was 4H:1V for a height of 18 feet. The subsurface conditions were obtained from boring logs B-9 and MW-4A.

Seismic Impact - The Seismic Impact Zone described in OAC 3745-30-07(C)(11) was considered in the design of the landfill. The landfill is located in an area with a 90 percent probability that an earthquake with a 0.1 gram horizontal acceleration will not be exceeded in 250 years. Figure 3 shows the location of the site and the horizontal acceleration.

Factor of Safety - The minimum allowable factor of safety (FS) for a slope failure was 1.3 for the static case and 1.0 for the dynamic case with low hazard potential (Huang, 1983). These values were established as a design basis for circular slope failure.

Water Level - The water level used for the slope stability analysis was obtained from the geologic cross section(s) contained in the Groundwater Quality Assessment Plan in (Appendix J).

Results and Recommendations:

The results of the slope stability analysis for the construction of the final cover and fill are as follows:

- Short-term conditions FS = 1.4
- Long-term conditions FS = 2.5
- Earthquake load FS = 1.7

Based on the results of the slope stability analysis, the subsurface materials will support the final cover construction.

References:

Bowles, J.E. 1984. Physical and geotechnical properties of soils. New York, New York: McGraw-Hill Book Company.

Holtz, R.D. and Kovacs, W.D. 1981. An introduction to geotechnical engineering. Englewood Cliffs. New Jersey: Prentice-Hall, Inc.

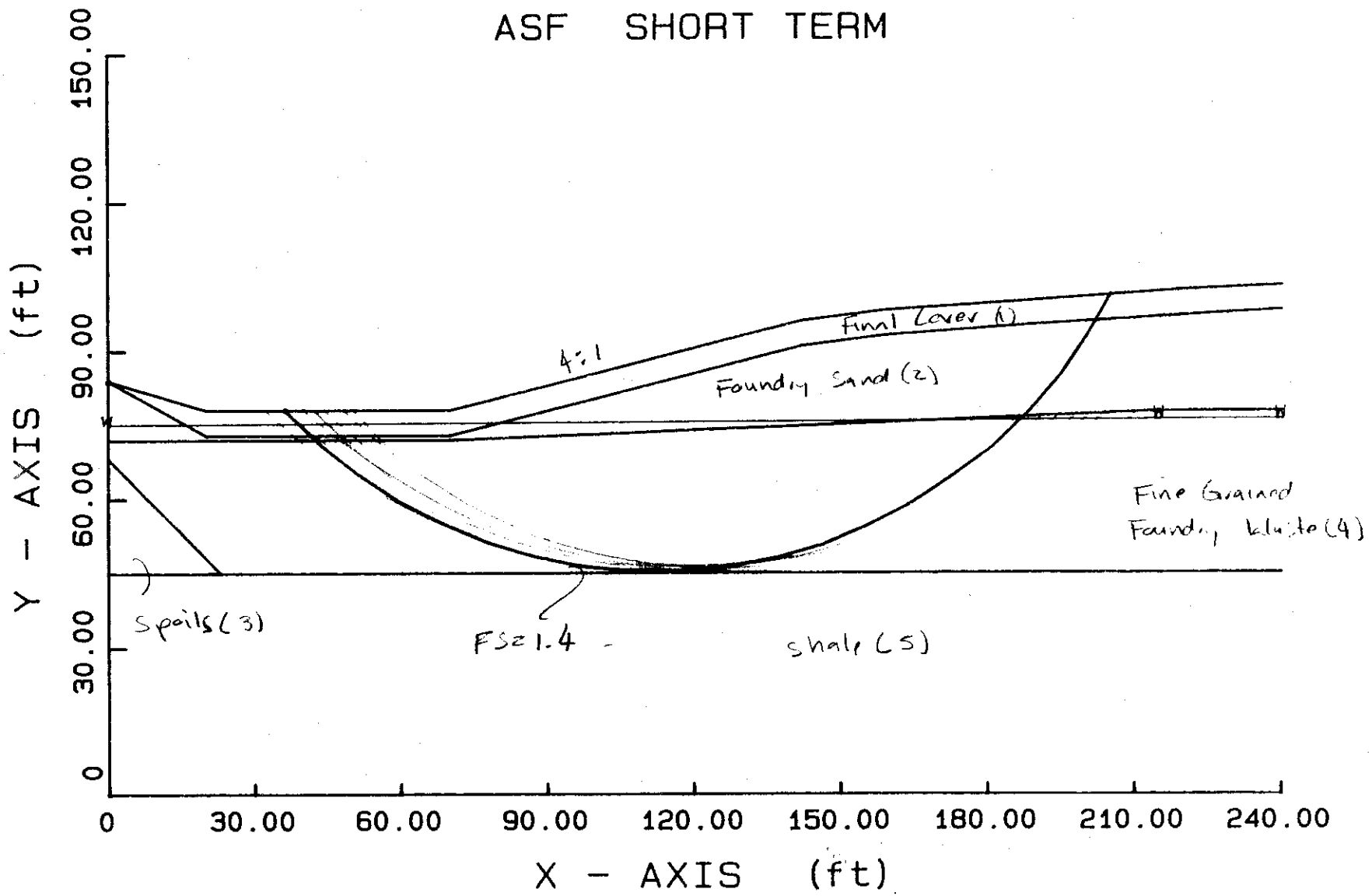
Huang, Y.H. 1983. Stability analysis of earth slopes. New York, New York: Van Nostrand Reinhold Company, Inc.

Siegel, Ronald A. 1985. STABL4 user manual. In Purdue University and Indiana State University Highway Commission. Joint Highway Research Project.

U.S. Navy. 1982. Soil mechanics. NAVFAC design manual DM-7.1. Washington, D.C.

U.S. Navy. 1982. Foundations and earth structures. NAVFAC design manual DM-7.2. Washington, D.C.

PCSTABL4 OUTPUTS



0 = EL-1,000'

PBOX 12/94

1/33

2/33

** PCSTABL4 **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu Method of Slices
or Simplified Bishop Method

Run Date:
Time of Run:
Run By: JDH
Input Data Filename: ASFSWST.STA
Output Filename: ASFSWST.OUT
Plotted Output Filename: ASFSWST.PLT

VBJK 12/94

PROBLEM DESCRIPTION ASF SOUTHWEST CORNER OF FINAL CLOSURE THROUGH MW-4A AND B-9 SHORT-TERM

BOUNDARY COORDINATES

7 Top Boundaries
22 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	84.00	20.00	78.00	1
2	20.00	78.00	70.00	78.00	1
3	70.00	78.00	142.00	96.00	1
4	142.00	96.00	159.00	98.00	1
5	159.00	98.00	188.00	100.00	1
6	188.00	100.00	219.00	102.00	1
7	219.00	102.00	240.00	103.00	1
8	.00	84.00	20.00	73.00	3
9	20.00	73.00	30.00	73.00	3
10	30.00	73.00	70.00	73.00	2
11	70.00	73.00	142.00	91.00	2
12	142.00	91.00	159.00	93.00	2
13	159.00	93.00	188.00	95.00	2
14	188.00	95.00	219.00	97.00	2
15	219.00	97.00	240.00	98.00	2
16	.00	72.00	70.00	72.00	4
17	70.00	72.00	215.00	77.60	4
18	215.00	77.60	240.00	77.60	4

19	.00	68.00	23.00	45.00	2
20	23.00	45.00	215.00	45.00	5
21	215.00	45.00	240.00	45.00	5
22	.00	45.00	23.00	45.00	5

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	115.0	115.0	.0	30.0	.00	.0	1
2	105.0	115.0	.0	33.0	.00	.0	1
3	125.0	125.0	2000.0	.0	.00	.0	1
4	90.0	90.0	500.0	.0	.00	.0	1
5	130.0	130.0	2000.0	20.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	.00	75.00
2	215.00	76.00
3	240.00	76.00

A Horizontal Earthquake Loading Coefficient
Of .000 Has Been Assigned

A Vertical Earthquake Loading Coefficient
Of .000 Has Been Assigned

Cavitation Pressure = .0 psf

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

1300 Trial Surfaces Have Been Generated.

50 Surfaces Initiate From Each Of 26 Points Equally Spaced Along The Ground Surface Between X = 20.00 ft.
and X = 70.00 ft.

Each Surface Terminates Between X = 142.00 ft.
and X = 240.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	36.00	78.00
2	43.20	71.06
3	51.03	64.84
4	59.42	59.40
5	68.29	54.77
6	77.55	51.02
7	87.14	48.16
8	96.95	46.23
9	106.90	45.24
10	116.90	45.21
11	126.86	46.13
12	136.68	47.99
13	146.29	50.78
14	155.58	54.47
15	164.48	59.04
16	172.90	64.42
17	180.78	70.59
18	188.02	77.48
19	194.59	85.03
20	200.40	93.16
21	204.99	101.10

Circle Center At X = 112.3 ; Y = 150.0 and Radius, 104.8

*** 1.418 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	78.00
2	47.74	71.67
3	55.94	65.94

4	64.55	60.86
5	73.52	56.44
6	82.80	52.71
7	92.33	49.69
8	102.07	47.41
9	111.95	45.87
10	121.92	45.09
11	131.92	45.06
12	141.89	45.79
13	151.78	47.28
14	161.53	49.51
15	171.08	52.47
16	180.38	56.15
17	189.37	60.52
18	198.01	65.56
19	206.24	71.24
20	214.02	77.53
21	221.29	84.39
22	228.03	91.78
23	234.18	99.66
24	236.29	102.82

Circle Center At X = 127.3 ; Y = 176.8 and Radius, 131.8

*** 1.418 ***

1

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	36.00	78.00
2	43.76	71.70
3	51.98	66.00
4	60.60	60.93
5	69.58	56.53
6	78.87	52.82
7	88.40	49.81
8	98.14	47.53
9	108.02	45.99
10	117.99	45.20
11	127.99	45.16
12	137.97	45.87
13	147.86	47.33
14	157.61	49.54
15	167.17	52.46
16	176.49	56.11
17	185.50	60.44
18	194.16	65.43

19	202.42	71.07
20	210.24	77.31
21	217.56	84.12
22	224.35	91.46
23	230.57	99.29
24	232.85	102.66

Circle Center At X = 123.5 ; Y = 177.9 and Radius, 132.8

*** 1.419 ***

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	42.00	78.00
2	49.39	71.26
3	57.37	65.23
4	65.86	59.96
5	74.81	55.49
6	84.13	51.87
7	93.75	49.12
8	103.57	47.27
9	113.53	46.33
10	123.53	46.31
11	133.49	47.21
12	143.32	49.03
13	152.95	51.74
14	162.28	55.33
15	171.25	59.76
16	179.76	65.00
17	187.76	71.00
18	195.18	77.71
19	201.94	85.07
20	208.00	93.03
21	213.30	101.51
22	213.36	101.64

Circle Center At X = 118.7 ; Y = 154.7 and Radius, 108.5

*** 1.421 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	36.00	78.00
2	43.26	71.12
3	51.14	64.96
4	59.56	59.57
5	68.45	54.99
6	77.73	51.27
7	87.32	48.45
8	97.14	46.54
9	107.09	45.57
10	117.09	45.53
11	127.05	46.44
12	136.88	48.29
13	146.49	51.05
14	155.80	54.71
15	164.72	59.23
16	173.18	64.56
17	181.09	70.68
18	188.40	77.51
19	195.02	84.99
20	200.92	93.07
21	205.71	101.14

Circle Center At X = 112.4 ; Y = 151.4 and Radius, 106.0

*** - 1.421 ***

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	48.00	78.00
2	55.40	71.28
3	63.38	65.25
4	71.87	59.97
5	80.80	55.47
6	90.10	51.79
7	99.70	48.97
8	109.51	47.03
9	119.45	45.98
10	129.45	45.82
11	139.42	46.57
12	149.29	48.22
13	158.96	50.75

14	168.37	54.14
15	177.43	58.36
16	186.08	63.38
17	194.24	69.17
18	201.84	75.66
19	208.83	82.81
20	215.15	90.57
21	220.74	98.86
22	222.56	102.17

Circle Center At X = 126.1 ; Y = 156.6 and Radius, 110.8

*** 1.421 ***

1

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	32.00	78.00
2	39.61	71.51
3	47.71	65.65
4	56.27	60.48
5	65.22	56.02
6	74.50	52.30
7	84.06	49.34
8	93.82	47.18
9	103.72	45.81
10	113.71	45.25
11	123.71	45.51
12	133.65	46.58
13	143.47	48.45
14	153.11	51.11
15	162.50	54.55
16	171.58	58.74
17	180.29	63.66
18	188.57	69.26
19	196.37	75.52
20	203.63	82.40
21	210.31	89.84
22	216.36	97.80
23	219.05	102.00

Circle Center At X = 115.6 ; Y = 168.2 and Radius, 122.9

*** 1.422 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	42.00	78.00
2	49.14	70.99
3	56.94	64.74
4	65.34	59.31
5	74.24	54.76
6	83.56	51.13
7	93.20	48.46
8	103.06	46.78
9	113.03	46.11
10	123.03	46.44
11	132.94	47.79
12	142.66	50.12
13	152.10	53.43
14	161.15	57.68
15	169.73	62.82
16	177.74	68.80
17	185.11	75.56
18	191.76	83.03
19	197.62	91.13
20	202.63	99.79
21	203.17	100.98

Circle Center At X = 114.7 ; Y = 144.9 and Radius, 98.8

*** 1.423 ***

1

Failure Surface Specified By 20 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	50.00	78.00
2	57.08	70.94
3	64.86	64.65
4	73.24	59.21
5	82.15	54.67
6	91.49	51.08
7	101.14	48.48
8	111.02	46.90
9	121.00	46.36
10	130.99	46.86
11	140.87	48.40

12	150.54	50.96
13	159.89	54.51
14	168.82	59.02
15	177.22	64.43
16	185.03	70.69
17	192.13	77.72
18	198.47	85.46
19	203.96	93.82
20	207.82	101.28

Circle Center At X = 121.2 ; Y = 142.3 and Radius, 95.9

*** 1.428 ***

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	44.00	78.00
2	51.55	71.44
3	59.64	65.56
4	68.21	60.41
5	77.20	56.03
6	86.54	52.45
7	96.15	49.70
8	105.97	47.80
9	115.91	46.76
10	125.91	46.60
11	135.89	47.30
12	145.76	48.88
13	155.46	51.31
14	164.91	54.58
15	174.04	58.67
16	182.78	63.53
17	191.06	69.14
18	198.81	75.45
19	205.99	82.41
20	212.53	89.98
21	218.39	98.08
22	220.78	102.08

Circle Center At X = 122.8 ; Y = 161.0 and Radius, 114.4

*** 1.428 ***

12/33

```
                Y           A     X     I     S           F     T

                .00     30.00     60.00     90.00    120.00    150.00

X          .00 +---------+----*----+--**W--*-+---------+---------+
               -
               -
               -
               -                       * *
               -              *         . .
         30.00 +                       *.7
               -                    .. ..1
               -                    ...7.2
               -                  .....1.0
               -                  . ..1.2.6
               -                  ..7.2.6..
A        60.00 +                ....1.0....
               -                ...72.6....
               -               ...136...*.*
               -               ..7429......
               -              ...13........
               -              ..142........
X        90.00 +             ....2..........
               -             ..140.........
               -            ....2...........
               -            ...14...........
               -            ...26............
               -            ...10............
I       120.00 +            ...2..............
               -            ...10.............
               -            ...29.............
               -            ....1..............
               -            ...26.............*.*
               -             ...41..............
S       150.00 +             ...298.............
               -             ....41..............
               -              ...248...........*.*
               -              ...37.1............
               -               ..26.48...........
               -               ....3015..........
        180.00 +                ...2.7481.........
               -                 ...36..98........
               -                 ...2..74.1.8...**
               -                  ....36.74.1......
               -                   ...2.36..4.81...
               -                    ....2..7...9.81
F       210.00 +                      ....3.6.74..9
               -               *       ..W*...6..74
               -                          ...2...*6*
               -                           ....3...6
               -                             ...2.3.
               -                                ..22
T       240.00 +               *         W*      **
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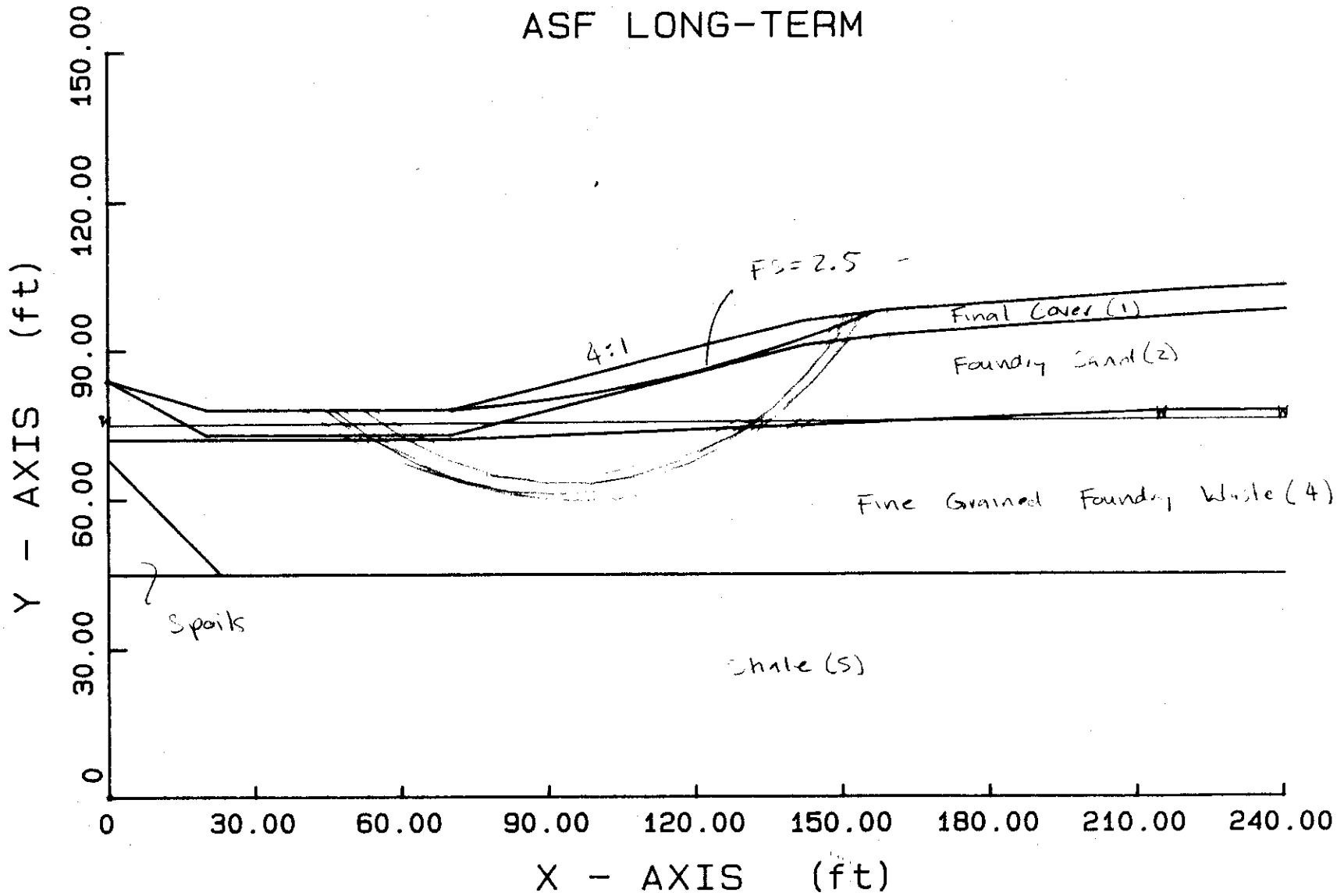

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12/94

13/33

** PCSTABL4 **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu Method of Slices
or Simplified Bishop Method

Run Date:
Time of Run:
Run By: JDH
Input Data Filename: ASFSWLT.STA
Output Filename: ASFSWLT.OUT
Plotted Output Filename: ASFSWLT.PLT

VBJK 12/94

PROBLEM DESCRIPTION ASF SOUTHWEST CORNER OF FINAL CLOSURE THROUGH MW-4A AND B-9 LONG-TERM

BOUNDARY COORDINATES

7 Top Boundaries
22 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	84.00	20.00	78.00	1
2	20.00	78.00	70.00	78.00	1
3	70.00	78.00	142.00	96.00	1
4	142.00	96.00	159.00	98.00	1
5	159.00	98.00	188.00	100.00	1
6	188.00	100.00	219.00	102.00	1
7	219.00	102.00	240.00	103.00	1
8	.00	84.00	20.00	73.00	3
9	20.00	73.00	30.00	73.00	3
10	30.00	73.00	70.00	73.00	2
11	70.00	73.00	142.00	91.00	2
12	142.00	91.00	159.00	93.00	2
13	159.00	93.00	188.00	95.00	2
14	188.00	95.00	219.00	97.00	2
15	219.00	97.00	240.00	98.00	2
16	.00	72.00	70.00	72.00	4
17	70.00	72.00	215.00	77.60	4
18	215.00	77.60	240.00	77.60	4

19	.00	68.00	23.00	45.00	2
20	23.00	45.00	215.00	45.00	5
21	215.00	45.00	240.00	45.00	5
22	.00	45.00	23.00	45.00	5

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	115.0	115.0	.0	30.0	.00	.0	1
2	105.0	115.0	.0	33.0	.00	.0	1
3	125.0	125.0	.0	33.0	.00	.0	1
4	90.0	90.0	.0	30.0	.00	.0	1
5	130.0	130.0	2000.0	20.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	.00	75.00
2	215.00	76.00
3	240.00	76.00

A Horizontal Earthquake Loading Coefficient
Of .000 Has Been Assigned

A Vertical Earthquake Loading Coefficient
Of .000 Has Been Assigned

Cavitation Pressure = .0 psf

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

1300 Trial Surfaces Have Been Generated.

50 Surfaces Initiate From Each Of 26 Points Equally Spaced Along The Ground Surface Between X = 20.00 ft.
and X = 70.00 ft.

Each Surface Terminates Between X = 142.00 ft.
and X = 240.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	78.00
2	79.97	78.81
3	89.90	79.99
4	99.78	81.52
5	109.60	83.40
6	119.35	85.64
7	129.01	88.23
8	138.57	91.17
9	148.01	94.45
10	156.36	97.69

Circle Center At X = 52.5 ; Y = 354.3 and Radius, 276.9

*** 2.463 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	46.00	78.00
2	54.00	72.00
3	62.77	67.20
4	72.14	63.70
5	81.91	61.58
6	91.89	60.87
7	101.86	61.59
8	111.63	63.73
9	121.00	67.23
10	129.76	72.04
11	137.76	78.05
12	144.81	85.14
13	150.78	93.16
14	153.02	97.30

Circle Center At X = 91.8 ; Y = 130.8 and Radius, 69.9

*** 2.601 ***

1

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	52.00	78.00
2	60.26	72.36
3	69.25	67.99
4	78.79	64.97
5	88.66	63.37
6	98.66	63.23
7	108.57	64.54
8	118.19	67.28
9	127.30	71.39
10	135.73	76.78
11	143.27	83.34
12	149.78	90.93
13	153.87	97.40

Circle Center At X = 94.7 ; Y = 131.6 and Radius, 68.5

*** 2.606 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	52.00	78.00
2	60.21	72.29
3	69.19	67.89
4	78.73	64.91
5	88.62	63.41
6	98.62	63.44
7	108.50	64.98
8	118.03	68.02
9	126.99	72.46
10	135.16	78.22
11	142.37	85.15
12	148.44	93.10
13	150.57	97.01

Circle Center At X = 93.4 ; Y = 128.8 and Radius, 65.6

*** 2.606 ***

1

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	44.00	78.00
2	52.01	72.02
3	60.80	67.24
4	70.18	63.78
5	79.96	61.71
6	89.94	61.05
7	99.91	61.84
8	109.67	64.05
9	119.00	67.64
10	127.72	72.52
11	135.65	78.62
12	142.63	85.78
13	148.50	93.87
14	150.12	96.96

Circle Center At X = 89.5 ; Y = 130.5 and Radius, 69.5

*** 2.609 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	48.00	78.00
2	55.91	71.88
3	64.60	66.93
4	73.89	63.23
5	83.61	60.87
6	93.56	59.87
7	103.55	60.28
8	113.39	62.07
9	122.88	65.21
10	131.84	69.64
11	140.10	75.28
12	147.50	82.02
13	153.88	89.71
14	158.99	98.00

Circle Center At X = 95.7 ; Y = 131.5 and Radius, 71.7

*** 2.610 ***

1

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	46.00	78.00
2	54.02	72.03
3	62.75	67.15
4	72.03	63.43
5	81.72	60.95
6	91.65	59.73
7	101.65	59.81
8	111.55	61.18
9	121.20	63.81
10	130.42	67.67
11	139.07	72.69
12	147.00	78.78

13	154.08	85.85
14	160.19	93.77
15	162.80	98.26

Circle Center At X = 96.0 ; Y = 136.9 and Radius, 77.3

*** 2.611 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	44.00	78.00
2	52.50	72.73
3	61.62	68.63
4	71.21	65.80
5	81.09	64.27
6	91.09	64.07
7	101.02	65.21
8	110.72	67.67
9	119.99	71.41
10	128.69	76.35
11	136.65	82.40
12	143.72	89.47
13	149.37	96.87

Circle Center At X = 87.5 ; Y = 138.7 and Radius, 74.7

*** 2.613 ***

1

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	54.00	78.00
2	62.61	72.91
3	71.84	69.05
4	81.51	66.51
5	91.43	65.32
6	101.43	65.51
7	111.31	67.08
8	120.88	69.99
9	129.95	74.20

10	138.35	79.62
11	145.93	86.14
12	152.54	93.65
13	155.11	97.54

Circle Center At X = 95.1 ; Y = 137.6 and Radius, 72.4

*** 2.615 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	78.00
2	48.34	72.49
3	57.32	68.09
4	66.79	64.87
5	76.60	62.90
6	86.57	62.20
7	96.55	62.78
8	106.38	64.64
9	115.89	67.74
10	124.92	72.03
11	133.33	77.45
12	140.97	83.89
13	147.73	91.27
14	151.87	97.16

Circle Center At X = 87.0 ; Y = 140.1 and Radius, 77.9

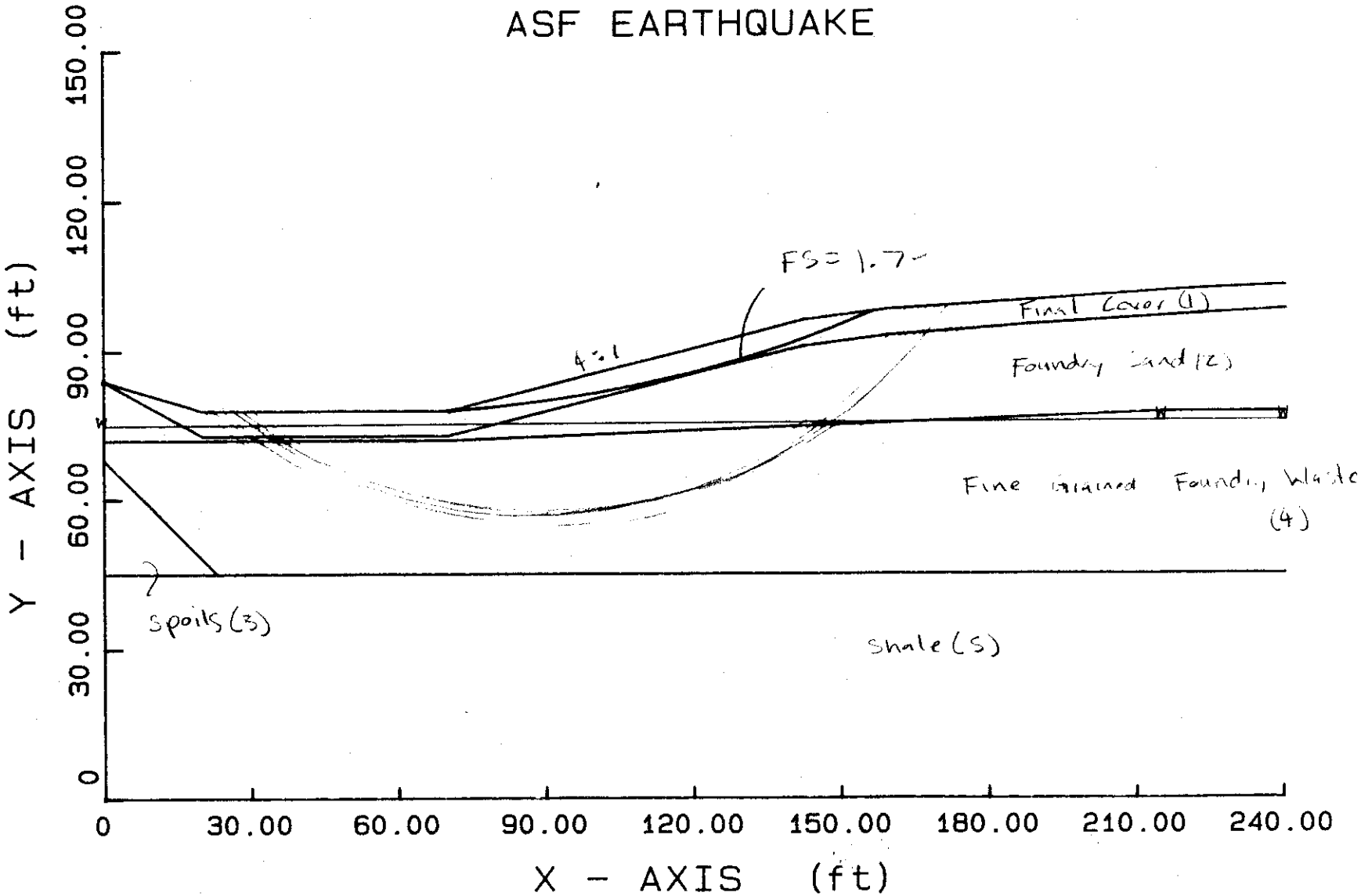
*** 2.615 ***

1

```
                Y            A     X     I     S            F     T

                .00      30.00     60.00     90.00    120.00    150.00

X          .00 +---------+----*----+--**W--*-+---------+---------+
                -
                -
                -
                -                       * *
                -              *         . .
         30.00 +                        *..
                -                    .. ...
                -                    .....0
                -                  .......2
                -                 . ....5.3
                -                 .....02.9
A        60.00 +               ......583..
                -               ......2.9..
                -              ......283*.*
                -              ......6.....
                -             ......723...1
                -             ......60.....
X        90.00 +            .......239....1
                -            .......60.....
                -           ........728....1
                -           ........6.0.....
                -           ........7238....1
                -           .........6.0.....
I       120.00 +           .........7248....1
                -           ..........6.3.....
                -           ...........628...1.
                -           ..............38....
                -           ............76294.*.*
                -            .............76258..
S       150.00 +            ................314
                -            ................76921
                -             ................*.*
                -             ...................7
                -              ...................
                -              ...................
         180.00 +               ..................
                -                ..................
                -                ...............**
                -                 ..................
                -                  ................
                -                   ...............
F       210.00 +                     .............
                -              *       ..W*........
                -                        .......*.*
                -                         .........
                -                           .......
                -                              ....
T       240.00 +              *         W*      **
```



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12/94

23/33

24133

** PCSTABL4 **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu Method of Slices
or Simplified Bishop Method

Run Date:
Time of Run:
Run By: JDH
Input Data Filename: ASFSWEQ.STA
Output Filename: ASFSWEQ.OUT
Plotted Output Filename: ASFSWEQ.PLT

PROBLEM DESCRIPTION ASF SOUTHWEST CORNER OF FINAL CLOSURE THROUGH MW-4A AND B-9 EARTHQUAKE

BOUNDARY COORDINATES

7 Top Boundaries
22 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	84.00	20.00	78.00	1
2	20.00	78.00	70.00	78.00	1
3	70.00	78.00	142.00	96.00	1
4	142.00	96.00	159.00	98.00	1
5	159.00	98.00	188.00	100.00	1
6	188.00	100.00	219.00	102.00	1
7	219.00	102.00	240.00	103.00	1
8	.00	84.00	20.00	73.00	3
9	20.00	73.00	30.00	73.00	3
10	30.00	73.00	70.00	73.00	2
11	70.00	73.00	142.00	91.00	2
12	142.00	91.00	159.00	93.00	2
13	159.00	93.00	188.00	95.00	2
14	188.00	95.00	219.00	97.00	2
15	219.00	97.00	240.00	98.00	2
16	.00	72.00	70.00	72.00	4
17	70.00	72.00	215.00	77.60	4
18	215.00	77.60	240.00	77.60	4

25/35

19	.00	68.00	23.00	45.00	2
20	23.00	45.00	215.00	45.00	5
21	215.00	45.00	240.00	45.00	5
22	.00	45.00	23.00	45.00	5

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	115.0	115.0	.0	30.0	.00	.0	1
2	105.0	115.0	.0	33.0	.00	.0	1
3	125.0	125.0	.0	33.0	.00	.0	1
4	90.0	90.0	.0	30.0	.00	.0	1
5	130.0	130.0	2000.0	20.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	.00	75.00
2	215.00	76.00
3	240.00	76.00

A Horizontal Earthquake Loading Coefficient
Of .100 Has Been Assigned

A Vertical Earthquake Loading Coefficient
Of .000 Has Been Assigned

Cavitation Pressure = .0 psf

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

1300 Trial Surfaces Have Been Generated.

50 Surfaces Initiate From Each Of 26 Points Equally Spaced Along The Ground Surface Between X = 20.00 ft.
and X = 70.00 ft.

Each Surface Terminates Between X = 142.00 ft.
and X = 240.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	78.00
2	79.97	78.81
3	89.90	79.99
4	99.78	81.52
5	109.60	83.40
6	119.35	85.64
7	129.01	88.23
8	138.57	91.17
9	148.01	94.45
10	156.36	97.69

Circle Center At X = 52.5 ; Y = 354.3 and Radius, 276.9

*** 1.693 ***

2-1133

Failure Surface Specified By 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	22.00	78.00
2	30.17	72.23
3	38.84	67.26
4	47.96	63.14
5	57.42	59.90
6	67.15	57.59
7	77.05	56.21
8	87.04	55.78
9	97.03	56.31
10	106.92	57.78
11	116.62	60.19
12	126.06	63.51
13	135.13	67.72
14	143.76	72.77
15	151.87	78.63
16	159.38	85.22
17	166.23	92.51
18	171.14	98.84

Circle Center At X = 86.5 ; Y = 160.6 and Radius, 104.8

*** 1.709 ***

1

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	26.00	78.00
2	34.11	72.15
3	42.78	67.17
4	51.92	63.10
5	61.42	59.99
6	71.19	57.87
7	81.13	56.76
8	91.13	56.68
9	101.09	57.62
10	110.89	59.58
11	120.45	62.53
12	129.65	66.45

13	138.40	71.29
14	146.61	77.00
15	154.19	83.52
16	161.06	90.79
17	167.02	98.55

Circle Center At X = 86.9 ; Y = 154.0 and Radius, 97.4

*** 1.710 ***

Failure Surface Specified By 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	28.00	78.00
2	36.23	72.32
3	44.99	67.49
4	54.17	63.54
5	63.71	60.52
6	73.49	58.46
7	83.43	57.38
8	93.43	57.29
9	103.39	58.19
10	113.22	60.07
11	122.80	62.91
12	132.06	66.69
13	140.90	71.37
14	149.24	76.89
15	156.98	83.22
16	164.06	90.28
17	170.41	98.00
18	170.96	98.82

Circle Center At X = 89.4 ; Y = 158.1 and Radius, 100.9

*** 1.713 ***

1

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	20.00	78.00
2	27.85	71.81

3	36.28	66.43
4	45.21	61.92
5	54.54	58.32
6	64.18	55.67
7	74.04	54.00
8	84.02	53.32
9	94.01	53.64
10	103.93	54.96
11	113.66	57.26
12	123.11	60.52
13	132.19	64.71
14	140.81	69.78
15	148.88	75.68
16	156.32	82.37
17	163.05	89.76
18	169.02	97.79
19	169.58	98.73

Circle Center At X = 85.8 ; Y = 153.4 and Radius, 100.1

*** 1.713 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	30.00	78.00
2	38.21	72.28
3	46.95	67.44
4	56.16	63.52
5	65.71	60.57
6	75.52	58.62
7	85.47	57.68
8	95.47	57.78
9	105.41	58.90
10	115.18	61.03
11	124.68	64.16
12	133.80	68.25
13	142.46	73.26
14	150.56	79.12
15	158.01	85.79
16	164.73	93.20
17	168.77	98.67

Circle Center At X = 89.6 ; Y = 154.8 and Radius, 97.2

*** 1.714 ***

1

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	28.00	78.00
2	36.00	72.00
3	44.61	66.91
4	53.72	62.80
5	63.24	59.72
6	73.03	57.70
7	82.99	56.77
8	92.99	56.94
9	102.91	58.20
10	112.63	60.55
11	122.03	63.96
12	131.00	68.37
13	139.43	73.75
14	147.22	80.02
15	154.28	87.10
16	160.51	94.92
17	162.61	98.25

Circle Center At X = 86.5 ; Y = 147.6 and Radius, 90.9

*** 1.714 ***

Failure Surface Specified By 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	24.00	78.00
2	31.81	71.75
3	40.24	66.37
4	49.19	61.92
5	58.57	58.46
6	68.27	56.02
7	78.17	54.63
8	88.17	54.31
9	98.14	55.06
10	107.98	56.88
11	117.56	59.73
12	126.78	63.60
13	135.54	68.43
14	143.73	74.17

15	151.25	80.75
16	158.03	88.10
17	163.99	96.13
18	165.34	98.44

Circle Center At X = 86.2 ; Y = 147.6 and Radius, 93.3

*** 1.717 ***

1

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	26.00	78.00
2	34.07	72.10
3	42.67	66.99
4	51.72	62.73
5	61.13	59.35
6	70.82	56.88
7	80.70	55.34
8	90.68	54.75
9	100.68	55.12
10	110.59	56.43
11	120.33	58.69
12	129.81	61.86
13	138.95	65.92
14	147.66	70.83
15	155.87	76.55
16	163.49	83.03
17	170.46	90.20
18	176.71	98.00
19	177.55	99.28

Circle Center At X = 91.9 ; Y = 159.6 and Radius, 104.9

*** 1.718 ***

Failure Surface Specified By 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	26.00	78.00
2	34.42	72.61

3	43.30	68.00
4	52.56	64.22
5	62.12	61.29
6	71.90	59.23
7	81.84	58.07
8	91.83	57.82
9	101.81	58.47
10	111.69	60.02
11	121.39	62.45
12	130.83	65.76
13	139.93	69.90
14	148.61	74.86
15	156.82	80.57
16	164.47	87.01
17	171.51	94.11
18	175.67	99.15

Circle Center At X = 89.7 ; Y = 168.2 and Radius, 110.4

*** 1.719 ***

1

```
                Y            A     X     I     S            F     T

                .00     30.00     60.00     90.00    120.00    150.00

X          .00 +---------+----*----+--**W--*-+---------+---------+
                -
                -
                -
                -                      * *
                -              *         . 3
         30.00 +                       *.4
                -                    .5 3..
                -                    .2.6..
                -                  ..530...
                -                  . .2.....
                -                  .524.....
A        60.00 +                ...83......
                -                ...24......
                -               ....30...*.*
                -               ...526......
                -              ....83......1
                -              ....52.......
X        90.00 +             .....83.......1
                -             .....52.......
                -            ......83.......1
                -            ......526.......
                -            .......83.......1
                -            .......52........
I       120.00 +            ........83.......1
                -            ........52........
                -            .........937.....1.
                -            ...........2........
                -            ..........9537....*.*
                -             ...........2837.....
S       150.00 +             ...........9528...1.
                -             .............9537...1
                -              ..............263*7*
                -              ..............904283
                -               ...............90.2
                -               ..................9
         180.00 +                ..................9
                -                 .................
                -                 ...............**
                -                  ................
                -                   ...............
                -                    ..............
F       210.00 +                      .............
                -              *        ..W*........
                -                         .......*.*
                -                          .........
                -                            .......
                -                               ....
T       240.00 +              *          W*      **
```

SHEAR STRENGTH PARAMETERS

COMPUTATION SHEET

RMT INC

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
HSF	[illegible]	11/94	BJK	12/94	2169.30

Shear Strength Parameters

FINE-GRAINED FOUNDRY WASTE

- Short-Term
  - SPT 'N' values ≅ 4 B-9 (pg 6/11)
  - use Table 3-3 ... Bowles (pg 9/11)

    q_u = 1,000 psf $c = q_u/2$ = 1,000 psf/2 = 500 psf

- Long-Term
  - use empirical relationship between Plasticity Index (PI) and effective friction angle Fig. 11.27 ... Holtz

PI

B-15 Depth 30-32 PI = 22 Table 2-1 Groundwater Quality Assessment Plan (pg 4/11)

B-18 Depth 35-42 PI = 27

$$PI_{ave} = \frac{22 + 27}{2} = 24.5 \cong \text{use } 25$$

Effective Friction Angle ϕ' = 30 degrees (pg 10/11)

Holtz Fig. 11-27

FOUNDRY SAND

- Short-Term and Long-Term (Same for granular soils)
  - SPT 'N' values ≅ 12 use Table 3-2 Bowles

    Friction Angle = 33 degrees (pg 9/11)

COMPUTATION SHEET

RMT INC

744 Heartland Trail P.O. Box 8923 Madison WI 53708-8923 (608) 831-4444 FAX (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
ASF	JJH	11/94	RJT	12/94	2169.30

FINAL COVER

The final cover is 5 feet thick and consists of both fine-grained and course grained material. Simplify by making final cover course grained. A friction angle of 30 degrees is reasonable. The effect of the final cover shear strength is minor on the overall stability of the slope.

Spoils / Natural Clay

- Short-Term

SPT 'N' Value ≅ 34 MW-4A (pg 5/11)

use Table 3-3 ... Bowles (pg 9/11)

q_u = 4000 psf (N = 16 conservative value)

$c = q_u/2$ = 4,000 psf / 2 = 2,000 psf

- long-term

- use empirical relationship between Plasticity Index (PI) and effective friction angle Figure 11.27 ... Holtz

PI

MW-2 Depth 9-11 PI = 9

MW-3 Depth 23-25 PI = 11

MW-12 Depth 15-22 PI = 13

MW-13 Depth 19-24 PI = 10

PI_{Ave} = 11 (pg 4/11)

COMPUTATION SHEET

RMT INC

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX. (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
ACF	JH	11/94	KJK	12/94	2169.30

Spoils (continued)

PI = 11 ϕ' = 33 degrees (p. 10/11)

BEDROCK (Shale)

The bedrock is a dense material that the critical failure surface will not go through, therefore, a friction angle of 20° and a cohesion of 2,000 psf have been used. These values have a shear strength that will prevent the failure surface from extending into the bedrock.

TAE 1

SUMMARY OF SOIL TEST DATA*

Sample Location	Depth (feet)	USCS Group	Geologic Material	Grain-size Distribution *	LL	PI	Vertical Hydraulic Conductivity
MW-1	3 to 5	ML	Weathered rock	1-17-58-24	33	7	—
MW-2	9 to 11	SC	Spoils	16-35-32-17	29	9	7.4×10^{-8} cm/sec
MW-3	23 to 25	CL	Spoils	4-10-52-34	34	11	--
MW-12	15 to 22	CL	Spoils	6-24-41-29	32	13	--
MW-13	19 to 24	GC	Spoils	37-30-17-15	29	10	--
B-15	30 to 32	CL	Foundry waste	53-47	46	22	--
B-18	10 to 22	SM	Foundry sand	1-72-26-1	--	--	--
B-18	35 to 42	CH	Foundry waste	47-53	54	27	--

MW-1, MW-2, MW-3 analysis by Bowser-Morner, 1985. All other analyses by RMT Soils Laboratory, 1992.

* 1-17-58-24: Percentages of gravel, sand, silt, and clay, respectively. 53-47: Percentages of gravel plus sand & silt plus clay.

LL = Liquid limit.
PI = Plasticity index.

Groundwater Quality Assessment Plan

LOG OF TEST BORING

F-203 (R 01-87)

BORING NO. MW-4A
SHEET NO. 1 OF 1
PROJECT NAME ASF-Chromite Sand Borings
PROJECT NO. 2169.02
LOCATION Sebring Landfill
INSTALLATION 08/08/91
CONTRACTOR R&R International
SURFACE ELEV. 1083.0
DRILLING METHOD HSA 4 1/4
BOREHOLE DIA. 6.5 IN.

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
1	SS	17	18	D		POORLY GRADED SAND (SP), top 8", loose, (Foundry Sand).
						LEAN CLAY WITH GRAVEL (CL), gray 10YR 5/1, slightly plastic, (Spoils).
2	SS	34	12		5	POORLY GRADED SAND (SP), black, fine, hard, (Foundry Sand).
					▽	
3	SS	4	24		10	
					1072	LEAN CLAY WITH SAND (CL), (Foundry Waste).
					1068 15	
						Boring Ends at 15.0 Ft. in Foundry Waste.
					20	
					25	
					30	
					35	

GENERAL NOTES

DATE STARTED AUG 8 91
DATE COMPLETED AUG 8 91
RIG CME 75
CREW CHIEF E. Pucci
LOGGED R. Welch CHECKED

WATER LEVEL OBSERVATIONS

WHILE DRILLING ▽ 7.0 Ft.
AT COMPLETION ▼
AFTER DRILLING
CAVE-IN: DATE/TIME DEPTH
WATER: DATE/TIME DEPTH

6/11

LOG OF TEST BORING

F-203 (R 01-87)

BORING NO. B-9
SHEET NO. 1 OF 1
PROJECT NO. 2169.02
INSTALLATION 05/23/91
SURFACE ELEV. 1089.6
BOREHOLE DIA. 6.5 IN.

PROJECT NAME ASF-Chromite Sand Borings
LOCATION Sebring Landfill
CONTRACTOR R&R International
DRILLING METHOD HSA 4 1/4

SAMPLING NOTES						VISUAL CLASSIFICATION AND GENERAL OBSERVATIONS
INTERVAL		RECOVERY		MOISTURE		
NO.	TYPE	N	IN		DEPTH	
1	SS	13	12	M		POORLY GRADED SAND WITH SILT (SP-SM), fine, dark gray, with brick, scrap metal, iron rod, (Foundry Sand).
					5	Same as surface except very fine to fine sand, trace yellow sand.
2	SS	11	6	W	▽ 10	Light gray sand as above with coarse sand and fine gravel (broken concrete or cast), loose, saturated (water ran out of sampler).
3	SS	4	4	W	15	LEAN CLAY (CL), brown, soft, (sludge).
4	SS	6	12	W	20	LEAN CLAY (CL), very dark gray, interbedded with SILTY SAND (SM), soft, ome coarse grained, (Foundry Waste).
						End of Boring at 20.0 Ft. in fine-grained Foundry Waste.
					25	
					30	
					35	

GENERAL NOTES

DATE STARTED MAY 23 91
DATE COMPLETED MAY 23 91
RIG CME 75
CREW CHIEF T. Bromley
LOGGED B. Socha CHECKED

WATER LEVEL OBSERVATIONS

WHILE DRILLING ▽ 8.0 Ft.
AT COMPLETION ▼
AFTER DRILLING
CAVE-IN: DATE/TIME DEPTH
WATER: DATE/TIME DEPTH

NAVFAC
DM-7

TABLE 6
Typical Values of Soil Index Properties

	Particle Size and Gradation				Voids(1)					Unit Weight(2) (lb./cu.ft.)						
	Approximate Size Range (mm)		Approx. D_{10} (mm)	Approx. Range Uniform Coefficient C_u	Void Ratio			Porosity (%)		Dry Weight			Wet Weight		Submerged Weight	
	D_{max}	D_{min}			e_{max} loose	e_{cr}	e_{min} dense	n_{max} loose	n_{min} dense	Min loose	100% Mod. AASHO	Max dense	Min loose	Max dense	Min loose	Max dense
GRANULAR MATERIALS																
Uniform Materials																
a. Equal spheres (theoretical values)	–	–	–	1.0	0.92	–	0.35	47.6	26	–	–	–	–	–	–	–
b. Standard Ottawa SAND	0.84	0.59	0.67	1.1	0.80	0.75	0.50	44	33	92	–	110	93	131	57	69
c. Clean, uniform SAND (fine or medium)	–	–	–	1.2 to 2.0	1.0	0.80	0.40	50	29	83	115	118	84	136	52	73
d. Uniform, inorganic SILT	0.05	0.005	0.012	1.2 to 2.0	1.1	–	0.40	52	29	80	–	118	81	136	51	73
Well-graded Materials																
a. Silty SAND	2.0	0.005	0.02	5 to 10	0.90	–	0.30	47	23	87	122	127	88	142	54	79
b. Clean, fine to coarse SAND	2.0	0.05	0.09	4 to 6	0.95	0.70	0.20	49	17	85	132	138	86	148	53	86
c. Micaceous SAND	–	–	–	–	1.2	–	0.40	55	29	76	–	120	77	138	48	76
d. Silty SAND & GRAVEL	100	0.005	0.02	15 to 300	0.85	–	0.14	46	12	89	–	146(3)	90	155(3)	56	92
MIXED SOILS																
Sandy or Silty CLAY	2.0	0.001	0.003	10 to 30	1.8	–	0.25	64	20	60	130	135	100	147	38	85
Skip-graded Silty CLAY with stones or rk fgmts	250	0.001	–	–	1.0	–	0.20	50	17	84	–	140	115	151	53	89
Well-graded GRAVEL, SAND, SILT & CLAY mixture	250	0.001	0.002	25 to 1000	0.70	–	0.13	41	11	100	140	148(4)	125	156(4)	62	94
CLAY SOILS																
CLAY (30%-50% clay sizes)	0.05	0.5μ	0.001	–	2.4	–	0.50	71	33	50	105	112	94	133	31	71
Colloidal CLAY (-0.002 mm: 50%)	0.01	10Å	–	–	12	–	0.60	92	37	13	90	106	71	128	8	66
ORGANIC SOILS																
Organic SILT	–	–	–	–	3.0	–	0.55	75	35	40	–	110	87	131	25	69
Organic CLAY (30% - 50% clay sizes)	–	–	–	–	4.4	–	0.70	81	41	30		100	81	125	18	62

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FOUNDATION ANALYSIS AND DESIGN

Third Edition

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McGraw-Hill Book Company

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ble 3-2 Empirical values for ϕ, D_r, and unit weight of granular soils based on the ndard penetration number with corrections for depth and for fine saturated sands.

Description	Very loose	Loose	Medium	Dense	Very dense
Relative density D_r*	0	0.15	0.35	0.65	0.85	1.00
Standard penetration no. N		5–10	8–15	10–40	20–70	> 35
Approx. angle of internal friction ϕ°†	25–30°	27–32°	30–35°	35–40°	38–43°	
Approx. range of moist unit weight γ, pcf (kN/m³)	70–100‡ (11–16)	90–115 (14–18)	110–130 (17–20)	110–140 (17–22)	130–150 (20–23)

N=12
φ=33°

* Depends on p_o ranging from 70 to 500 kPa. Low value of N corresponds to lesser p_o.

† After Meyerhof (1956). $\phi = 25 + 25D_r$ with more than 5 percent fines and $\phi = 30 + 25D_r$ with less than 5 cent fines. Use larger values for granular material with 5 percent or less fine sand and silt. See also Eq. (4-10) for imate of ϕ.

‡ It should be noted that excavated material or material dumped from a truck will weigh 70 to 90 pcf. aterial must be quite dense and hard to weigh much over 130 pcf. Values of 105 to 115 pcf for nonsaturated soils e common.

than 15 as

$$N' = 15 + \tfrac{1}{2}(N - 15) \tag{3-5}$$

Bazaraa (1967) also made a recommendation for correcting N in these soils as

$$N' = 0.6N \tag{3-5a}$$

where $N > 15$. The rationale for these corrections was that the soil must be dense if the blow count is greater than 15; therefore, the volume displacement at a high penetration rate of the SPT would produce high pore pressures which would further increase the blow count. It appears that not many persons use any correction for the blow count in these soils at present.

The penetration test in gravel or gravelly soils requires careful interpretation, since pushing a piece of gravel can greatly change the blow count. Generally if one uses a statistical average of the blow count in the stratum from the several borings, either excessively high or very low (pushing a gravel or creating a void space) values will be averaged out so that approximately the correct blow count can be estimated for design.

The SPT was originally developed for cohesionless soils so that samples would not have to be taken. The test has evolved to the current practice of routinely determining N for all soils supplemented with on-site determinations of q_u for cohesive strata. The test is usually performed every 2.5 ft or 1 m of depth starting at about 2.5 ft or 1 m below the ground surface. The boring is extended ... base width of the foundation below the

Table 3-3 Empirical values for q_u* and consistency of cohesive soils based on penetration number.

Consistency	Very soft	Soft	Medium	Stiff	Very stiff
q_u, ksf (kPa)	0	0.5 (25)	1.0 (50)	2.0 (100)	4.0 (200)
N, standard penetration resistance	0	2	4	8	16
γ_{sat}, pcf (kN/m³)		100–120 (16–19)	110–130 (17–20)		120–14 (19–22

use

* These values should be used as a guide only. Local cohesive samples should be tested, a between N and the unconfined compressive strength q_u established as $q_u = KN$.

estimated foundation base. Sometimes the borings are extended to bed ever, at greater depths the SPT may be done at 5-ft or 2-m increment "estimated" is used extensively here since these data are not precisely the time of the exploration.

Empirical correlations, such as Table 3-2, between N and various s ties have been made for cohesionless soils. The low values for N roughly to p_o of 75 kPa, the higher to about 500 kPa. Tables such a should always be used with caution.

Table 3-3 is an empirical correlation between N and unconfined c strength. These should be used even more cautiously than for cohesi It is preferable to measure q_u directly on samples than use a table s Alternatively, a table might be developed locally which has some measuring q_u and N and solving

$$q_u = KN$$

for the constant of proportionality K. The reason for poor correl versus N tables is that inadvertent changes in water content, excess sures during sampling, and other factors may give very low blow cou 10, on soils where the measured q_u may be on the order of 300 to 60 in Table 3-3 the value of K is approximately 0.25.

There are varied opinions on how to use N when it is obtained stratum of finite thickness the values may range by a factor of 2 or recommendations were to use the smallest value in the stratum—w tainly conservative. Current thinking is to use a statistical average fo several adjacent borings) and only for the zone of interest. That is, use the entire stratum, use that zone just above to about two times width below the footing. Of course, one should not ignore low blow layer which may cause settlement problems.

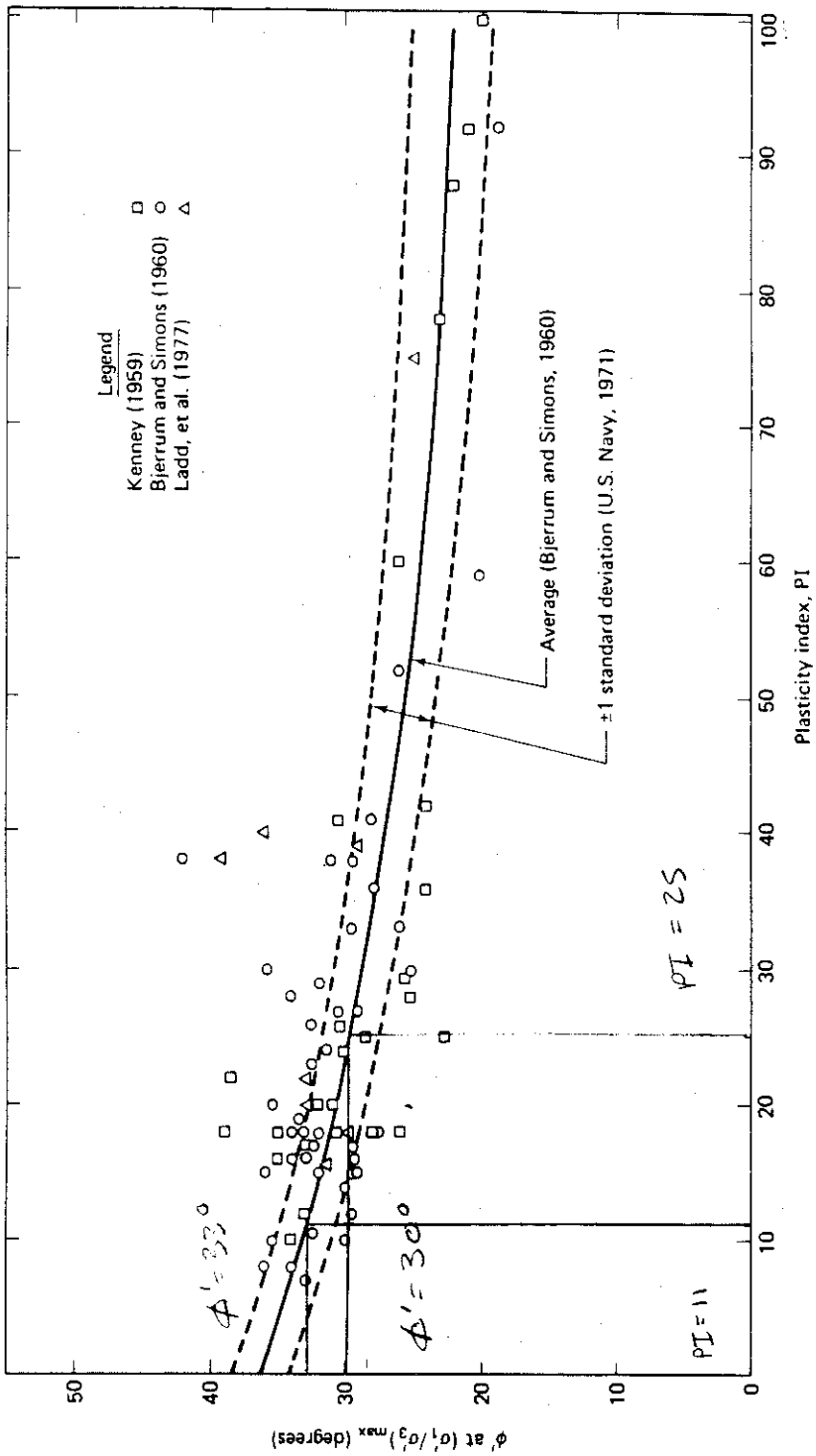

Fig. 11.27 Empirical correlation between ϕ' and PI from triaxial compression tests on normally consolidated undisturbed clays (after U.S. Navy, 1971, and Ladd, et al., 1977).

10/11

on work by Kenney (1959), Bjerru
and Ladd, et al. (1977). Since tl
"average line," you should use th
However Fig. 11.27 is useful for
laboratory results.

11.9.3 Use of CD Strength in Enc

Where do we use the strengths d
tioned previously, the limiting dra
test refer to real field situations. CI
long-term steady seepage case for
stability of excavations or slopes i
CD analysis are shown in Fig. 11.
these analyses for stability can be
embankment dam engineering.

You should be aware that,
actually conduct a CD test on a cl
pore pressure is really induced in t
with very low permeabilities, the r
time required to fail the specimen
(Bishop and Henkel, 1962). Such a l
the laboratory such as leakage of
surrounds the sample. Consequent
induced pore pressures in a consoli
calculate the effective stresses in the
for obtaining the effective stress st
axial tests are not very popular in n

11.9.4 Consolidated-Undrained (CU

As the name implies, the test spe
valves open, obviously) under the de
these can either be hydrostatic or r
After consolidation is complete, the
specimen is loaded to failure in un
pressures developed during shear a
effective stresses may be calculated
test can either be a total *or* an effec
called the *R-test*.

Total, neutral, and effective str
the several phases of the CU test are

RING AND ENGINEERING

ors

An Introduction to Geotechnical Engineering

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FIGURES

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RMT INC

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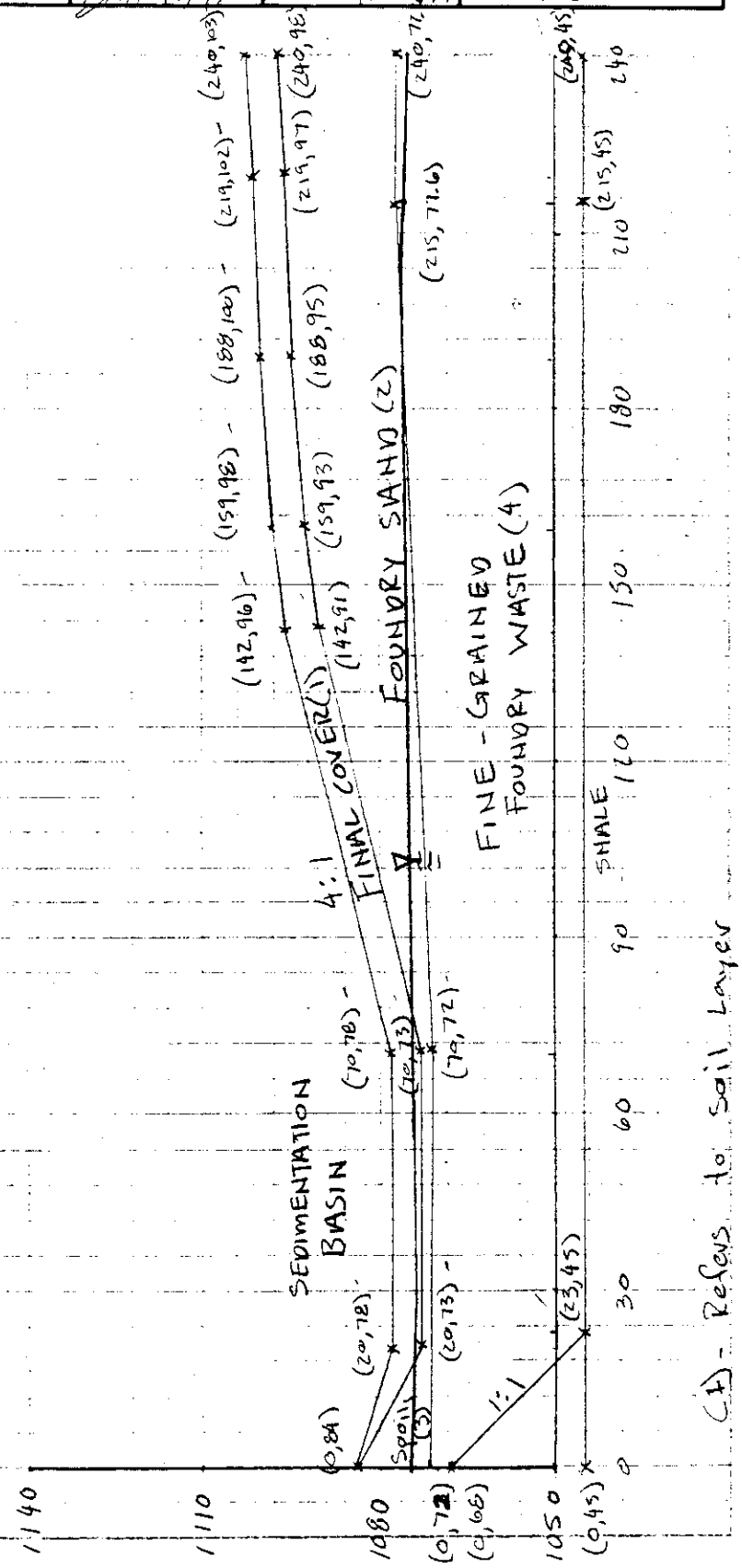
Slope Stability Analysis

Profile - SW Corner LANDFILL



(1) - Refers to Soil Layer

FIGURE 1

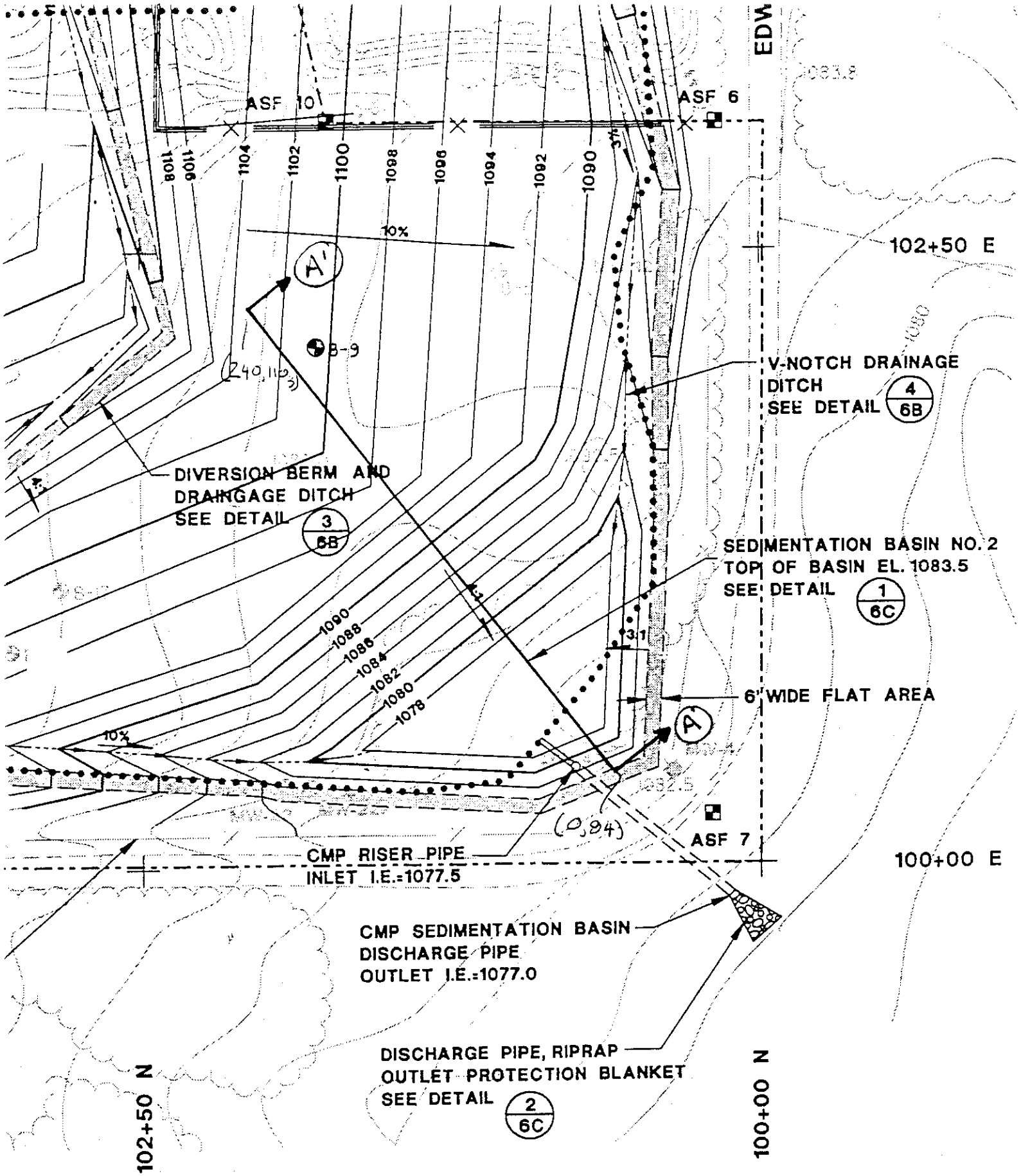


FIGURE 2 1"=50'

Slope Stability Cross Section

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U. S. GEOLOGICAL SURVEY

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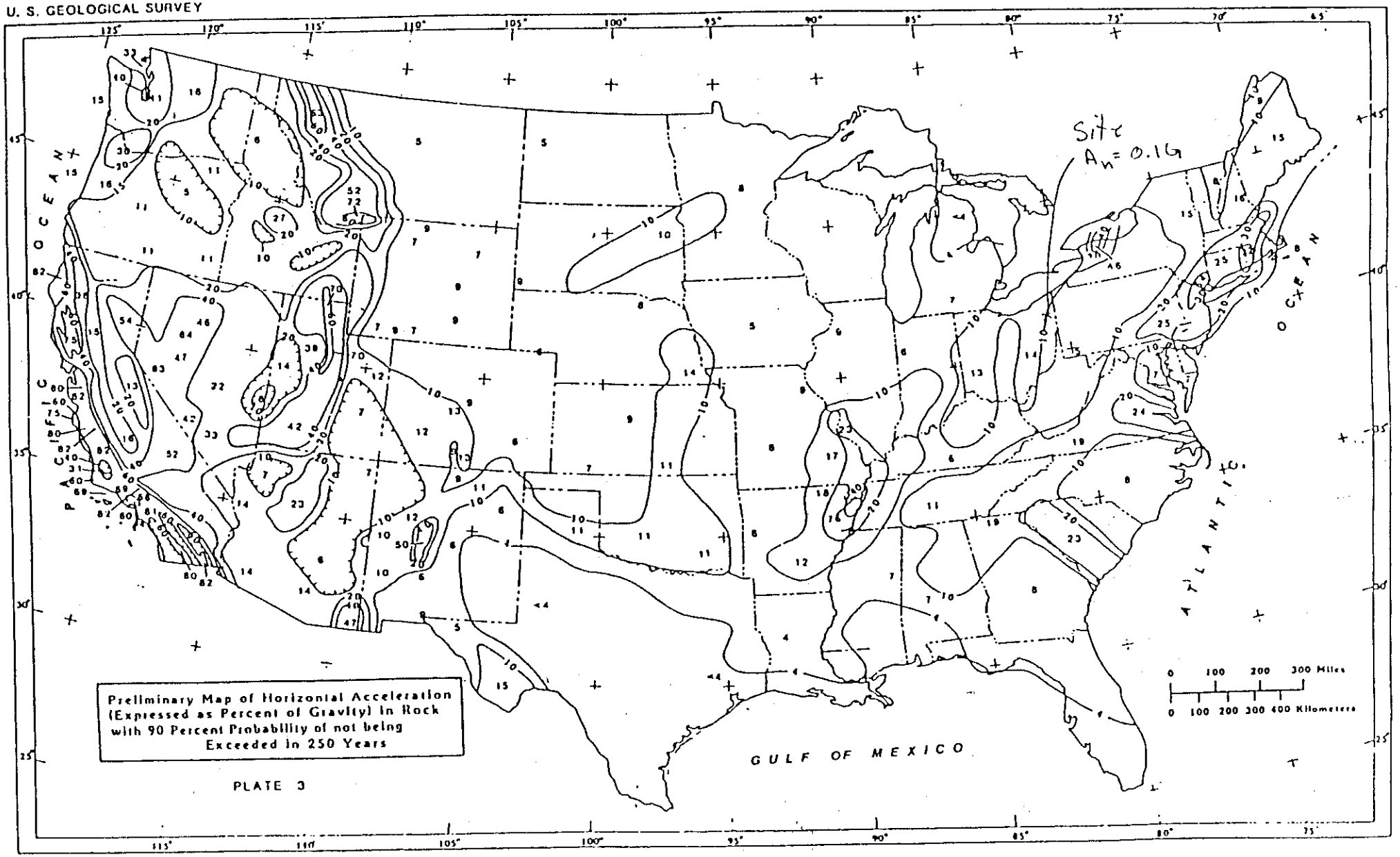

Preliminary Map of Horizontal Acceleration (Expressed as Percent of Gravity) in Rock with 90 Percent Probability of not being Exceeded in 250 Years

PLATE 3

Figure 3

SETTLEMENT ANALYSIS

SETTLEMENT ANALYSIS

Table of Contents

- Purpose/Approach/Methodologies/Assumptions/Results and Recommendations/References
- Settlement Calculations
- Consolidation Parameters
- Figures

SETTLEMENT ANALYSIS

Purpose:

The purpose of the settlement analysis is to estimate the amount of settlement that may occur due to additional filling of new waste and the construction of the final cover, and to determine the potential effects of settlement on the final cover system.

Approach:

The settlement analysis was performed using the following approach:

STEP 1 Identify settlement profile locations.

The profiles used in the analysis are representative of the geologic cross sections and boring logs from the Groundwater Assessment Plan by RMT shown in Appendix J. No borings were drilled through the former pond area; therefore, the subsurface profile in the CENTER AREA is an approximation based on the geologic cross sections. The following settlement profiles were used in the analysis:

- CENTER AREA - STATION 105+80N, 102+50E - Generalized profile from the former pond area. The profile on the cross section shows that the first 17 feet are composed of foundry sand. However, in the former pond area, it is likely that the material is fine-grained foundry waste.
- SOUTH AREA - Boring B-9- Southern area where the subsurface profile consists of foundry and overlying fine-grained foundry waste.
- NORTH AREA - Boring B-15 - Northern area where the subsurface profile consists of foundry sand overlying fine-grained foundry waste overlying spoils overlying shale.
- WEST AREA - Boring B-16 - West area where the subsurface profile consists of foundry sand overlying spoils overlying shale.

STEP 2 Determine consolidation parameters.

No consolidation tests were performed on the materials; therefore, the consolidation parameters were determined from empirical relationships based on Atterberg limits, and on consolidation parameters from a similar foundry site in Ohio. The empirical relationships are based on extensive testing of soil. The waste is assumed to have similar characteristics to soil. The fill will be monitored for settlement during

construction, and the settlement results will be compared to the predicted settlement. Testing of existing waste will be performed if the actual results vary significantly from predicted results. The basis for the values is presented in the section entitled "Consolidation Parameters."

Foundry sand and shale are considered not to be affected by the placement of the final cover and fill. Foundry sand is a coarse-grained material that will not be affected by the loads. The interparticle forces between the coarse grains will be able to support the anticipated loads. Immediate settlement of the foundry sand will occur during the placement of the fill and final cover, and thus will not affect the long-term performance of the final cover.

STEP 3 Calculate settlement.

Calculate the settlement for the various profiles under the different loads shown on the calculation sheets. The time for primary consolidation is assumed to be at 90 percent of the anticipated primary settlement, which corresponds to a time coefficient of 0.848.

Methodologies:

Waste settlement in the landfill is due to primary and secondary compression of the waste materials. The one-dimensional consolidation equations used for this analysis are as follows:

Primary Consolidation:

$$\Delta H_p = H C_{C\epsilon} \log [(\theta' + \Delta \sigma') / \sigma_0']$$

where:

ΔH_p = settlement from primary compression,

H = thickness of waste layer,

$C_{C\epsilon}$ = primary compression index (strain basis),

θ' = initial effective stress at the midpoint of the waste layer, and

$\Delta \sigma'$ = increase in vertical effective stress.

Secondary Consolidation:

$\Delta H_s = H C_{S\epsilon} \log [t_2 / t_1]$

where:

ΔH_s = settlement from secondary compression,

H = thickness of waste layer,

$C_{S\epsilon}$ = secondary compression index (strain basis),

t_2 = time elapsed since the end of primary compression, and

t_1 = time to complete primary compression.

Time Rate: $t = \frac{T (H)^2}{cv}$

Refer to the attached reference page following the primary consolidation calculations for a more detailed description of the formulas.

Assumptions:

One-dimensional primary consolidation - One-dimensional primary consolidation calculations are the standard of practice for settlement estimate calculations.

Secondary consolidation - Secondary consolidation was assumed to occur after the installation of the final cover system (i.e., after final loading). This assumption is considered conservative for evaluating the potential differential settlement effects on the final cover system. The time for secondary consolidation to occur was assumed to be 30 years, (i.e., long-term care period).

Incompressible materials - The *in situ* material underlying the existing waste layer is shale. Due to the incompressible nature of shale (rock), the foundation is assumed to contribute no settlement due to the additional overburden materials (i.e., waste and/or final cover materials).

Profile - The cross sections selected to be analyzed are representative worst-case profiles with regard to settlement potential (Figures 1 and 2 show geologic cross sections, water levels, and Final Cover and fill profiles; and Figure 3 shows the Final Cover detail).

Waste Parameters - The waste is assumed to have similar characteristics as soil. The determination of the parameter is shown in the "Consolidation Parameters" section.

Settlement Parameters - The characteristics for the fine-grained foundry waste and spoils are as follows:

Fine-Grained Foundry Waste:

- Coefficient of consolidation C_v = 1.0 ft^2/day, the value for horizontal and vertical would be the same.
- Strain based compression index $C_{C\epsilon}$ = 0.15 calculated from the compression curve.
- Strain based secondary compression index $C_{S\epsilon}$ = 0.0075.
- Total unit weight = 90 pcf.

Spoils (clay material):

- Coefficient of consolidation C_v = 0.08 ft^2/day.
- Strain based compression index $C_{C\epsilon}$ = 0.118 calculated from the compression curve.
- Strain based secondary compression index $C_{S\epsilon}$ = 0.005.
- Total unit weight = 125 pcf.

Soil Parameters - The characteristics of the soil materials used in the final cover system were estimated based on typical values for sand and clay materials published in the literature (see Bowles reference). The primary soil characteristic for this analysis is the total unit weight, which was assumed to be 115 pcf. Figure 3 shows a cross section of the assumed final cover system considered.

Fill Parameters - The fill material used to reach the proposed subbase grades is foundry sand, which has an estimated moist unit weight of 105 pcf and is considered to be relatively incompressible.

Loadings - The overburden loads are separated into two different cases as follows:

- Final Cover and fill placed at the same time or single-phase construction.
- Final Cover placed after fill has been in place long enough for primary consolidation to be completed, or phased cover construction. Fill will be placed as it is generated at the foundry. The estimated area of filling is shown on Figure 4.

Water Level - The water level used in the settlement analysis is obtained from the geologic cross sections (see Figures 1 and 2), with the exception of the CENTER AREA profile. The former pond area has an assumed saturated condition for the fine-grained foundry waste.

Results and Recommendations:

Based on the settlement analysis, the magnitude of the settlement due to the loading would be as shown in Table K-1. The settlement in the south, north, and west areas would not result in ponding of surface water or excessive strain on the recompacted barrier layer. This is due to the following:

- Settlement due to the fill and final cover is lessened due to the preconsolidation of the compressible material from the foundry sand overburden.
- The increase in pressure caused by the fill and Final Cover is relatively small compared to the existing pressure.

However, the settlement in the center of the landfill (i.e., the location of the former pond area) may cause ponding of surface water and may possibly strain the recompacted barrier layer. This is due to the following:

- No foundry sand exists over the former pond area; therefore, the fine-grained foundry waste has not been preconsolidated.
- The former pond area will have a significant amount of fill and Final Cover placed over the surface, which will result in a higher pressure.
- The time for primary consolidation in the center area was estimated to be 1.1 years based on the assumption for the coefficient of consolidation and the thickness of the fine-grained foundry waste. Prefilling the fill and allowing primary

consolidation to occur prior to final cover construction will reduce the magnitude of final cover settlement. Figure 5 shows the settlement versus time curves for both conditions. The effects from settlement would then be minor.

- The filling over the center area shall be performed using staged construction techniques. Instrumentation to measure settlement (settlement plates) and pore water pressure (piezometers) will be spaced on 100-foot spacings to control construction of the fill and surcharge. Information gathered from reading the instrumentation shall be used to rerun the settlement analysis to determine when the surcharge can be removed and the Final Cover constructed. Sampling of the fine-grained foundry waste will be performed if the settlement results significantly deviate from the predicted results.

The maximum strain calculated for the barrier layer due to differential settlement was 0.2 percent. The barrier layer will be able to maintain its characteristics under this level of strain.

References:

Bowles, J. Foundation analysis and design. New York, New York: McGraw-Hill Book Company.

Das, B.M. Principles of geotechnical engineering and principles of foundation engineering.

Holtz , R.J. and Kovacs. Introduction to geotechnical engineering. Englewood Cliffs, New Jersey: Prentice-Hall.

Koerner, R.M. Designing with geosynthetics. Second Edition. Englewood Cliffs, New Jersey: Prentice-Hall.

U.S. Navy. Design manual 7.01. Naval Facilities Engineering Command. Alexandria, Virginia.

TABLE K-1

RESULTS OF THE SETTLEMENT ANALYSIS

Load	Area	Compressible Material Thickness[1] (ft)	S_C (ft)	T_{90} (ft)	S_S (ft)	S_T (ft)
Final Cover and fill[2]	Center	44.0	5.02	1.1 yrs	0.47	5.49
Final Cover[3]	Center	44.0	0.63	1.1 yrs	0.47	1.10
Final Cover and fill[2]	South	32.5	0.99	0.6 yrs	0.41	1.40
Final Cover and fill[2]	North	30.0	0.66	0.5 yrs	0.24	0.90
Final Cover[1,4]	West	8.0	0	--	0	0

NOTES:

S_C Primary consolidation
T_{90} Time for 90 percent of primary consolidation to occur after load placement
S_S Secondary settlement (based on 30 years after closure)
S_T Total settlement after final cover placement

1 Includes both fine-grained foundry waste and spoils.
2 Single-phase construction.
3 Phased cover placement.
4 The existing foundry sand on top of the spoils has resulted in surcharging of this area resulting in no settlement.

SETTLEMENT CALCULATIONS

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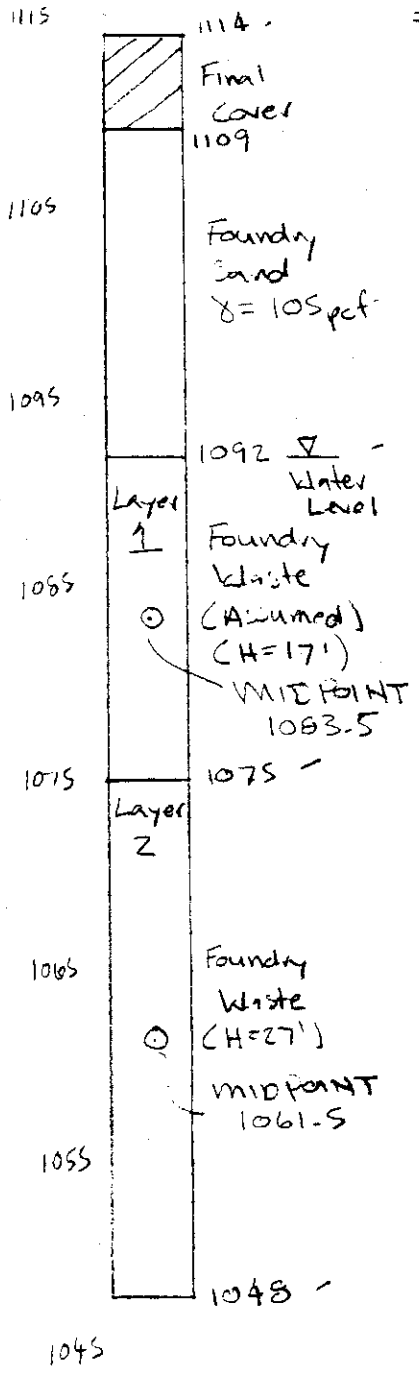
CENTER AREA - 10S+50N 102+50E
(Former Pond Area)



CASE 1 - Loading Final Cover + Foundry Sand

$$\Delta p = 5'(115\ pcf) + (1109' - 1092')\ 105\ pcf$$
$$= 2360\ psf$$

Primary Consolidation

$$P_{o_1}^{*} = (1092' - 1053.5')(90\ pcf - 62.4\ pcf)$$
$$= 234.6\ psf$$

$$S_{c_1} = 0.15(17')\log\frac{2360\ psf + 234.6\ psf}{234.6\ psf}$$
$$= 2.67'$$

$$P_{o_2} = [(1092' - 1075') + (1075' - 1061.5')] \times (90\ pcf - 62.4\ pcf)$$
$$= 841.8\ psf$$

$$S_{c_2} = 0.15(27')\log\frac{2360\ psf + 841.8\ psf}{841.8\ psf}$$
$$= 2.35'$$

$$S_{c_{1+2}} = 2.67' + 2.35' = 5.02'$$

Time Primary Consolidation (90%)

$$t = \frac{0.848[(17' + 27')/2]^2}{1.0\ ft^2/day} = 410\ days$$
$$1.12\ years$$

* subscript refers to layer #

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CENTER AREA (Continued)

Secondary Settlement

$$S_s = 0.0075(17' + 27') \log \frac{(30\text{ yr} - 1.12\text{ years})}{1.12\text{ years}}$$
$$= 0.47'$$

$$S_{Total} = S_c + S_s = 5.02' + 0.47' = 5.49$$

CASE 2 – Loading Final Cover

$$\Delta P = 5'(115\text{ pcf}) = 575\text{ psf}$$

Primary Consolidation

$$P_{o_1} = (1109' - 1092')105\text{pcf} + (1092' - 1083.5')(90\text{pcf} - 62.4\text{pcf})$$
$$= 2019.6\text{ psf}$$

$$S_{c_1} = 0.15(17') \log \frac{575\text{ psf} + 2019.6\text{ psf}}{2019.6\text{ psf}}$$
$$= 0.28'$$

$$P_{o_2} = (1109' - 1092')105\text{ pcf} + [(1092' - 1075') + (1075' - 1061.5')] \times (90\text{ pcf} - 62.4\text{ pcf})$$
$$= 2626.8\text{ psf}$$

$$S_{c_2} = 0.15(27') \log \frac{575\text{ psf} + 2626.8\text{ psf}}{2626.8\text{ psf}}$$
$$= 0.35'$$

$$S_{c_{1+2}} = 0.28' + 0.35' = 0.63'$$

$$S_T = S_{c_{1+2}} + S_s = 0.63' + 0.47' = 1.1'$$

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CASE 2 Loading Fill Only (Preloading)

$\Delta P = (1109' - 1092')(105\ pcf) = 1785\ psf$

Primary Consolidation [P_{o_1} and P_{o_2} same as case 1]

$P_{o_1} = 234.6\ psf$ (pg 1/10)

$S_{c_1} = 0.15\,(17')\log \dfrac{1785\,psf + 234.6\,psf}{234.6\,psf}$

$= 2.38'$

$P_{o_2} = 841.8\ psf$ (pg 1/10)

$S_{c_2} = 0.15\,(27')\log \dfrac{1785\,psf + 841.8\,psf}{841.8\,psf}$

$= 2.00'$

$S_T = 2.38' + 2.00' = 4.38'$

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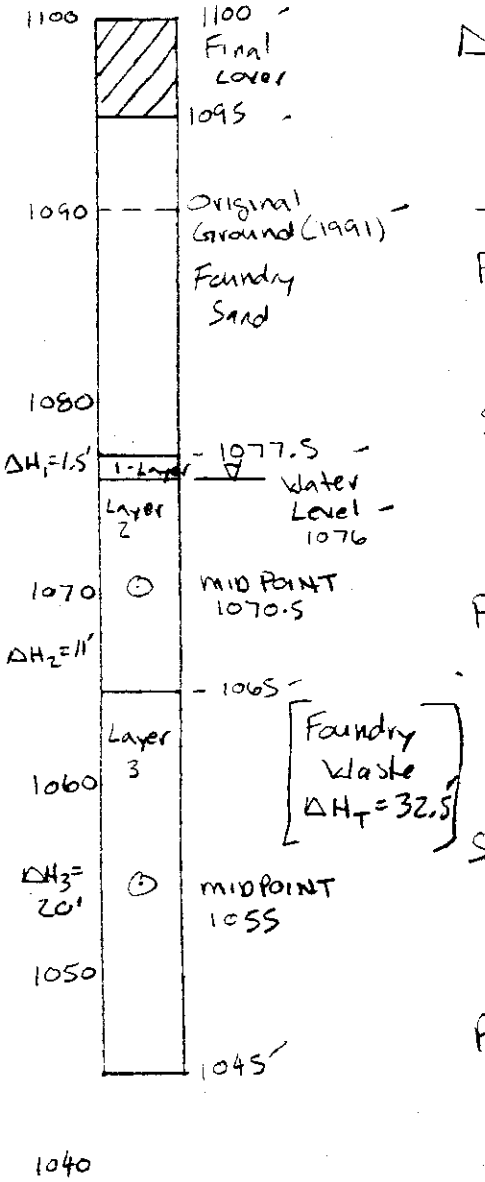
ASF	[illegible]	11/94	BJK	12/94	2169.30

SOUTH AREA - B-9

CASE 1 - Loading Final Cover + Foundry Sand



$\Delta P = 5'(115\ pcf) + (1095' - 1090')\ 105\ pcf$

$= 1100\ psf$

Primary Consolidation

$P_{o_1} = (1090' - 1077.5')\ 105\ pcf + (1077.5' - 1076')(90\ pcf)(0.5) = 1350\ psf$

$S_{c_1} = 0.15\ (1.5')\ \log \dfrac{1100\ psf + 1350\ psf}{1350\ psf}$

$= 0.06'$

$P_{o_2} = (1090' - 1077.5')\ 105\ pcf + (1077.5' - 1076')\ 90\ pcf + (1076' - 1070.5')(90\ pcf - 62.4\ pcf) = 1599\ psf$

$S_{c_2} = 0.15\ (11')\ \log \dfrac{1599\ psf + 1100\ psf}{1599\ psf}$

$= 0.37'$

$P_{o_3} = (1090 - 1077.5')\ 105\ pcf + (1077.5' - 1076')\ 90\ pcf + (1076' - 1055') \times (90\ pcf - 62.4\ pcf) = 2027\ psf$

$S_{c_3} = 0.15\ (20')\ \log \dfrac{2027\ psf + 1100\ psf}{2027\ psf}$

$= 0.56'$

$S_{c_{1+2+3}} = 0.06' + 0.37' + 0.56' = 0.99'$

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SOUTH AREA (continued)

Time for Primary Consolidation (90 percent)

$$t = \frac{0.848\,[(1.5' + 11' + 20')/2]^2}{1.0 \text{ ft}^2/\text{day}} = 224 \text{ days}$$

$$0.61 \text{ yr}$$

Secondary Settlement

$$S_S = 0.0075\,(1.5' + 11' + 20')\,\log \frac{30 \text{ yr} - 0.61}{0.61}$$

$$= 0.41$$

$$S_T = 0.99' + 0.41 = 1.4 \text{ feet}$$

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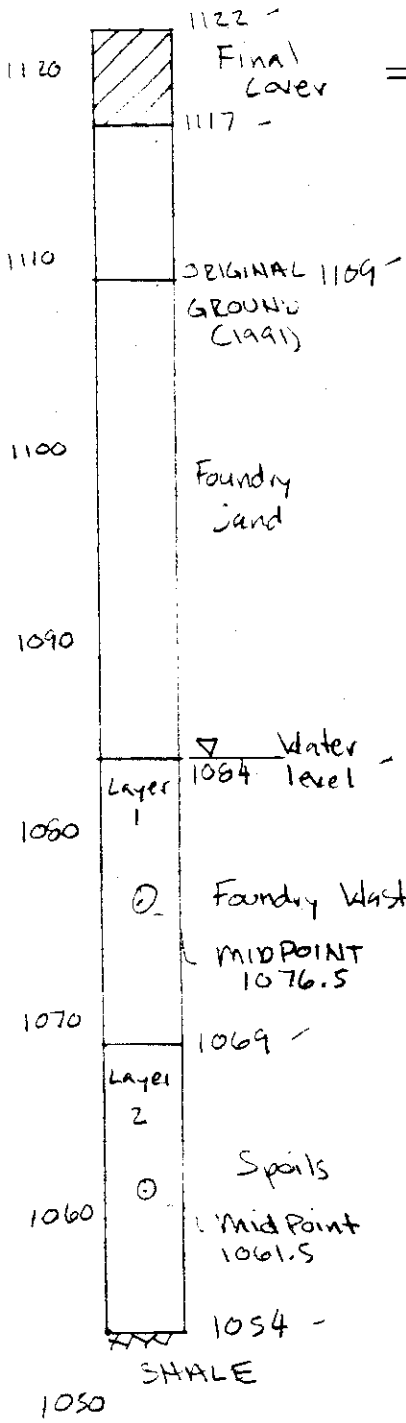
NORTH AREA - B-15



CASE 1 - Loading Final Cover + Foundry Sand

$\Delta P = 5'(115\,pcf) + (1117' - 1109')\,105\,pcf$

$= 1415\ psf$

PRIMARY CONSOLIDATION

$P_{o_1} = (1109' - 1084')(105\ pcf) + (1084' - 1076.5')(90\ pcf - 62.4\ pcf) = 2832\ psf$

$S_{c_1} = 0.15\,(15')\,\log \frac{2832\ psf + 1415\ psf}{2832\ psf}$

$= 0.40'$

$P_{o_2} = (1109' - 1084')\,105\,pcf + (1084' - 1069')(90\ pcf - 62.4\ pcf) + (1069' - 1061.5')(125\,pcf - 62.4\ pcf) = 3508.5\ psf$

$S_{c_2} = 0.118\,(15')\,\log \frac{3508.5\ psf + 1415\ psf}{3508.5\ psf}$

$= 0.26'$

Time for Primary Consolidation 90 percent

Layer 1 - Single drainage (Fine grained Foundry Waste)

$t = \frac{0.848\,(15')^2}{1.0\ ft^2/day} = 191$ days

0.52 years

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North Area (continued)

Layer 2 - Single drainage (spoils)

$$t = \frac{0.848 (15')^2}{0.05 \text{ ft}^2/\text{day}} = 2355 \text{ days}$$

$$6.5 \text{ yr}$$

Secondary Settlement

Layer 1 - Fine-grained Foundry Waste

$$S_{s_1} = 0.0075 (15') \log \frac{30 \text{ yr} - .52 \text{ yr}}{0.52 \text{ yr}}$$

$$= 0.20$$

Layer 2 - Spoils

$$S_{s_2} = 0.005 (15') \log \frac{30 \text{ yr} - 6.5 \text{ yr}}{6.5 \text{ yr}}$$

$$= 0.04'$$

$$S_T = S_{c_1} + S_{c_2} + S_{s_1} + S_{s_2}$$

$$= 0.40' + 0.26' + 0.20' + 0.04'$$

$$= 0.90'$$

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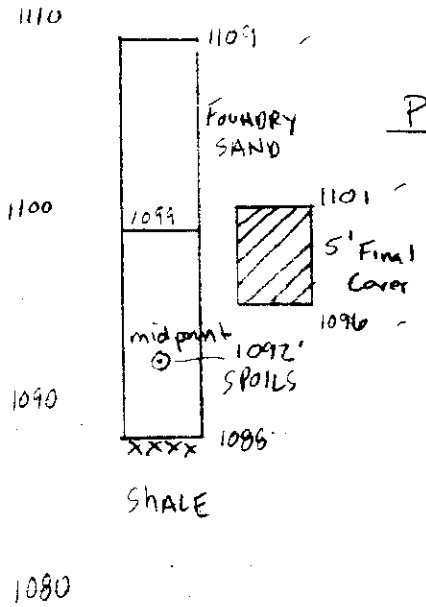
WEST AREA - B-16



CASE 1 - FINAL COVER - [FOUNDRY SAND + SPOILS]

PRIMARY

$P_{o_1} = (1109 - 1099')(105\ pcf) + (1099' - 1092')$
$\times\ 125\ pcf = 1925\ psf$

$P_{after\ cover} = (1101' - 1096')(115\ pcf) + (1096' - 1092')$
$\times\ (125\ pcf) = 1075\ psf$

$P_{o_1} > P_{after\ cover}$ ∴ $1925\ psf > 1075\ psf$

Spoils are preloaded with existing foundry sand. Therefore, no primary settlement is expected.

Secondary

The surcharging of the spoils by the foundry sand has resulted in the consolidation of the spoils. The magnitude of settlement caused by the foundry sand is more than the settlement caused by the cover. Therefore, due to the preconsolidation of the spoils, the secondary settlement would be zero.

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Differential Settlement

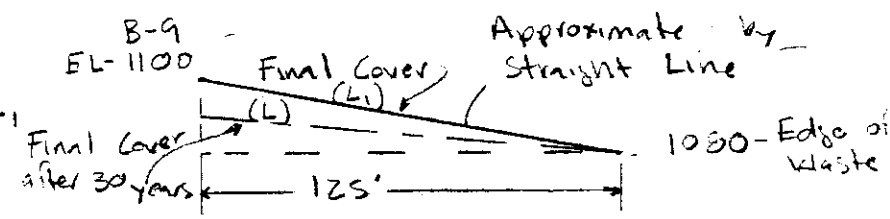
Purpose: Determine the maximum differential settlement and the resulting strain on the recompacted barrier layer

Strain = $\Delta L / L$

ΔL - Change in length of barrier layer

L - Distance between location

The maximum strain would occur at the location where the change in settlement is greatest over the shortest distance. For this analysis, that would be the South Area ($S_T = 1.4'$) to the edge of the final cover (No fill, therefore $S_T = 0$). The distance between the locations is 125 feet (See Figure 6)



$STRAIN = \Delta L / L = L_1 - L / L_1$

$L_1 = [(125'^2 + (1101' - 1080')^2]^{1/2}$
$= 126.59'$

$L = [(125'^2 + ((1100' - (1.4') - (1080' - 0')^2]^{1/2} = 126.32'$

$Strain = \frac{126.59' - 126.32'}{126.59'}$

$\boxed{Strain = 0.2\%}$

SETTLEMENT

THE ONE-DIMENSIONAL CONSOLIDATION SETTLEMENT EQUATIONS USED FOR THIS ANALYSIS ARE AS FOLLOWS:

$$S_c = \frac{C_c H_c}{1 + e_o} \log \frac{p_o + \Delta p_{av}}{p_o} \quad \text{(for normally consolidated clays)}$$

$$S_c = \frac{C_s H_c}{1 + e_o} \log \frac{p_o + \Delta p_{av}}{p_o} \quad \text{(for overconsolidated clays with } p_o + \Delta p_{av} < p_c\text{)}$$

$$S_c = \frac{C_s H_c}{1 + e_o} \log \frac{p_c}{p_o} + \frac{C_c H_c}{1 + e_o} \log \frac{p_o + \Delta p_{av}}{p_c}$$

(for overconsolidated clays with $p_o < p_c < p_o + \Delta p_{av}$)

where p_o = average effective pressure on the clay layer before the construction of the foundation
Δp_{av} = average increase of pressure on the clay layer caused by the foundation construction
p_c = preconsolidation pressure
e_o = initial void ratio of the clay layer
C_c = compression index
C_s = swelling index $\qquad C_s \simeq \frac{1}{5}$ to $\frac{1}{10} C_c$
H_c = thickness of the clay layer

Terzaghi and Peck (1967) suggest the following empirical expressions for compression index:

for undisturbed clays

$$C_c = 0.009(LL - 10)$$

for remolded clays

$$C_c = 0.007(LL - 10)$$

where LL = liquid limit, in percent

$$\Delta p = \frac{q_o \times B \times L}{(B + z)(L + z)}$$

where, q_o: OVERBURDEN PRESSURE
B: WIDTH OF FOUNDATION
L: LENGTH OF FOUNDATION
Z: DEPTH OF STRESS POINT

Note that the increase of pressure, Δp, on the clay layer is not constant with depth. The magnitude of Δp will decrease with the increase of depth measured from the bottom of the foundation. However, the average increase of pressure can be approximated by the equation

$$\Delta p_{av} = \tfrac{1}{6}(\Delta p_t + 4\,\Delta p_m + \Delta p_b) \qquad (3.74)$$

where Δp_t, Δp_m, and Δp_b are the pressure increases at the *top*, *middle*, and *bottom* of the clay layer that are caused by the foundation construction.

REFERENCES:

Principles of Geotechnical Engineering
Braja M. Das

Principles of Foundation Engineering
Braja M. Das

CONSOLIDATION PARAMETERS

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Consolidation Parameters

- Fine-grained Foundry Waste

From Table 2-1 - Groundwater Quality Assessment Plan

B-15 Depth 30-32' LL* = 46 - pg 6/26

B-18 Depth 35-42' LL = 54 -

*Liquid Limit

$$LL_{ave} = \frac{54 + 46}{2} = 50$$

$C_c^* = 0.009(LL - 10)$ - Eq 8-21 ... Holtz

* Compression Index (pg 7/26)

$C_c = 0.009(50 - 10) = 0.36$

Void Ratio

e_o range 1.8 to 0.25 - Sandy or Silty Clay

Table 6 NAVFAC DM-7 (pg 12/26)

- Since the SPT blow counts from the boring logs where low ($N \leq 4$) use a higher void ratio,

$e_o = 1.3$ -

see Groundwater Quality Assessment Plan for boring logs

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ACF	JOH	11/94	BJK	12/94	2169.30

Modified Compression Index

$$C_{c\epsilon} = \frac{C_c}{1+e_o} = \frac{0.36}{1+1.3} = 0.156$$

From other Foundry Site (pg 15-17/26)

90B-27 Depth 17-19.5' $C_{c\epsilon} = \frac{0.502}{1+1.99} = 0.168$

90B-27 Depth 9-11.5' $C_{c\epsilon} = \frac{0.445}{1+1.89} = 0.154$

90B-25 Depth 12-14.5' $C_{c\epsilon} = \frac{0.189}{1+1.25} = 0.084$

USE $C_{c\epsilon} = \underline{0.15}$

Modified Secondary Compression Index

use C_c / C_α relationship Table 9-4 - Holtz

organic silt and clays - Range of values

0.04 to 0.06 use 0.05

$$C_{\alpha\epsilon} = 0.05\,(0.15) = \underline{0.0075}$$

(pg 8/26)

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COEFFICIENT OF CONSOLIDATION (C_v)

The following table shows the results of three consolidation tests* (Dial reading vs time). The square root of time method was used to calculate C_v.

Load (tsf)	LOCATION 90B-27 D=17-19.5'	90B-27 D=9-11.5'	90B-25 D=12-14.5'
0.25	1.3 ft²/day	3.0 ft²/day	7.0 ft²/day
0.50	3.2 ft²/day	4.5 ft²/day	6.4 ft²/day
1.0	2.9 ft²/day	5.6 ft²/day	6.1 ft²/day
2.0	0.5 ft²/day	4.7 ft²/day	6.1 ft²/day
4.0	1.5 ft²/day	5.7 ft²/day	5.4 ft²/day
8.0	1.3 ft²/day	4.9 ft²/day	2.2 ft²/day

(pg 18-26/26)

$C_{v_{AVG}}$ = 4.0 ft²/day use **1.0 ft²/day**

This value seems on the high side of typical results therefore, reduce to 1.0 ft²/day (conservative)

* Tests were performed on fine-grained foundry waste at a Foundry in Northwest Ohio.

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• Spoils (clay material)

From Table 2-1 - Groundwater Quality Assessment Plan

MW-2 Depth 9-11' LL = 29

MW-3 Depth 23-25' LL = 34 (pg 6/26)

MW-12 Depth 15-22' LL = 32

MW-13 Depth 19-24' LL = 29

$LL_{AVE} = 31$

$C_c = 0.009(LL - 10)$ Eq. 8-21 ... Holtz

$= 0.009(31 - 10)$ (pg 7/26)

$= 0.189$

Chicago Silty Clay
Table 8-3 - Holtz
(pg 9/26)

Void Ratio

e_o range 1.8 to 0.25 - Sandy or Silty Clay

Table 6 NAVFAC DM-7
(pg 12/26)

• Since the SPT blow counts from the boring logs where higher ($N \geq 15$) use a lower void ratio

$e_o = 0.6$, see Groundwater Quality Assessment Plan for boring logs

Modified Compression Ratio

$$C_{c\epsilon} = \frac{C_c}{1+e_o} = \frac{0.189}{1+0.6} = \underline{\underline{0.118}}$$

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AJF	JH	11/94	BJK	12/94	2169.30

Modified Secondary Compression Index

Use C_c / C_α relationship Table 9-4 - Holtz

Lodi clay 0.03 to 0.06 use 0.045

$C_{\alpha\epsilon} = 0.045(0.118) = 0.005$ (pg 9/26)

Coefficient of Consolidation

Chicago Silty Clay (CL)

$C_v = 2.7\ m^2/yr\ (10.764\ ft^2/m^2) / 365\ days/yr$

$= 0.08\ ft^2/days$

(pg 10/26)

TAB' 1

SUMMARY OF SOIL TEST DATA*

Sample Location	Depth (feet)	USCS Group	Geologic Material	Grain-size Distribution *	LL	PI	Vertical Hydraulic Conductivity
MW-1	3 to 5	ML	Weathered rock	1-17-58-24	33	7	—
MW-2	9 to 11	SC	Spoils	16-35-32-17	29	9	7.4×10^{-8} cm/sec
MW-3	23 to 25	CL	Spoils	4-10-52-34	34	11	--
MW-12	15 to 22	CL	Spoils	6-24-41-29	32	13	--
MW-13	19 to 24	GC	Spoils	37-30-17-15	29	10	--
B-15	30 to 32	CL	Foundry waste	53-47	46	22	--
B-18	10 to 22	SM	Foundry sand	1-72-26-1	--	--	--
B-18	35 to 42	CH	Foundry waste	47-53	54	27	--

MW-1, MW-2, MW-3 analysis by Bowser-Morner, 1985. All other analyses by RMT Soils Laboratory, 1992.

* 1-17-58-24: Percentages of gravel, sand, silt, and clay, respectively. 53-47: Percentages of gravel plus sand & silt plus clay.

LL = Liquid limit.
PI = Plasticity index.

GROUND WATER QUALITY ASSESSMENT PLAN

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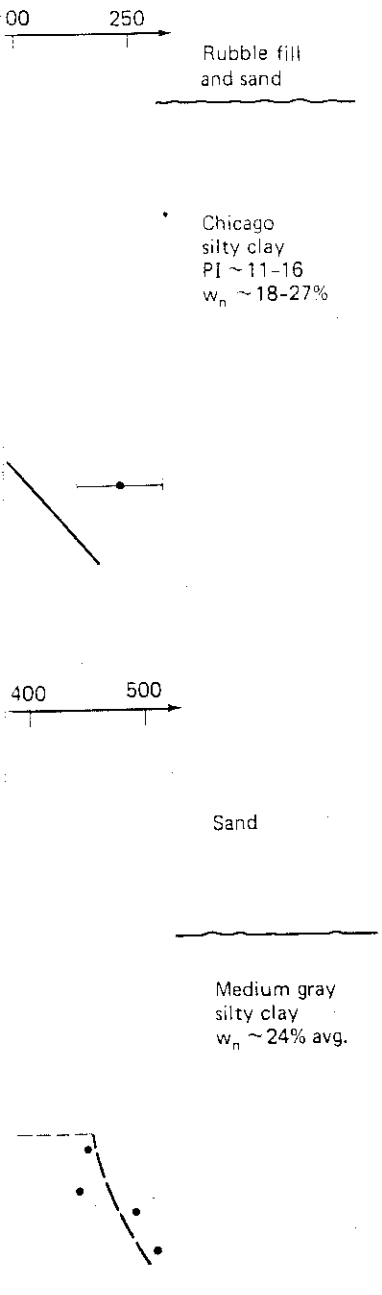

tion stress profiles for glacial
rea: (a) Chicago "Loop" (after
e soil mechanics class, North-
ndiana (after Osterberg, 1963).

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8.11 APPROXIMATE METHODS AND TYPICAL VALUES OF COMPRESSION INDICES

Because of the time and expense involved in consolidation testing, it is sometimes desirable to be able to relate the compression indices to the simple classification properties of soils. These relationships are also commonly used for preliminary designs and estimates and for checking the validity of test results.

Table 8-2 is a list of some published equations for the prediction of compression indices (Azzouz, Krizek, and Corotis, 1976).

TABLE 8-2 Some Empirical Equations for C_c and $C_{c\epsilon}$*

Equation	Regions of Applicability
$C_c = 0.007\,(\mathrm{LL} - 7)$	Remolded clays
$C_{c\epsilon} = 0.208 e_o + 0.0083$	Chicago clays
$C_c = 17.66 \times 10^{-5} w_n^2 + 5.93 \times 10^{-3}\, w_n - 1.35 \times 10^{-1}$	Chicago clays
$C_c = 1.15(e_o - 0.35)$	All clays
$C_c = 0.30(e_o - 0.27)$	Inorganic, cohesive soil; silt, some clay; silty clay; clay
$C_c = 1.15 \times 10^{-2} w_n$	Organic soils–meadow mats, peats, and organic silt and clay
$C_c = 0.75(e_o - 0.50)$	Soils of very low plasticity
$C_{c\epsilon} = 0.156 e_o + 0.0107$	All clays
$C_c = 0.01 w_n$	Chicago clays

*As summarized by Azzouz, Krizek, and Corotis (1976).
Note: w_n = natural water content.

Terzaghi and Peck (1967) proposed the following equation, based on research on undisturbed clays of low to medium sensitivity:

$$\boxed{C_c = 0.009\,(\mathrm{LL} - 10)} \tag{8-21}$$

which has a reliability range of about ±30%. This equation is widely used, despite its wide reliability range, to make initial consolidation settlement estimates. The equation should not be used where the sensitivity of the clay is greater than 4, if the LL is greater than 100, or if the clay contains a high percentage of organic matter. Some typical values of the compression index, based on our experience and the geotechnical literature, are listed in Table 8-3.

Often, C_r is assumed to be 5% to 10% of C_c. Typical values of C_r range from 0.015 to 0.035 (Leonards, 1976). The lower values are for clays of lower plasticity and low OCR. Values of C_r outside the range of 0.005 to 0.05 should be considered questionable.

assumptions are admittedly an oversimplification of real behavior. For example, the secondary compression curves of Fig. 9.11 may not be actually parallel or even have a constant slope. There is some evidence that C_α may change with time, both in the laboratory (Mesri and Godlewski, 1977) and in the field (Leonards, 1973). Also, the duration and therefore the magnitude of secondary settlement is a function of the time required for completion of primary consolidation (t_p), and from earlier work in this chapter you know that the thicker the consolidating layer, the longer is the time required for primary consolidation. Even though the strain at the end of primary consolidation for both thin and thick layers is about the same (as shown in Fig. 9.11a), there is limited evidence (Aboshi, 1973) that the slopes may not be parallel and that C_α may decrease as the thickness of the soil layer increases.

Assumptions 3 and 4 are approximately correct. Assumption 3 was verified by Leonards and Girault (1961) and Mesri and Godlewski (1977), except that the load increment must be sufficient to go well beyond the preconsolidation stress. The fourth assumption, that the ratio C_α/C_c is approximately a constant, has also been verified by Mesri and Godlewski (1977) for a wide variety of natural soils. Their work is summarized in Table 9-4. The average value of C_α/C_c is about 0.05, and in no case did they find a value of that ratio to exceed 0.1. The range for inorganic soils is 0.025 to 0.06, while the range for organic soils and peats is somewhat higher. They also showed that this ratio holds at any time, effective stress, and void ratio during secondary compression. The only exception, as shown by Leonards and Girault (1961, Fig. 3) seems to be the load increment that straddles the preconsolidation stress, σ_p'. Obviously, many questions remain to be answered concerning the topic of secondary compression.

TABLE 9-4 Values of C_α/C_c for Natural Soils*

Soil	C_α/C_c
Organic silts	0.035–0.06
Amorphous and fibrous peat	0.035–0.085
Canadian muskeg	0.09–0.10
Leda clay (Canada)	0.03–0.06
Post-glacial Swedish clay	0.05–0.07
Soft blue clay (Victoria, B.C.)	0.026
Organic clays and silts	0.04–0.06
Sensitive clay, Portland, ME	0.025–0.055
San Francisco Bay Mud	0.04–0.06
New Liskeard (Canada) varved clay	0.03–0.06
Mexico City clay	0.03–0.035
Hudson River silt	0.03–0.06
New Haven organic clay silt	0.04–0.075

*Modified after Mesri and Godlewski (1977).

spoils use 0.045

Fine-Grained Foundry waste use 0.05

5/26

If, for some reason, you do not laboratory test data, you can use the soils, or simply use an average C_α/C_c preliminary calculations. Mesri (197 obtain the secondary compression inc compression index, and it is shown i versus natural water content of the soi

We will illustrate how to estima 9.10, 9.11, and 9.12.

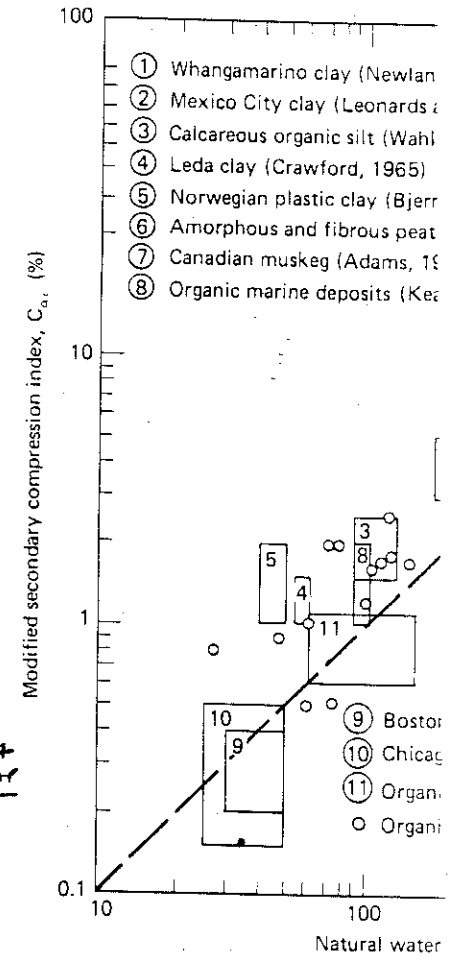

Fig. 9.12 Modified secondary com water content. (After Mesri, 1973. Se references included in this figure.)

9/26

TABLE 8-3 Typical Values of the Compression Index C_c

Soil	C_c
Normally consolidated medium sensitive clays	0.2 to 0.5
Chicago silty clay (CL)	0.15 to 0.3
Boston blue clay (CL)	0.3 to 0.5
Vicksburg buckshot clay (CH)	0 5 to 0.6
Swedish medium sensitive clays (CL-CH)	1 to 3
Canadian Leda clays (CL-CH)	1 to 4
Mexico City clay (MH)	7 to 10
Organic clays (OH)	4 and up
Peats (Pt)	10 to 15
Organic silt and clayey silts (ML-MH)	1.5 to 4.0
San Francisco Bay Mud (CL)	0.4 to 1.2
San Francisco Old Bay clays (CH)	0.7 to 0.9
Bangkok clay (CH)	0.4

use 0.15

8.12 STRESS DISTRIBUTION

In the previous sections of this chapter when we calculated settlements, the increase in stress $\Delta\sigma$ caused by an applied load was given. In this section, we shall show you how to estimate the stress increase in the soil due to boundary or surface loads.

Suppose a very large area such as a subdivision or shopping mall is to be filled with several metres of select compacted material. In this instance, the loading is *one dimensional*, and the stress increase felt at depth would be 100% of the applied stress at the surface. However, near the edge or end of the filled area you might expect a certain amount of attenuation of stress with depth because no stress is applied beyond the edge. Likewise, with a footing of limited size, the applied stress would dissipate rather rapidly with depth.

One of the simplest methods to compute the distribution of stress with depth for a loaded area is to use the *2 to 1 (2:1) method*. This is an empirical approach based on the assumption that the area over which the load acts increases in a systematic way with depth. Since the same vertical force is spread over an increasingly larger area, the unit stress decreases with depth, as shown in Fig. 8.19. In Fig. 8.19a, a strip or continuous footing is seen in elevation view. At a depth z, the enlarged area of the footing increases by $z/2$ on each side. The width at depth z is then $B + Z$, and the stress σ_z at that depth is

$$\sigma_z = \frac{\text{load}}{(B+z)\times 1} = \frac{\sigma_o(B\times 1)}{(B+z)\times 1} \tag{8-22}$$

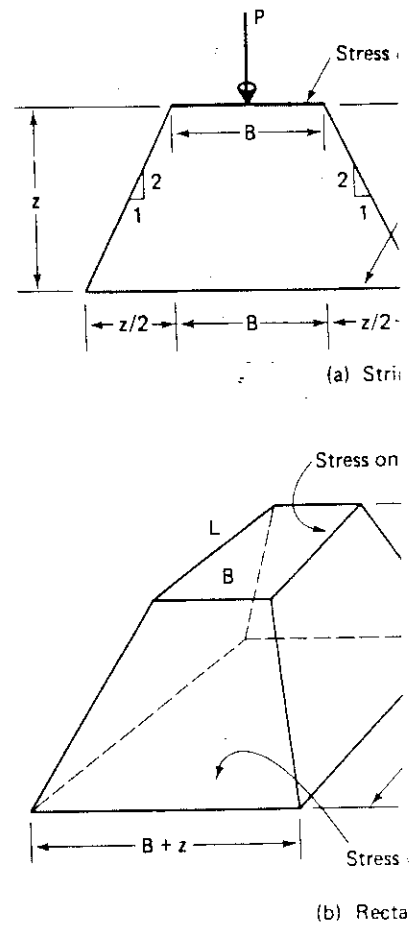

Fig. 8.19 The 2:1 approximati
stress with depth.

where σ_o is the surface or contact str

By analogy, a rectangular foo
have an area of $(B + Z)(L + Z)$ at
corresponding stress at depth z woul

$$\Delta\sigma_z = \frac{\text{load}}{(B+z)(L+}$$

Example 8.17 illustrates the use of tl

10/26

TABLE 9-3 Typical Values of the Coefficient of Consolidation c_v

Soil	c_v cm²/s, $\times 10^{-4}$	c_v m²/yr
Boston blue clay (CL) (Ladd and Luscher, 1965)	40 ± 20	12 ± 6 × 10.764 = [illegible]
Organic silt (OH) (Lowe, Zaccheo, and Feldman, 1964)	2–10	0.6–3
Glacial lake clays (CL) (Wallace and Otto, 1964)	6.5–8.7	2.0–2.7
Chicago silty clay (CL) (Terzaghi and Peck, 1967)	8.5	2.7
Swedish medium sensitive clays (CL-CH) (Holtz and Broms, 1972)		
1. laboratory	0.4–0.7	0.1–0.2
2. field	0.7–3.0	0.2–1.0
San Francisco Bay Mud (CL)	2–4	0.6–1.2
Mexico City clay (MH) (Leonards and Girault, 1961)	0.9–1.5	0.3–0.5

SPOILS

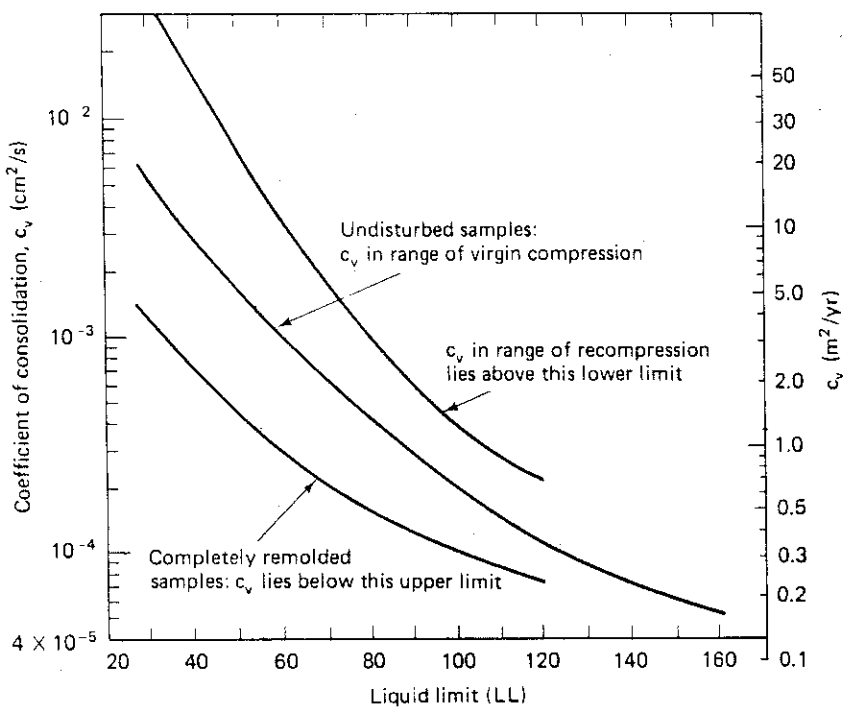

Fig. 9.10 Approximate correlations of the coefficient of consolidation c_v with the liquid limit (after U.S. Navy, 1971).

9.6 TYPICAL VA

Typical values of th
soils are listed in Table 9-
limit are presented in Fig.

9.7 EVALUATIO SETTLEMENT

Thus far we have d
primary settlement s_c, and
nents of total settlement as
s_i and secondary settleme
elastic theory, and it invo
and Poisson's ratio of the c
distribution in the soil un
estimation of immediate s
textbooks and will not be c

Secondary compressi
started during primary co
slower rate. Secondary cor
tion in that it takes plac
essentially all the excess pc
settlement seems to result fr
ual clay particles and dom
which are not yet clearly u
in the field it is difficult to
dation settlement, especiall
thick. Parts of the layer ne
dated, and therefore underg
near the center of the layer
contribute to the total surf
order to predict the final
However, in this section we
acceptable for engineering p
and we shall show you how
some simple cases.

There is, unfortunately
ture as to the best way to de
compression. In this section,

11/26

:ERING AND ENGINEERING

Editors

An Introduction to Geotechnical Engineering

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National Bureau of Standards
Washington, DC

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NAVFAC DM-7

TABLE 6
Typical Values of Soil Index Properties

	Particle Size and Gradation				Voids[1]					Unit Weight[2] (lb./cu.ft.)						
	Approximate Size Range (mm)		Approx. D_{10} (mm)	Approx. Range Uniform Coefficient C_u	Void Ratio			Porosity (%)		Dry Weight			Wet Weight		Submerged Weight	
	D_{max}	D_{min}			e_{max} loose	e_{cr}	e_{min} dense	n_{max} loose	n_{min} dense	Min loose	100% Mod. AASHO	Max dense	Min loose	Max dense	Min loose	Max dense
GRANULAR MATERIALS																
Uniform Materials																
a. Equal spheres (theoretical values)	–	–	–	1.0	0.92	–	0.35	47.6	26	–	–	–	–	–	–	–
b. Standard Ottawa SAND	0.84	0.59	0.67	1.1	0.80	0.75	0.50	44	33	92	–	110	93	131	57	69
c. Clean, uniform SAND (fine or medium)	–	–	–	1.2 to 2.0	1.0	0.80	0.40	50	29	83	115	118	84	136	52	73
d. Uniform, inorganic SILT	0.05	0.005	0.012	1.2 to 2.0	1.1	–	0.40	52	29	80	–	118	81	136	51	73
Well-graded Materials																
a. Silty SAND	2.0	0.005	0.02	5 to 10	0.90	–	0.30	47	23	87	122	127	88	142	54	79
b. Clean, fine to coarse SAND	2.0	0.05	0.09	4 to 6	0.95	0.70	0.20	49	17	85	132	138	86	148	53	86
c. Micaceous SAND	–	–	–	–	1.2	–	0.40	55	29	76	–	120	77	138	48	76
d. Silty SAND & GRAVEL	100	0.005	0.02	15 to 300	0.85	–	0.14	46	12	89	–	146[3]	90	155[3]	56	92
MIXED SOILS																
Sandy or Silty CLAY	2.0	0.001	0.003	10 to 30	1.8	–	0.25	64	20	60	130	135	100	147	38	85
Skip-graded Silty CLAY with stones or rk fgmts	250	0.001	–	–	1.0	–	0.20	50	17	84	–	140	115	151	53	89
Well-graded GRAVEL, SAND, SILT & CLAY mixture	250	0.001	0.002	25 to 1000	0.70	–	0.13	41	11	100	140	148[4]	125	156[4]	62	94
CLAY SOILS																
CLAY (30%-50% clay sizes)	0.05	0.5μ	0.001	–	2.4	–	0.50	71	33	50	105	112	94	133	31	71
Colloidal CLAY (-0.002 mm: 50%)	0.01	10Å	–	–	12	–	0.60	92	37	13	90	106	71	128	8	66
ORGANIC SOILS																
Organic SILT	–	–	–	–	3.0	–	0.55	75	35	40	–	110	87	131	25	69
Organic CLAY (30% - 50% clay sizes)	–	–	–	–	4.4	–	0.70	81	41	30		100	81	125	18	62

12/26

Naval Facilities Engineering Command
200 Stovall Street
Alexandria, Virginia 22332-2300

APPROVED FOR PUBLIC RELEASE

13/26

Soil Mechanics

RMT
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DESIGN MANUAL 7.01
REVALIDATED BY CHANGE 1 SEPTEMBER 1986

14/20

Description of Fine-Grained Foundry Waste

Sludges

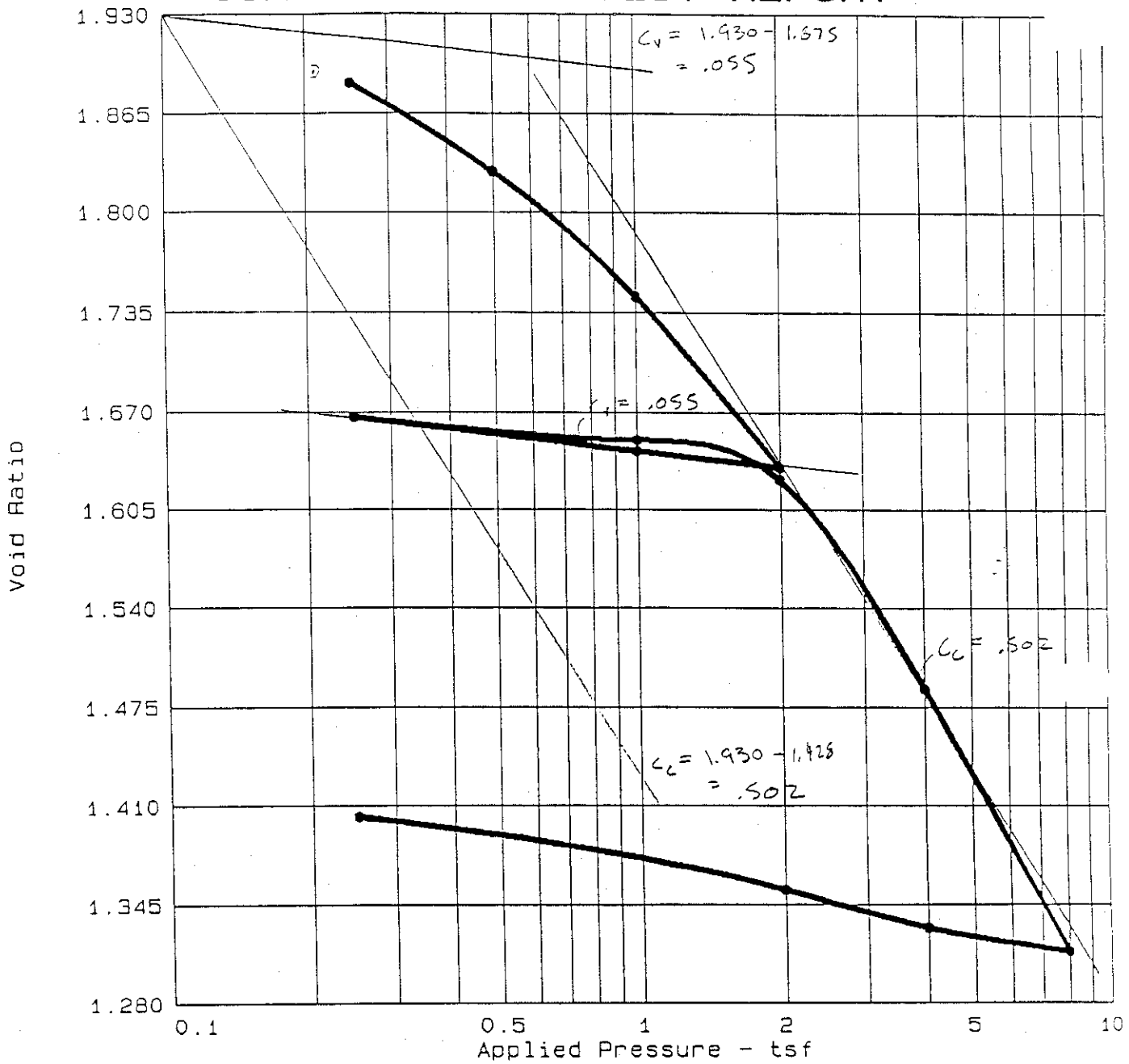
The sludges were determined to be typically a fine-grained material (i.e., > 50 percent by weight passing through a #200 mesh sieve) with a majority of the material having silt-size particles. Based on the Atterberg limits, this material is classified as an MH material by the Unified Soil Classification System (USCS). However, there were locations where the sludge had a majority of sand-size particles, for example the eastern end of Area 1 near the dredge outlet. The solids content varied from 35 percent to 78 percent (i.e., 28 percent to 185 percent moisture content) by weight, and the specific gravity varied from 2.03 to 2.50.

Foundry Wastes

The foundry wastes were typically a coarse-grained material (i.e., > 50 percent by weight does not pass through a #200 mesh sieve) with approximately 20 percent fines. This material is classified as an SP material by the USCS. The solids content

15126
✓ JMS 2-90
6/03

CONSOLIDATION TEST REPORT



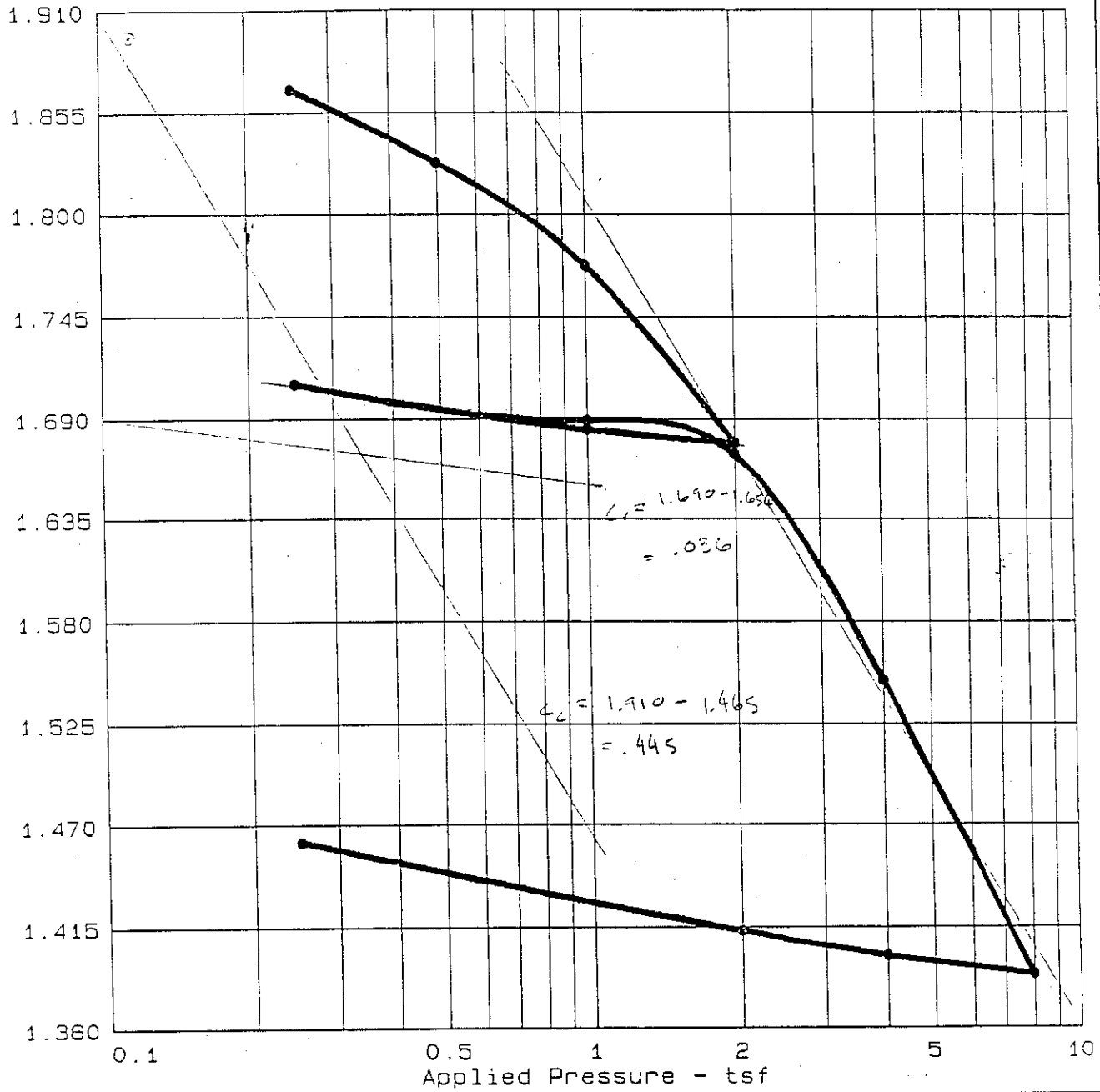
Swell press.	Nat. Sat.	Nat. Moist.	Dry Density	LL	PI	Sp.Gr.	Initial void ratio
	97.2 %	89.1	45.3			2.17	1.9884

TEST RESULTS	MATERIAL DESCRIPTION
C_v at 2.00 tsf applied = 1.093 sq. in./min. C_v at 4.00 tsf applied = 0.408 sq. in./min.	
Project No.: 188.91 Project: Location: 908-27, 17-19.5' Date: 04/24/90 γ_d' = 23.3 pcf P_o = 419 pcf (.21 tsf)	Remarks:
CONSOLIDATION TEST REPORT RMT, INC.	Fig. No. _____

✓ JPA 5-22-90

16/26

CONSOLIDATION TEST REPORT



Swell press.	Nat. Sat.	Nat. Moist.	Dry Density	LL	PI	Sp.Gr.	Initial void ratio
	94.2 %	80.9	47.5			2.20	1.8897

TEST RESULTS	MATERIAL DESCRIPTION

Project No.: 188.91 γ_d' = 23.5 pcf
Project: AREAS 1 & 2
Location: 908-27, 9-11.5' p_o' = 235 psf (.12 tsf)

Date: 4/30/90

Remarks:

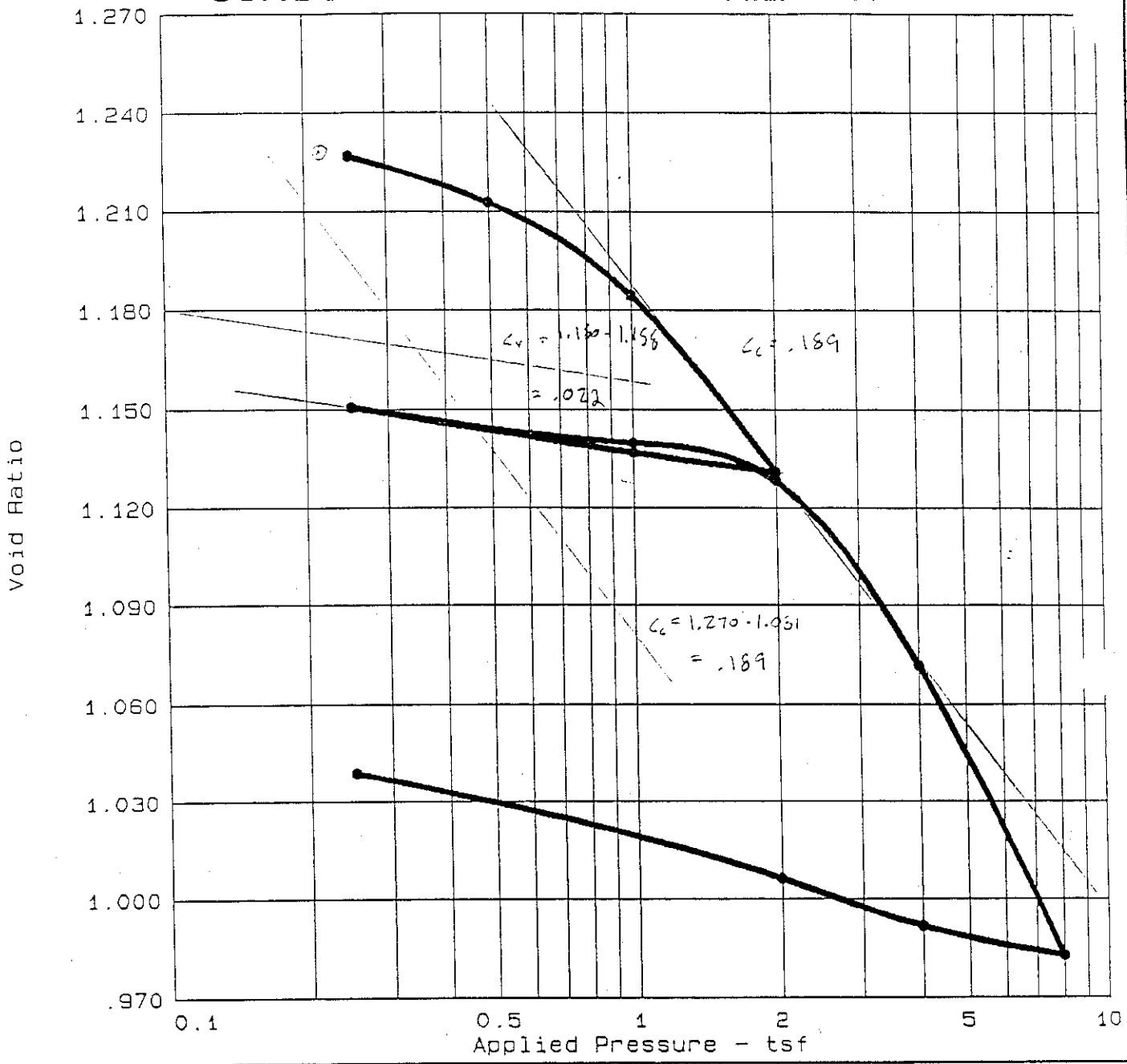
CONSOLIDATION TEST REPORT

RMT, INC.

Fig. No. _____

GIN ...
✓ JPH 5-31-90
17/26

CONSOLIDATION TEST REPORT



Swell press.	Nat. Sat.	Nat. Moist.	Dry Density	LL	PI	Sp.Gr.	Initial void ratio
	95.3 %	51.0	64.7			2.33	1.2468

TEST RESULTS	MATERIAL DESCRIPTION
	BLACK FOUNDRY SLUDGE

Project No.: 188.91
Project: AREA 1
Location: 90B-25, 12-14.5'

Date: 05/21/90

γ' = 55.3 pcf
P_o' = 459 psf (.23 tsf)

Remarks:

CONSOLIDATION TEST REPORT

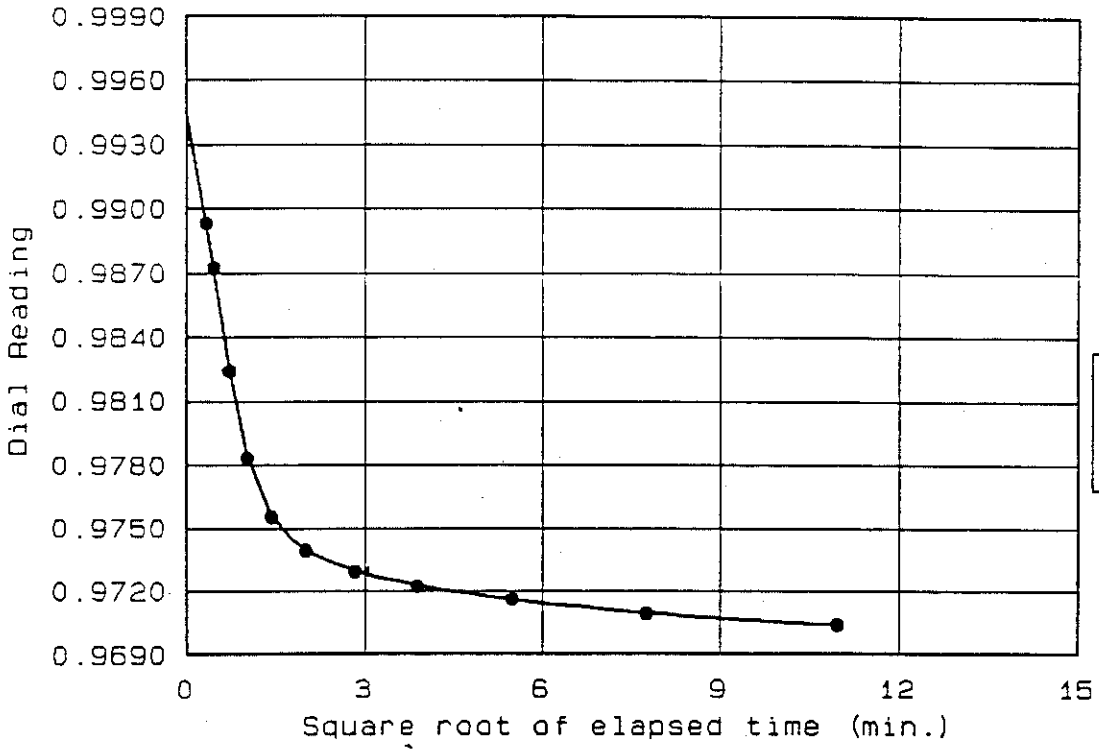
RMT, INC.

Fig. No. _____

Dial Reading vs. Time

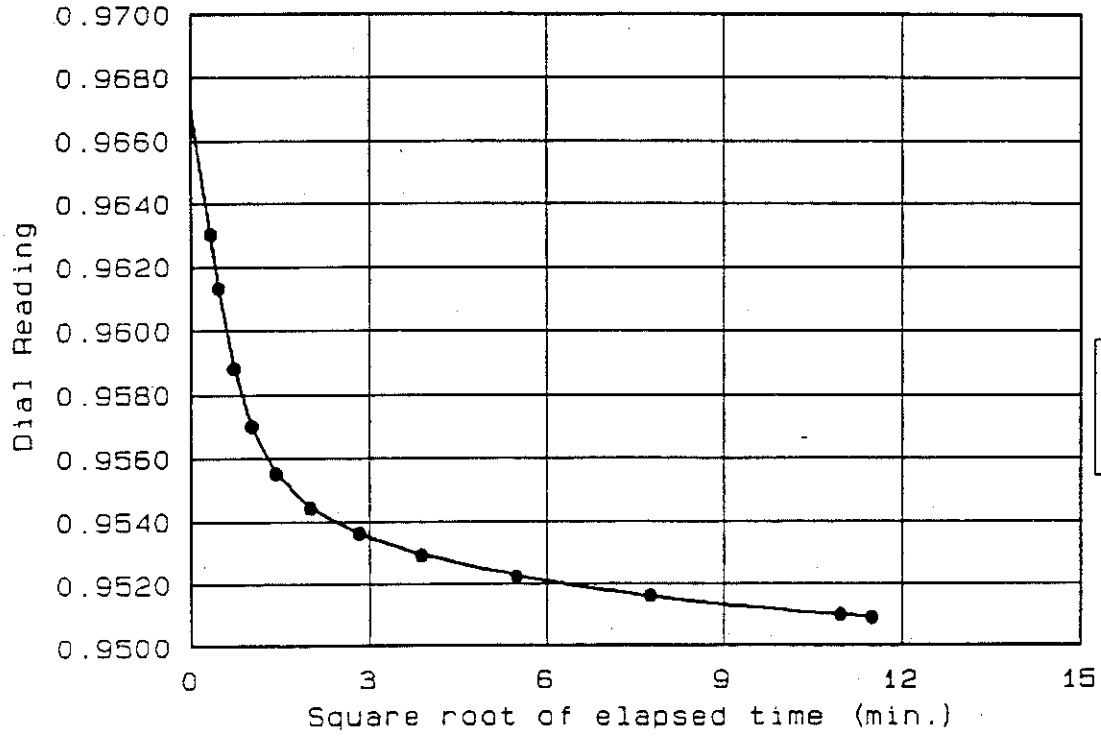
Project No.: 188.91
Project:
Location: 908-27, 17-19.5'

Date: 04/24/90



Load No.= 1
Load= 0.25 tsf
D_0 = 0.9944
D_{90} = 0.9765
D_{100}= 0.9745
T_{90}= 1.59 min.

C_v @ T_{90} =
1.3 ft^2/day



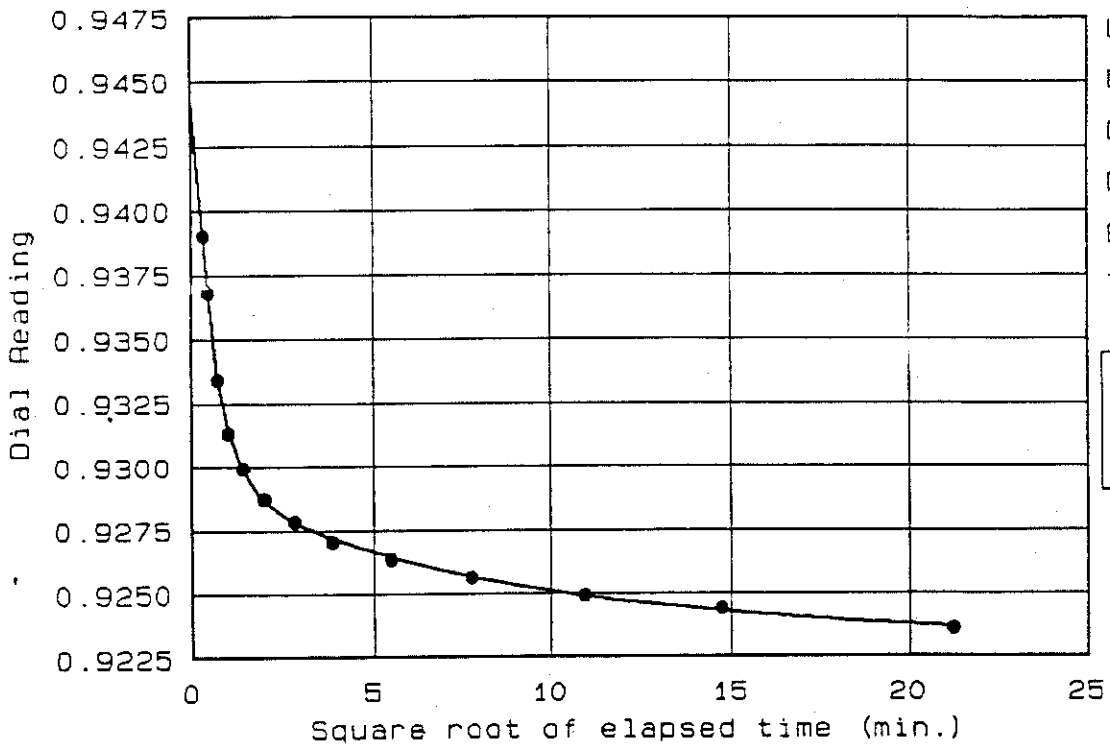
Load No.= 2
Load= 0.50 tsf
D_0 = 0.9671
D_{90} = 0.9584
D_{100}= 0.9574
T_{90}= 0.60 min.

C_v @ T_{90} =
3.2 ft^2/day

Dial Reading vs. Time

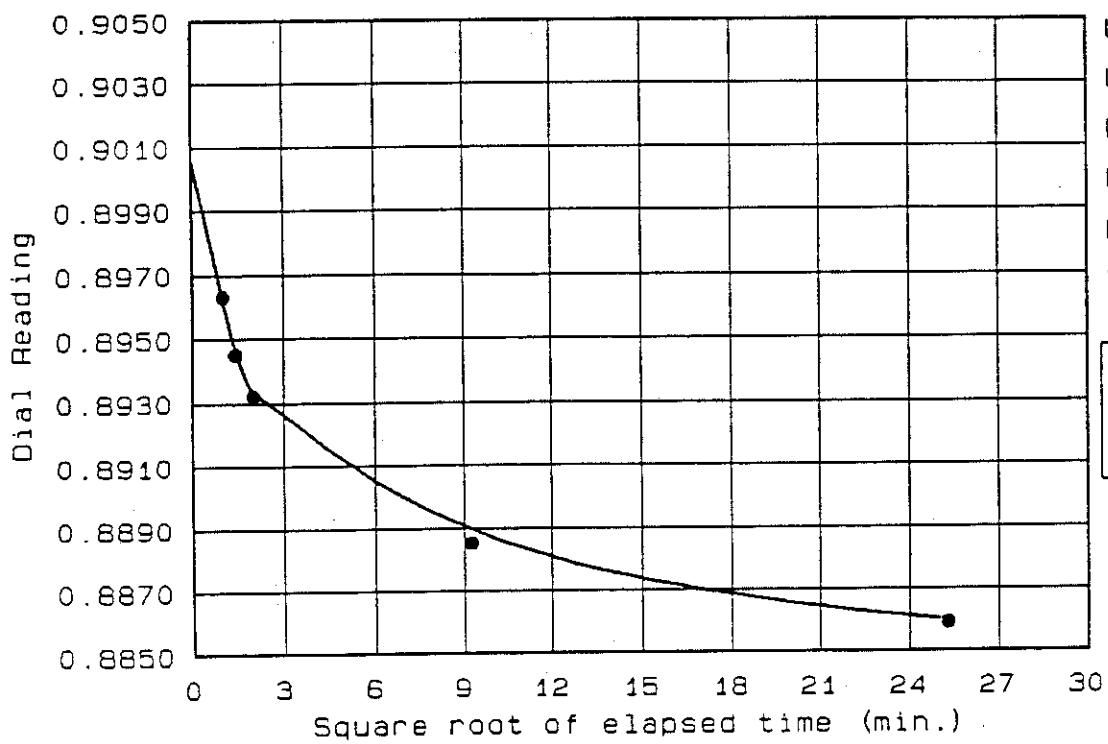
Project No.: 188.91
Project:
Location: 908-27, 17-19.5'

Date: 04/24/90



Load No.= 3
Load= 1.00 tsf
D_0 = 0.9443
D_{90} = 0.9327
D_{100}= 0.9314
T_{90}= 0.64 min.

C_v @ T_{90} =
2.9 ft^2/day



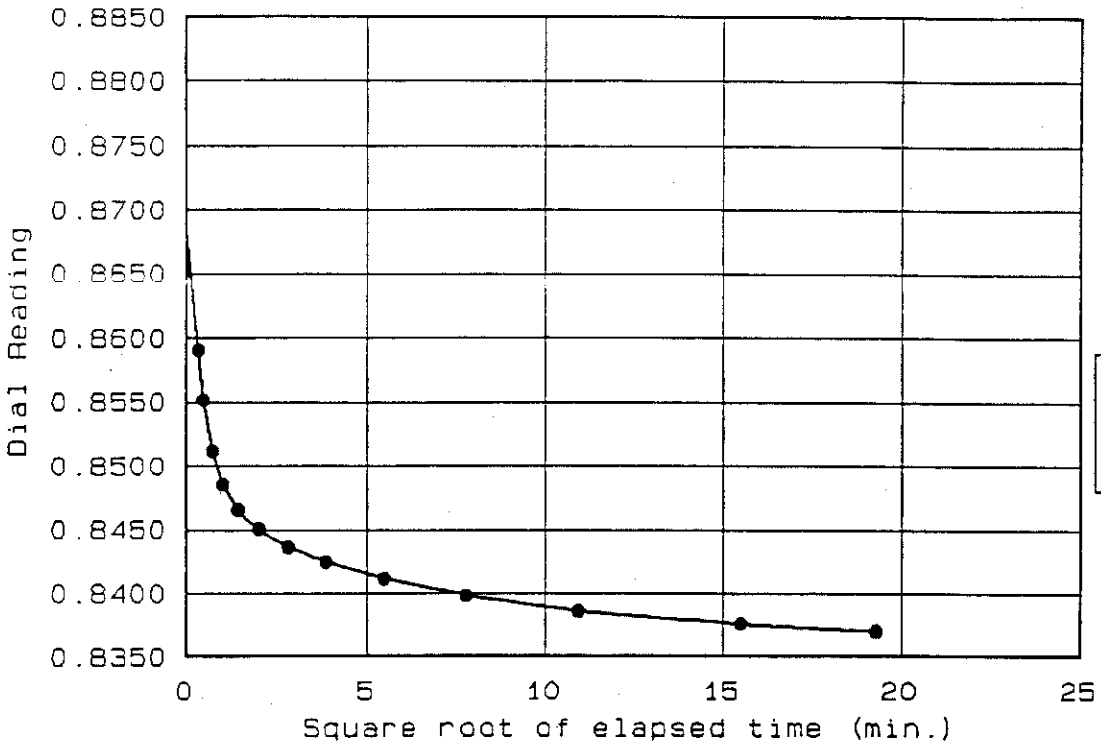
Load No.= 4
Load= 2.00 tsf
D_0 = 0.9006
D_{90} = 0.8934
D_{100}= 0.8926
T_{90}= 3.69 min.

C_v @ T_{90} =
0.5 ft^2/day

Dial Reading vs. Time

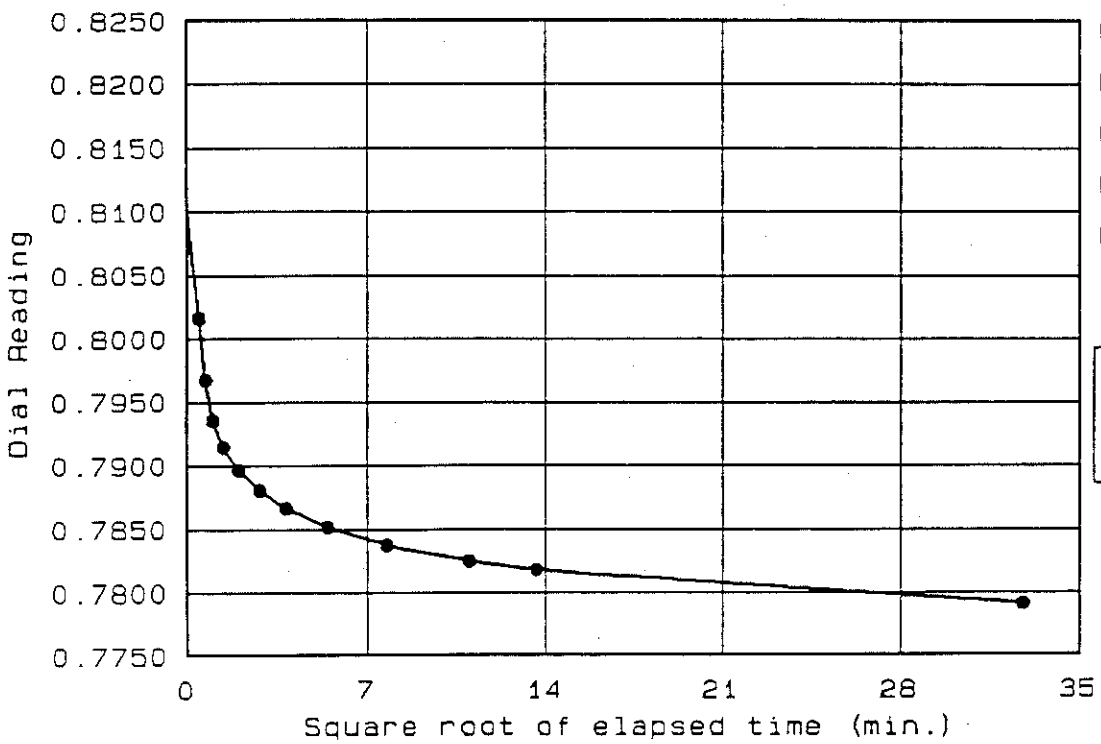
Project No.: 188.91
Project:
Location: 908-27, 17-19.5'

Date: 04/24/90



Load No.= 9
Load= 4.00 tsf
D_0 = 0.8684
D_{90} = 0.8485
D_{100}= 0.8463
T_{90}= 1.03 min.

C_v @ T_{90} = 1.5 ft^2/day



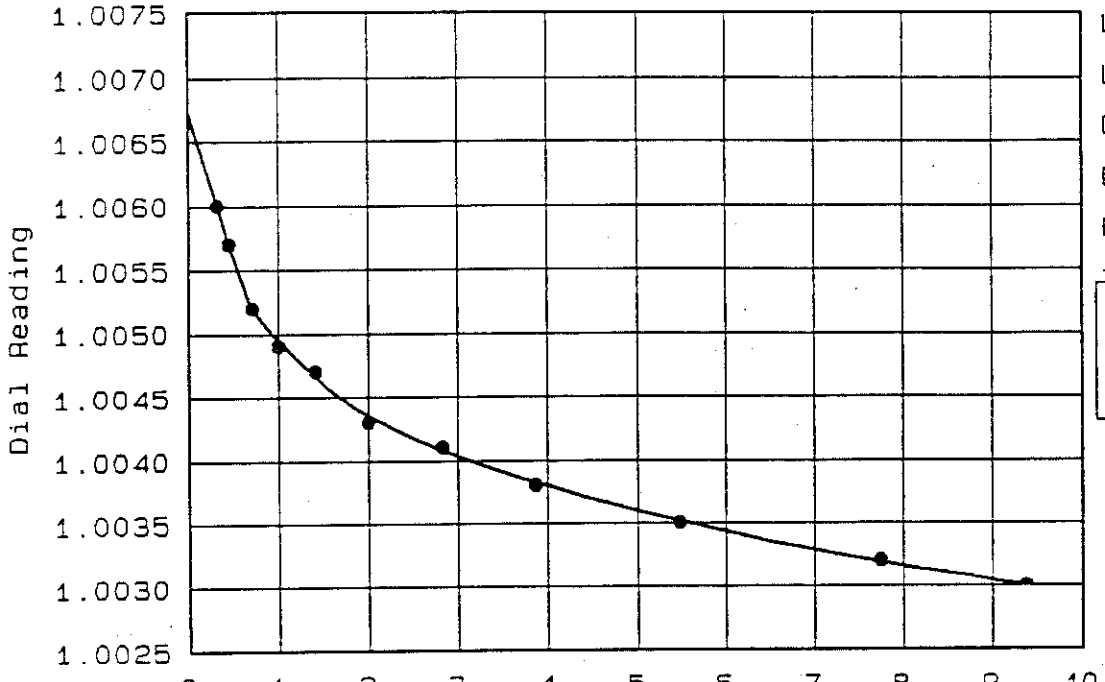
Load No.= 10
Load= 8.00 tsf
D_0 = 0.8100
D_{90} = 0.7934
D_{100}= 0.7916
T_{90}= 1.02 min.

C_v @ T_{90} = 1.3 ft^2/day

Dial Reading vs. Time

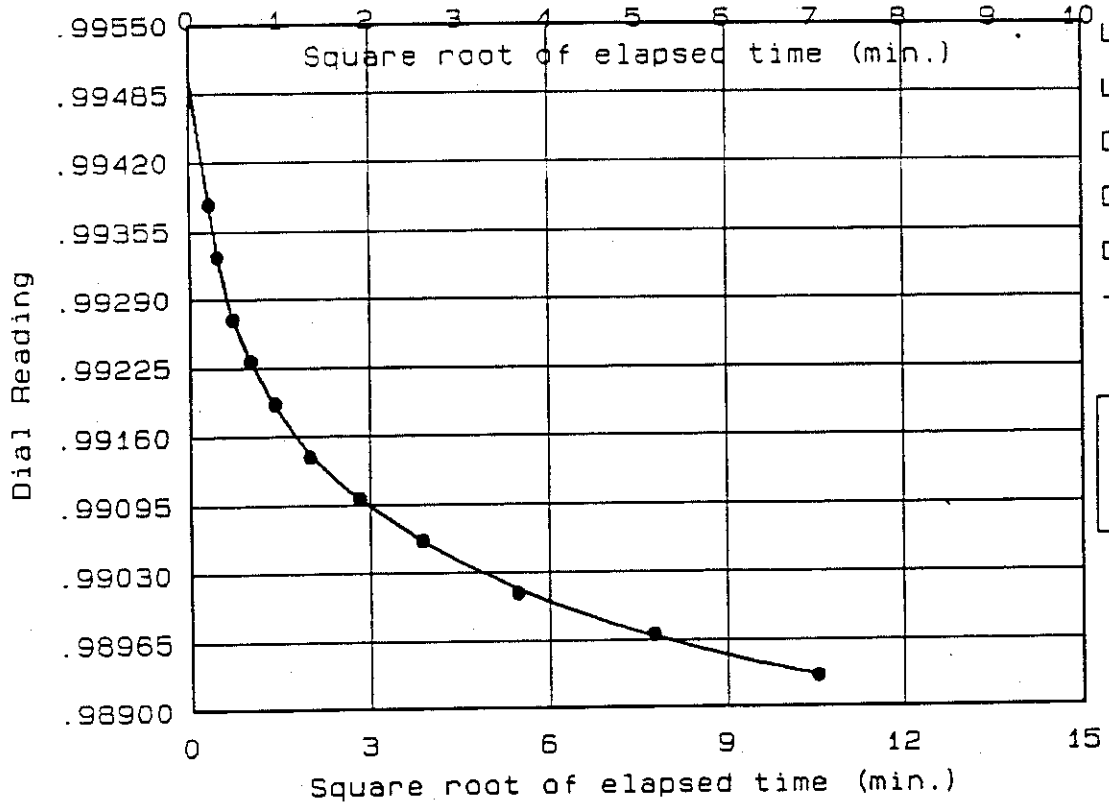
Project No.: 188.91
Project: AREAS 1 & 2
Location: 90B-27, 9-11.5'

Date: 4/30/90



Load No.= 1
Load= 0.25 tsf
D_0 = 1.0067
D_{90} = 1.0051
D_{100}= 1.0049
T_{90}= 0.70 min

C_v @ T_{90} =
3.0 ft^2/day



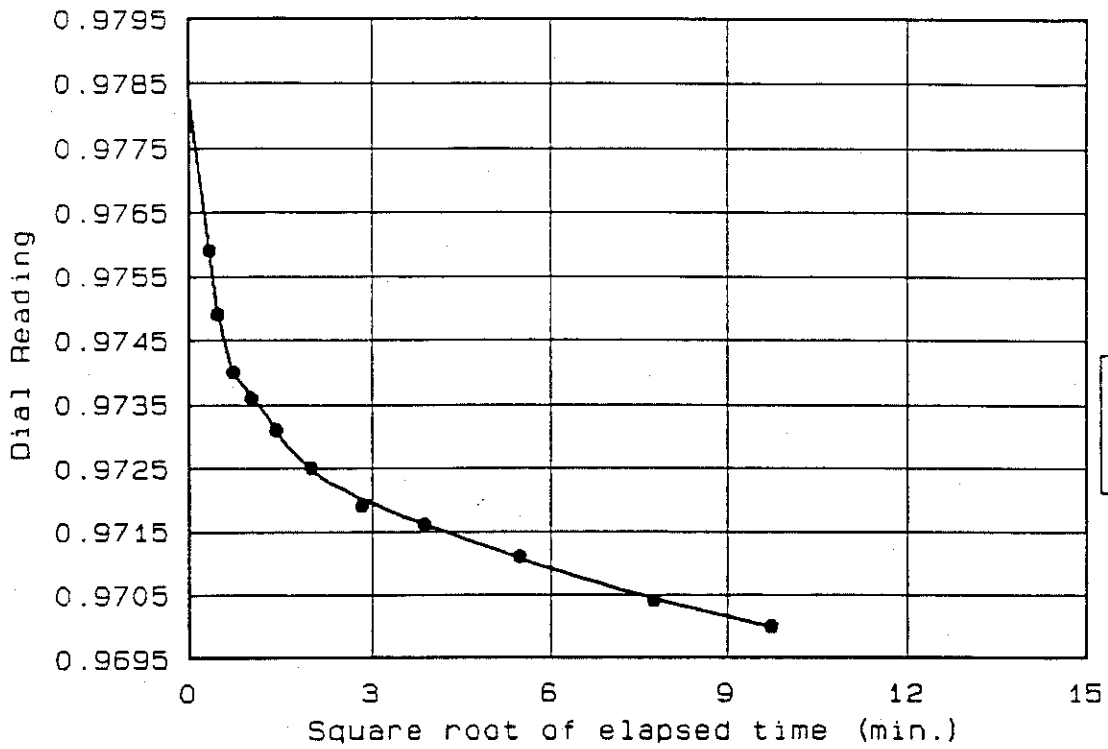
Load No.= 2
Load= 0.50 tsf
D_0 = 0.9950
D_{90} = 0.9928
D_{100}= 0.9925
T_{90}= 0.46 min.

C_v @ T_{90} =
4.5 ft^2/day

Dial Reading vs. Time

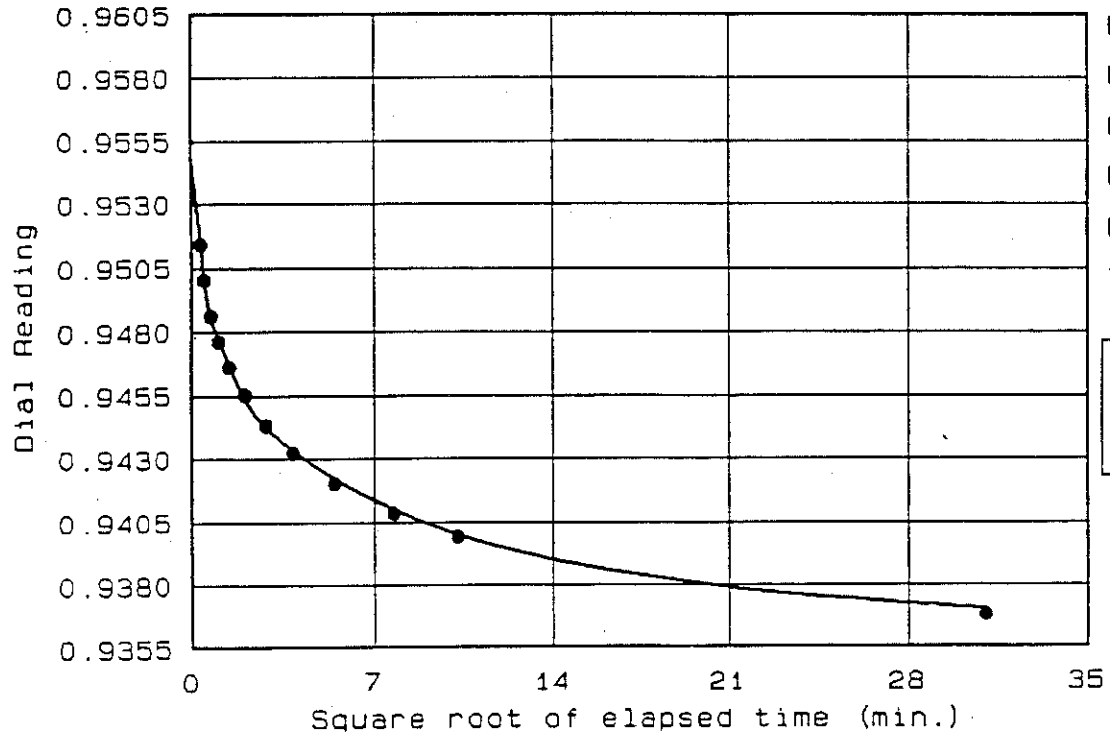
Project No.: 188.91
Project: AREAS 1 & 2
Location: 908-27, 9-11.5'

Date: 4/30/90



Load No.= 3
Load= 1.00 tsf
D_0 = 0.9783
D_{90} = 0.9743
D_{100}= 0.9739
T_{90}= 0.36 min.

C_v @ T_{90} =
5.6 ft^2/day



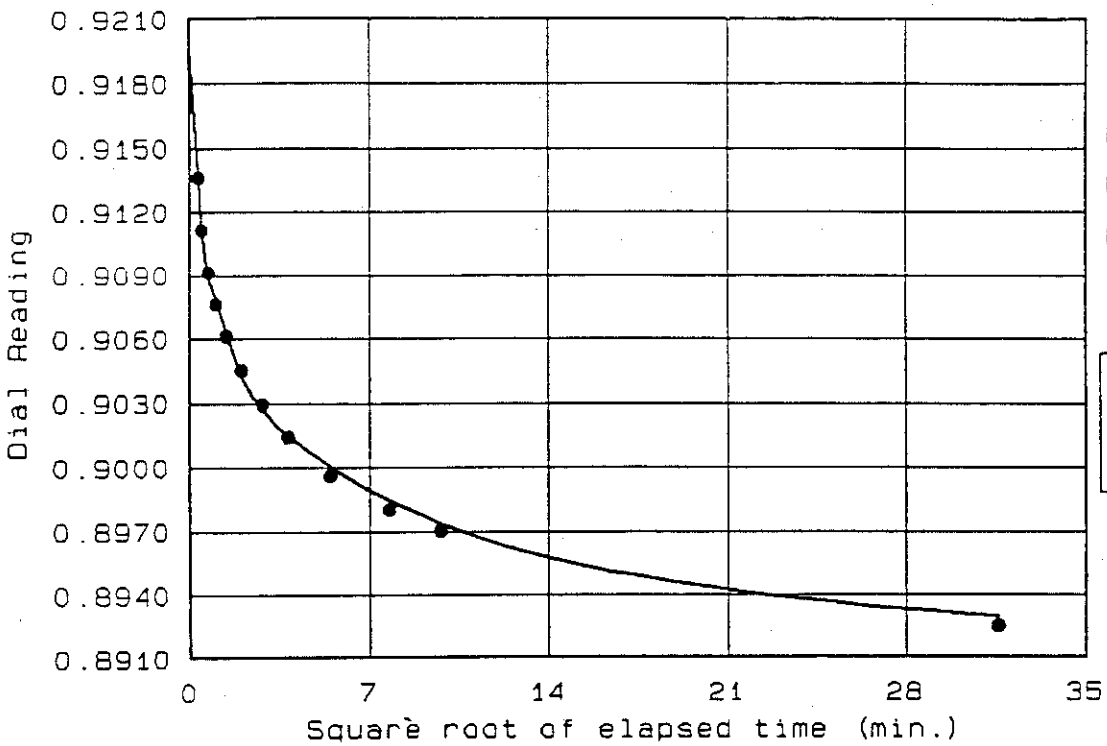
Load No.= 4
Load= 2.00 tsf
D_0 = 0.9548
D_{90} = 0.9489
D_{100}= 0.9483
T_{90}= 0.40 min.

C_v @ T_{90} =
4.7 ft^2/day

Dial Reading vs. Time

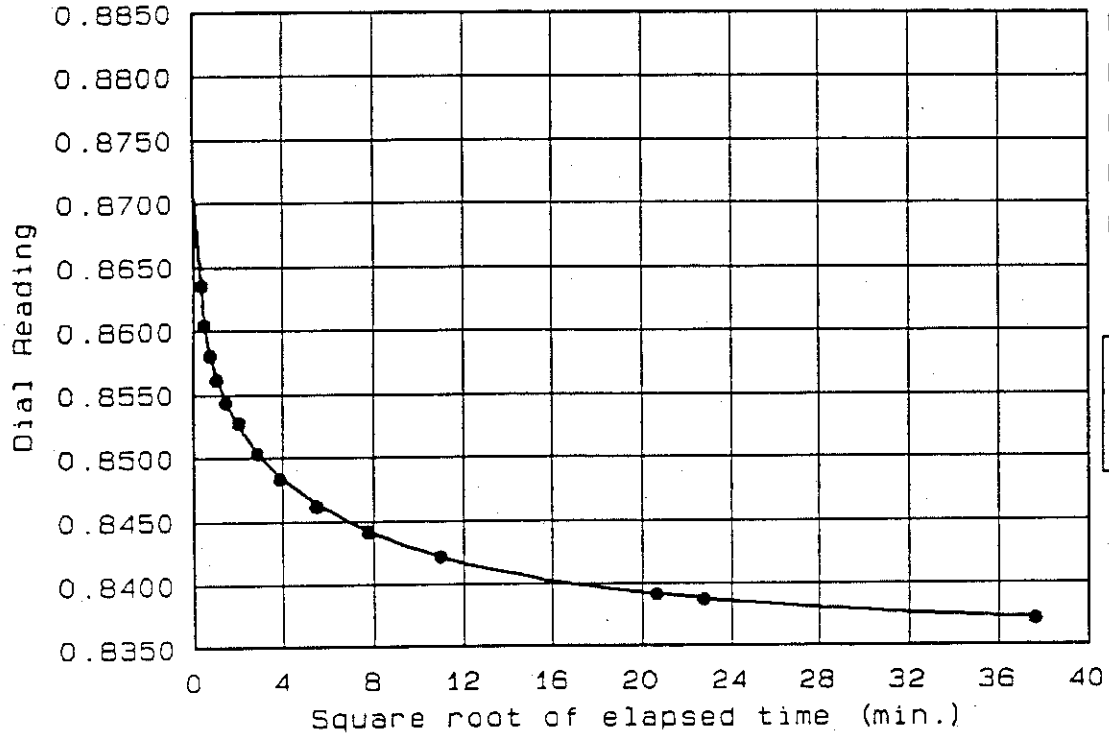
Project No.: 188.91
Project: AREAS 1 & 2
Location: 908-27, 9-11.5'

Date: 4/30/90



Load No.= 9
Load= 4.00 tsf
D_0 = 0.9196
D_{90} = 0.9105
D_{100}= 0.9095
T_{90}= 0.30 min.

C_v @ T_{90} =
5.7 ft^2/day



Load No.= 10
Load= 8.00 tsf
D_0 = 0.8710
D_{90} = 0.8594
D_{100}= 0.8581
T_{90}= 0.32 min.

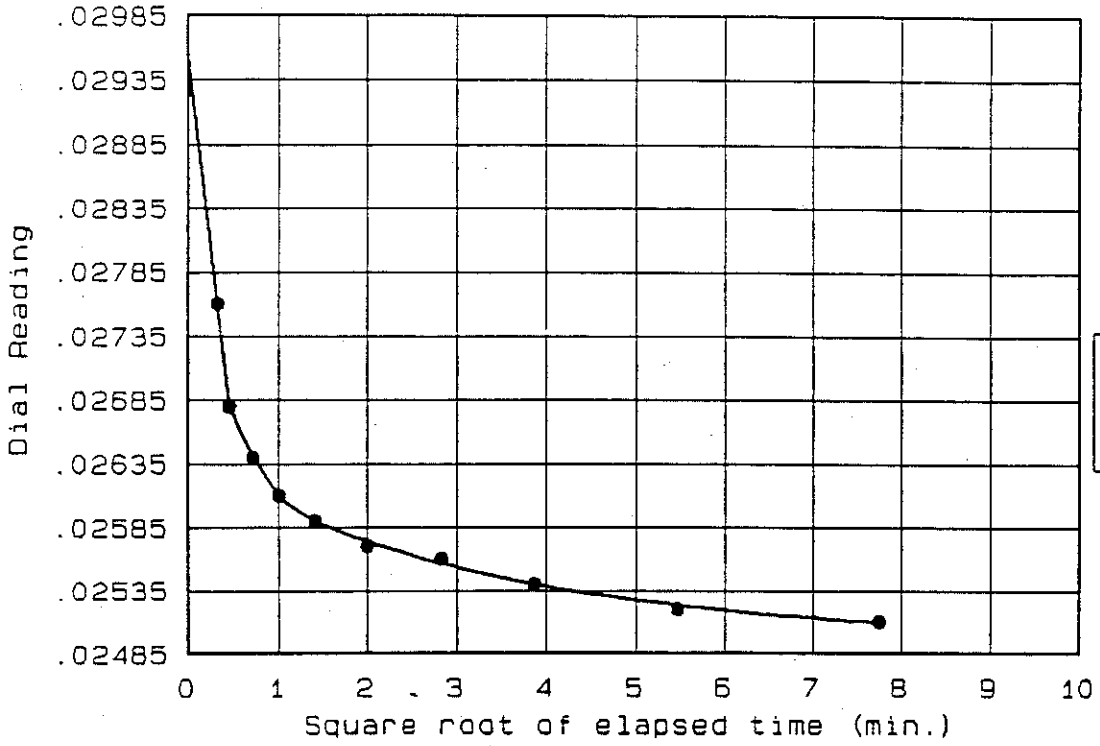
C_v @ T_{90} =
4.9 ft^2/day

24/26

Dial Reading vs. Time

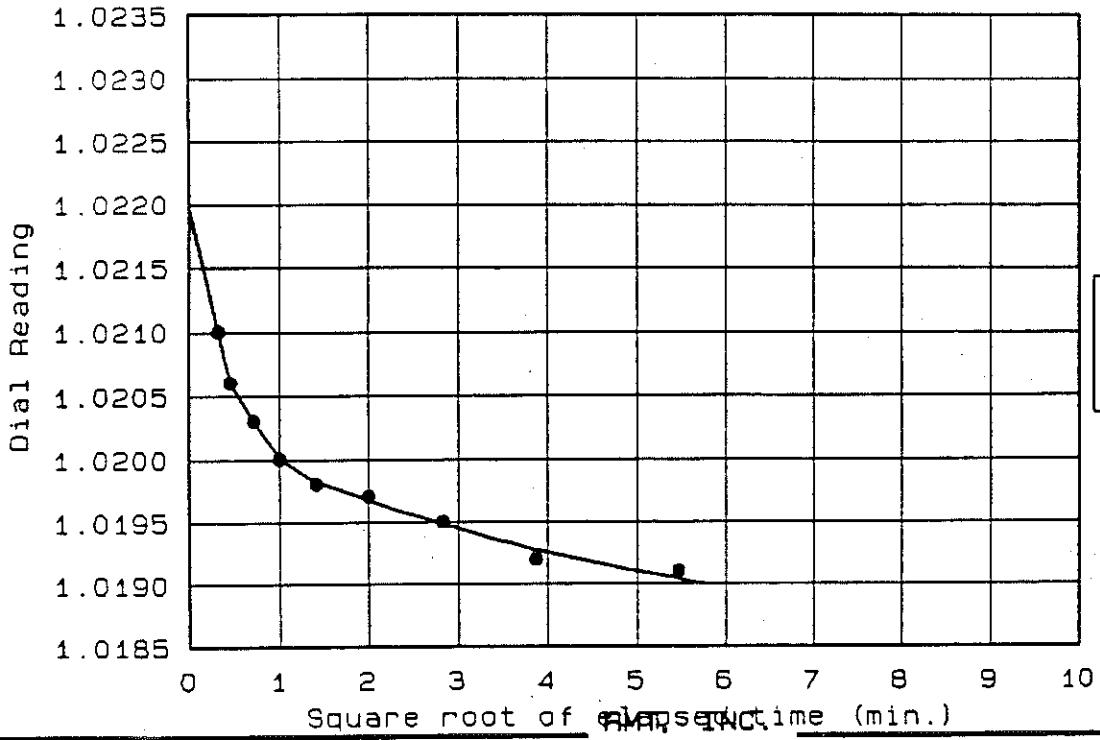
Project No.: 188.91
Project: AREA 1
Location: 908-25, 12-14.5'

Date: 05/21/90



Load No.= 1
Load= 0.25 tsf
D_0 = 1.0295
D_{90} = 1.0266
D_{100}= 1.0263
T_{90}= 0.30 min.

C_v @ T_{90} = 7.0 ft^2/day



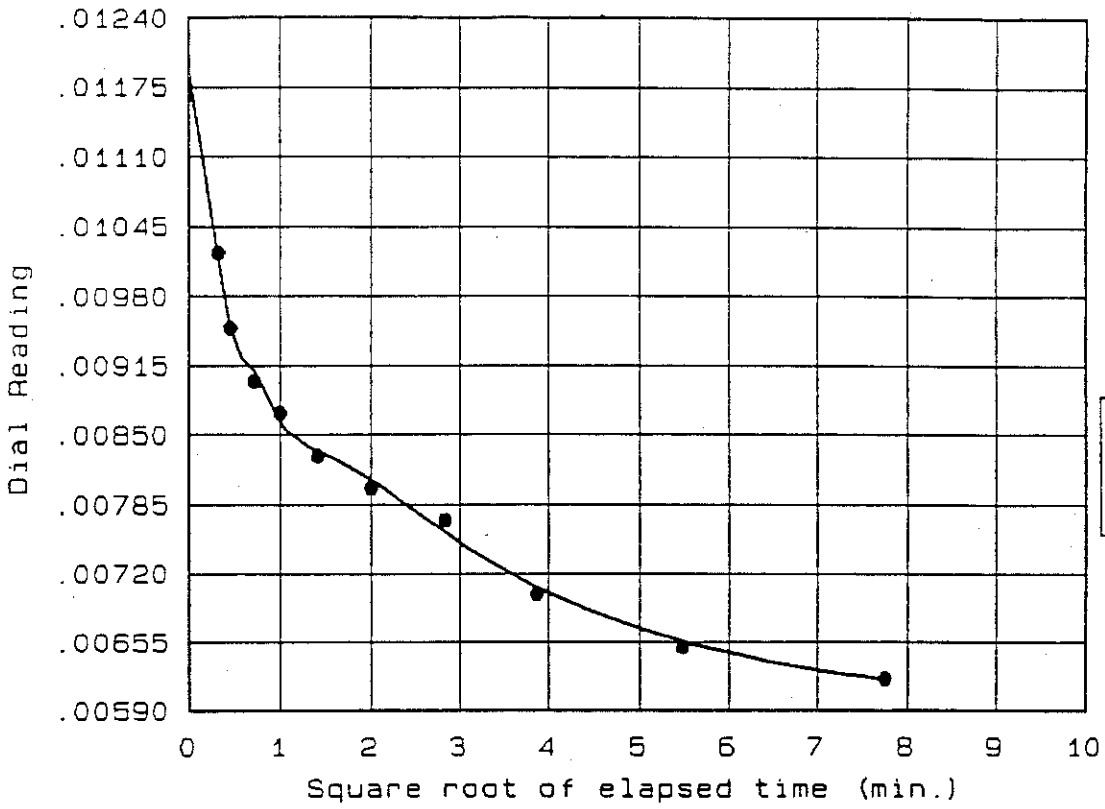
Load No.= 2
Load= 0.50 tsf
D_0 = 1.0220
D_{90} = 1.0205
D_{100}= 1.0203
T_{90}= 0.32 min.

C_v @ T_{90} = 6.4 ft^2/day

Dial Reading vs. Time

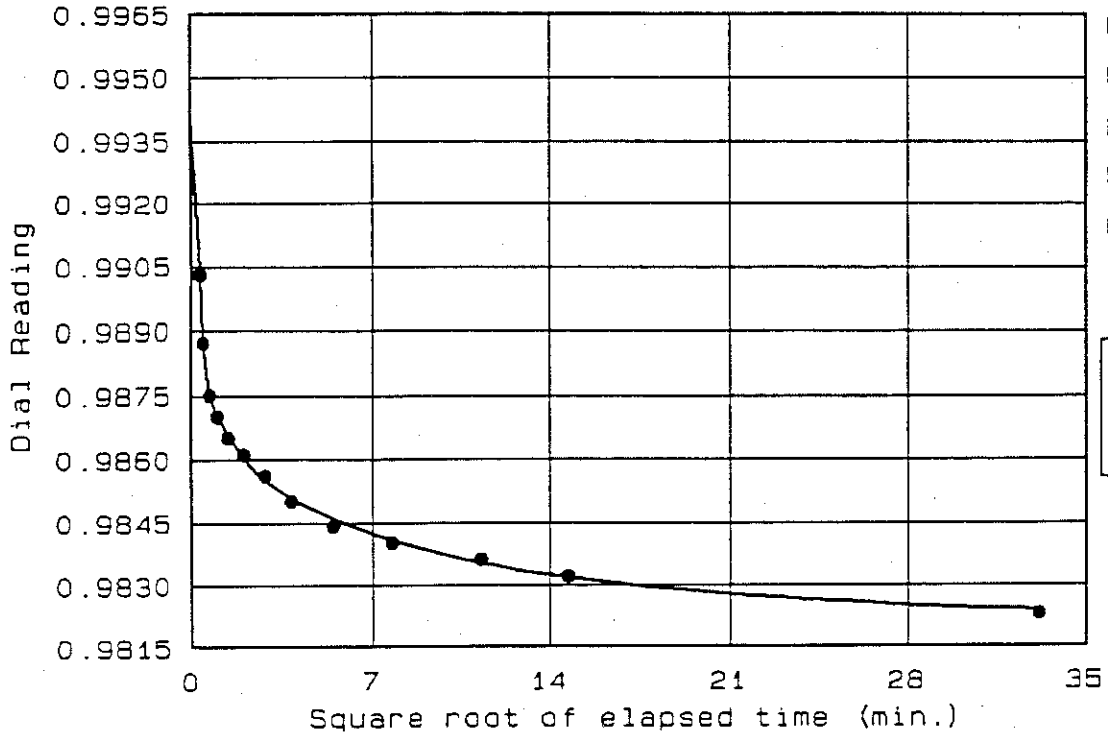
Project No.: 188.91
Project: AREA 1
Location: 90B-25, 12-14.5'

Date: 05/21/90



Load No.= 3
Load= 1.00 tsf
D_0 = 1.0119
D_{90} = 1.0092
D_{100}= 1.0089
T_{90}= 0.32 min.

C_v @ T_{90} =
6.1 ft^2/day



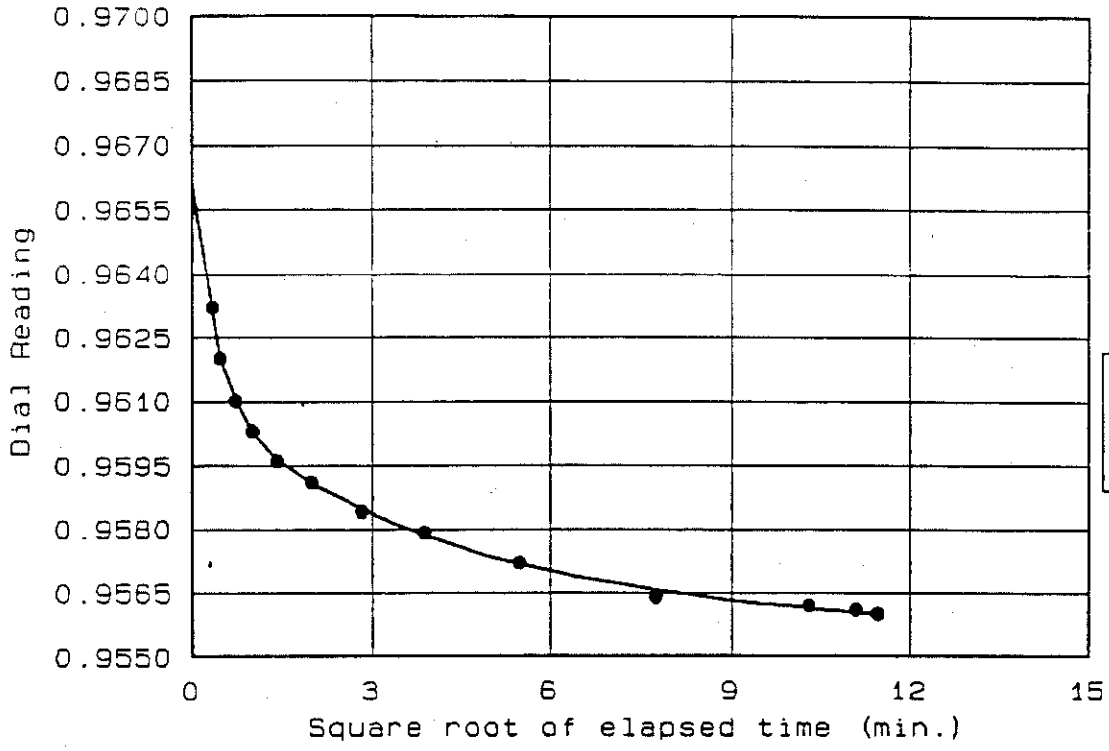
Load No.= 4
Load= 2.00 tsf
D_0 = 0.9942
D_{90} = 0.9881
D_{100}= 0.9875
T_{90}= 0.32 min.

C_v @ T_{90} =
6.1 ft^2/day

Dial Reading vs. Time

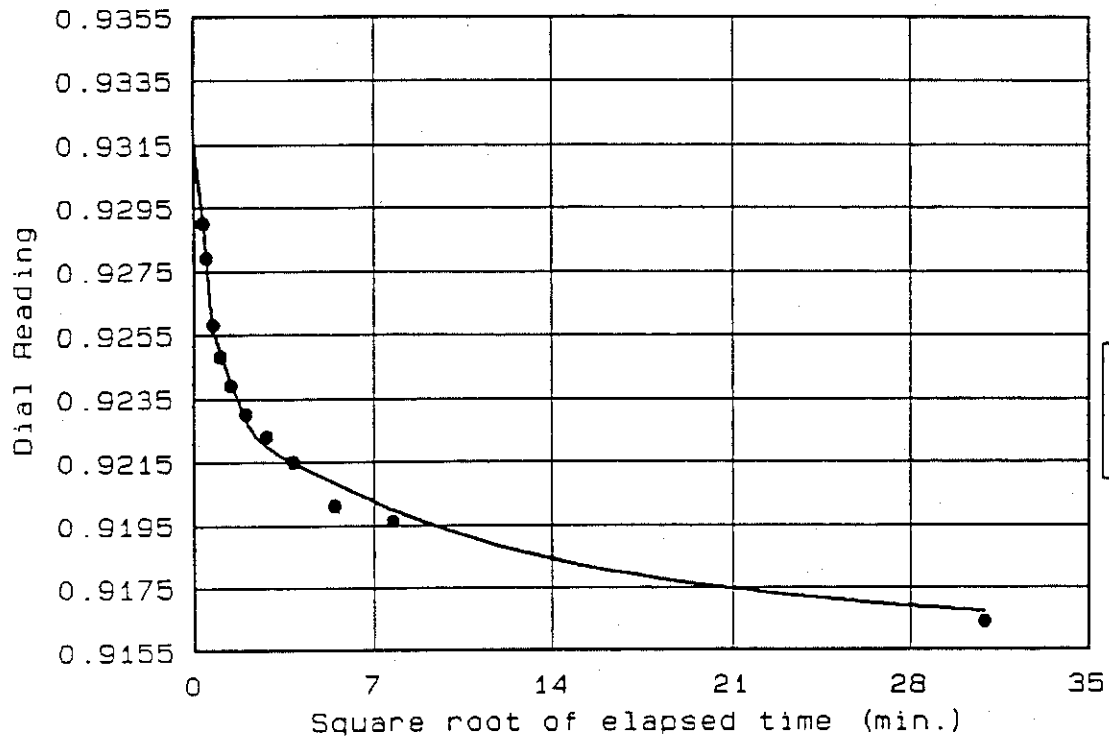
Project No.: 188.91
Project: AREA 1
Location: 908-25, 12-14.5'

Date: 05/21/90



Load No.= 9
Load= 4.00 tsf
D_0 = 0.9661
D_{90} = 0.9614
D_{100}= 0.9609
T_{90}= 0.34 min.

C_v @ T_{90} =
5.4 ft^2/day



Load No.= 10
Load= 8.00 tsf
D_0 = 0.9317
D_{90} = 0.9251
D_{100}= 0.9244
T_{90}= 0.80 min.

C_v @ T_{90} =
2.2 ft^2/day

FIGURES

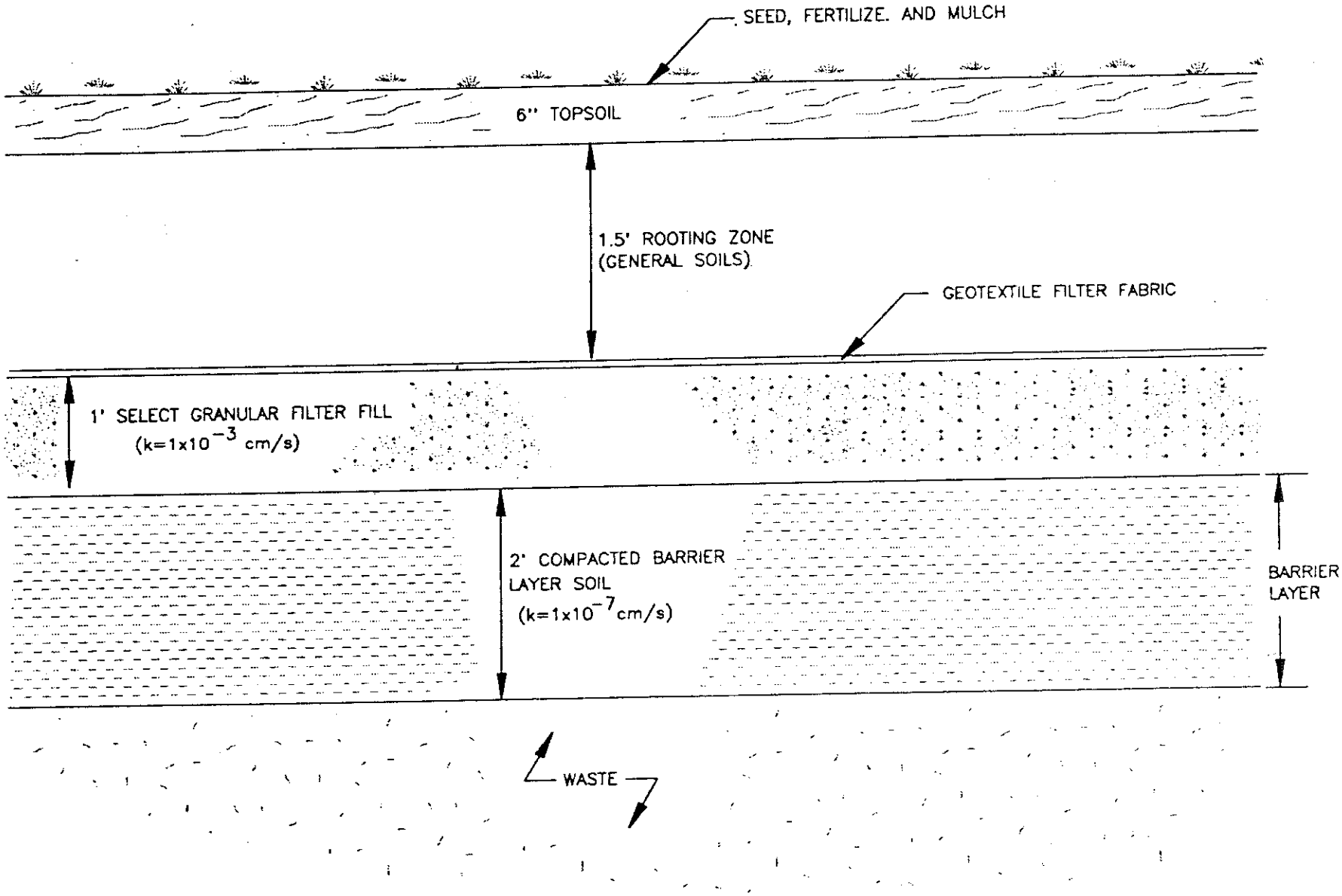
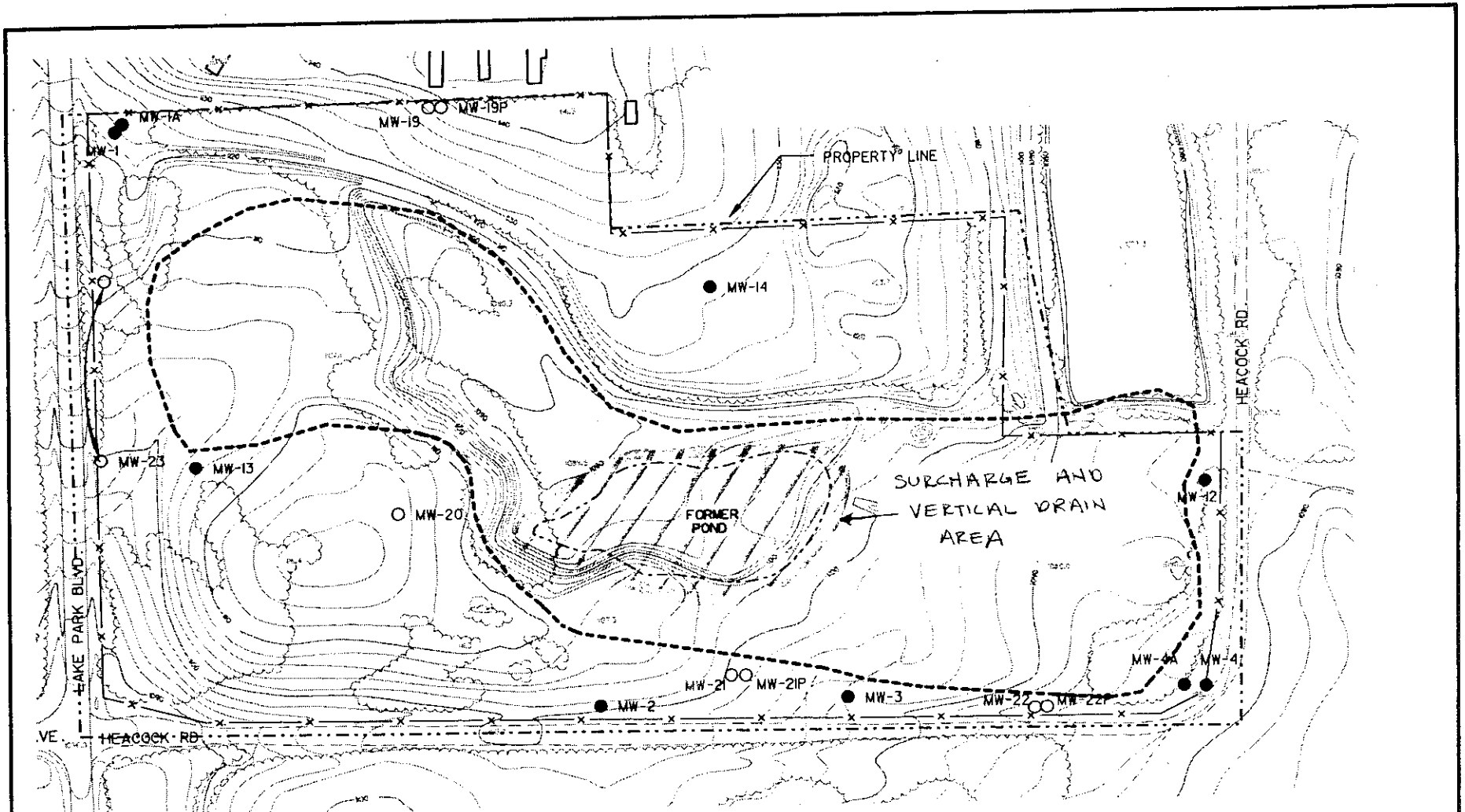


FIGURE 3

1
6B

FINAL COVER

NOT TO SCALE



LEGEND

- ● MONITORING WELL LOCATION
- ○ PROPOSED MONITORING WELL
- FORMER POND BOUNDARY
- TREES, BRUSH
- —×— FENCE LINE
- APPROXIMATE AREA OF WASTE PLACEMENT

NOTES:

1) CONTOUR INTERVAL IS 2 FEET
2) BASEMAP BY KBM, INC., GRAND FORKS, N.D. FROM AN AERIAL SURVEY BY KUCERA INTERNATIONAL ON NOV. 17, 1991.

0 100 200
SCALE: 1"=100'

SEBRING FACILITY
AMERICAN STEEL FOUNDRIES
ALLIANCE, OHIO

RMT INC.

Drawn By:	RJB
Approved By:	
Date:	FEBRUARY 1993
Proj. No.:	2169.02

FIGURE 4

Design File = 05.dgn
User ID = project
Plot File = 05.prf
Plot Date = Thu Jan 28 14:52:47 1993
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SETTLEMENT vs TIME

CENTER AREA (FORMER POND AREA)

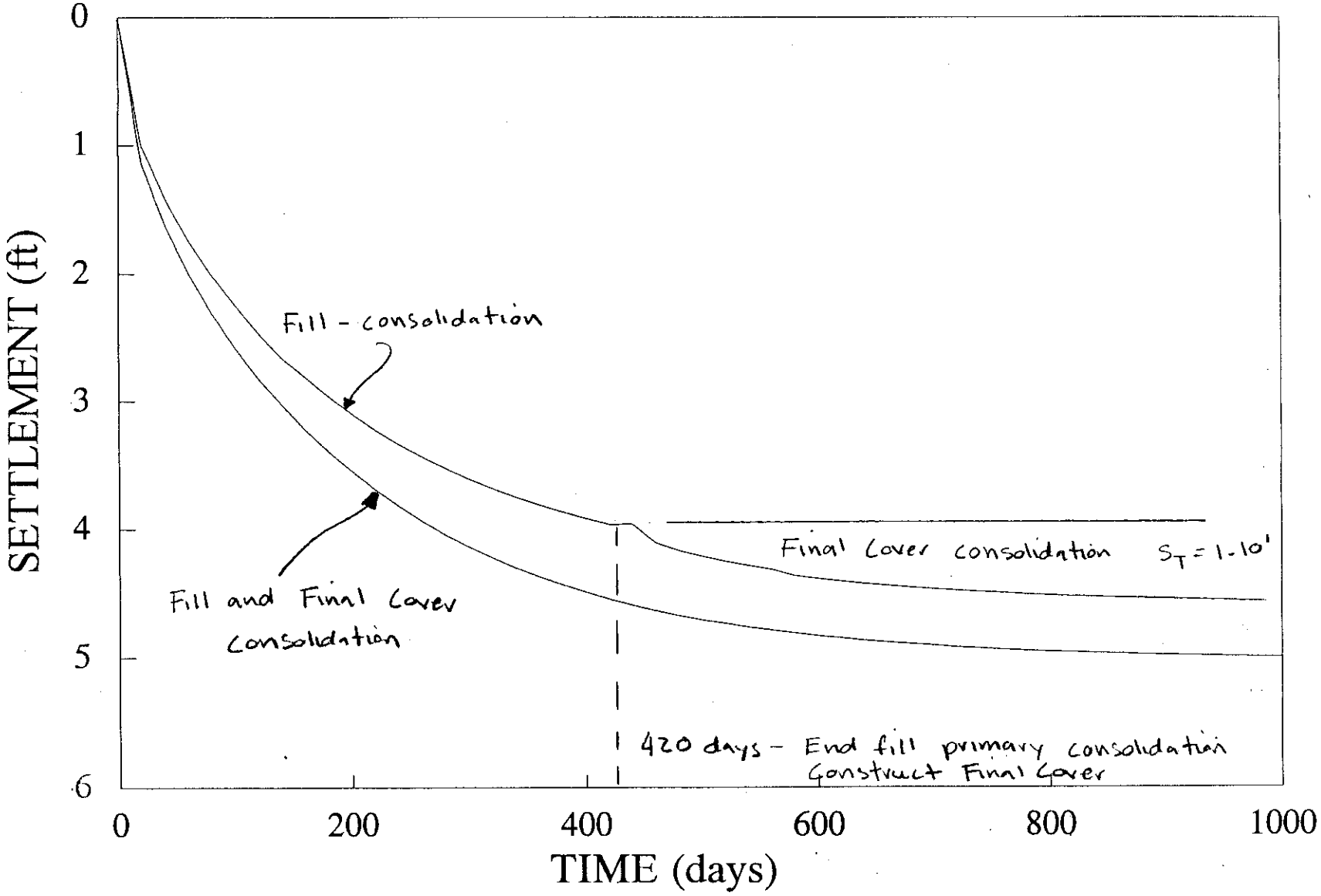
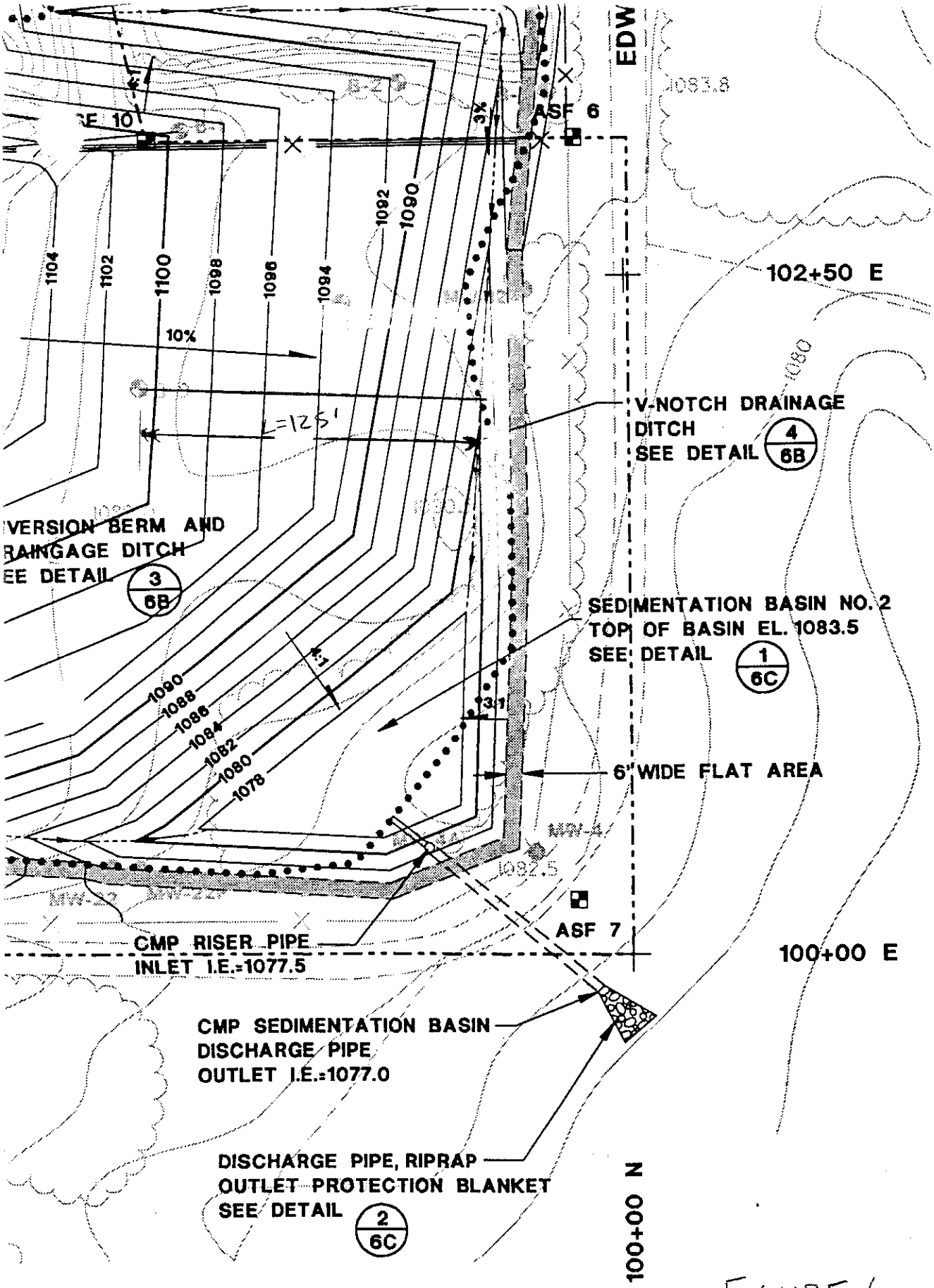


Figure 5



PROPERTY CORNER
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6. ALL AREAS WHERE
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7. FINAL COVER GRADE

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9. EXISTING LANDFILL
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PROJECT:

SHEET TITL

DRAWN BY:
CHECKED BY:
APPROVED BY:

FIGURE 6

Distance from B-9
to Edge of Waste

APPENDIX L

RECOMPACTED BARRIER LAYER TEST FILL PLAN

RECOMPACTED BARRIER LAYER TEST FILL PLAN

TABLE OF CONTENTS

- Introduction
- Test Fill Description
- Recompacted Barrier Layer
- Field Hydraulic Conductivity
- Sealed Dougle-Ring Infiltrometers
- Laboratory Testing
- References

APPENDIX L

AMERICAN STEEL FOUNDRY
RECOMPACTED BARRIER LAYER TEST FILL PLAN

DECEMBER 1994

APPENDIX L
TEST FILL PLAN

Introduction:

This test fill plan is being submitted as an appendix to the Closure Plan and is intended as a workplan of activities required for test pad construction under OAC 3745-30-08. As discussed in Section 4.3 of the Closure Plan, the cover system for the landfill will consist of a 2-foot-thick recompacted barrier layer. Test fills, constructed according to this Test Fill Plan, will be undertaken to evaluate and establish effective procedures for the placement of the low-hydraulic conductivity (i.e., permeability) material in the the final cover system (i.e., clay).

Test Fill Description:

During the test fill construction, the primary objective will be to confirm that the required soil property specifications can be consistently achieved with the same construction equipment and procedures as those that are to be used during full-scale construction. Field variables will be carefully measured and controlled in the test fill and during construction of the full-scale final cover recompacted barrier layer. These variables include the following:

- Compaction equipment
- Number of passes of the compaction equipment
- Method used to breakdown clods before compaction
- Method used to control and adjust moisture content
- Speed of the compaction equipment traveling over the liner
- Uncompacted and compacted lift thicknesses

Additional test fills will be constructed whenever significant changes occur in the cover material, equipment, or procedures used to construct the final cover recompacted barrier layer.

In order to meet the objective, the test fill area will be constructed with a minimum width of three times the width of the compaction equipment and a minimum length of two times the length of the compaction equipment.

The clay soil material to be used for construction of the test fill will be excavated from off-site soils and will be approved by the on-site representative.

The on-site representative will observe and document the clay soils being excavated from the borrow area with emphasis being placed on segregation and removal of unsuitable material; changes in color, texture, and moisture content; removal of rocks, cobbles, stumps, and roots; and removal of unsuitable materials. The clay used for the construction of this test will be representative of the off-site soils to be used in the landfill construction. The test fill will be comprised of at least six compacted lifts. The clay material will be placed in less than 8-inch-thick loose lifts.

During construction of the clay barrier layer, in-field density, and moisture content tests will be performed in various locations for each lift, including the full thickness of the first lift, to demonstrate the ability to place and compact the clay to the required specifications. The frequency of the density and moisture content testing, along with other field and laboratory testing, is discussed in subsequent sections

Fill placement and compaction means and methods will be carefully documented by the on-site representative. One pass of the compaction equipment is defined as follows:

> The contact of one drum or the drums of one side of a compactor with any given area of soil. Contacts need to be counted based on the number of times a compactor moves back and forth in a lane and also the amount of overlap of each lane as the compactor moves sideways across the test pad or liner.

Also, the on-site representative will closely observe and document the thickness of the uncompacted (loose) and compacted lifts, the physical properties of the test fill material, the characteristics of the construction surface under the compaction equipment (i.e., equipment penetration, pumping, and cracking).

Holes left in the clay from the probe of the nuclear density-moisture gauge will be filled with dry sodium bentonite. Holes left in the test fill from the removal of undisturbed samples using Shelby tubes also shall be filled with dry sodium bentonite. Although the methods used in the repair process will be documented, the repair process will not be necessary during full-scale cover construction since destructive testing is not planned on the actual compacted barrier layer.

Upon completion of the 3-foot clay barrier layer test pad, the final surface of the test fill will be rolled smooth to facilitate drainage. The top of clay grades will be surveyed and compared with the clay foundation grades to document final clay thickness.

Immediately following completion of the recompacted barrier layer and prior to performing the field hydraulic conductivity testing, a portion of the recompacted barrier layer will be removed and the freshly compacted fill will be examined for evidence of defects such as lift separation or inadequate clod compaction. The area will then be reconstructed and retested to evaluate the means and methods for recompaction of defective portions of the full-scale barrier layer.

During the field hydraulic conductivity testing, the test fill will be covered with a plastic tarp to minimize desiccation of the clay. Moisture will be added to the surface as needed to condition the clay and minimize cracking.

Select Clay Fill Barrier Layer:

One test fill representing the recompacted barrier layer for the final cover will be constructed over waste of the landfill. Testing will be performed to document that the recompacted barrier layer meets the hydraulic conductivity requirements. As a result, the test fill will adequately represent the conditions under which the recompacted barrier layer will be completed.

The clay will be placed in maximum 6-inch compacted lifts. Once a contractor is selected, the specific equipment and methods to be used will be finalized. As during construction of the recompacted barrier layer test fill, in-field density and moisture will be tested throughout each lift to demonstrate the ability to place and compact the clay to the required specifications. The frequency of the density and moisture testing shall be 3 per lift.

The on-site representative will observe and document fill placement, compaction means and methods, uncompacted (loose) and compacted lift thicknesses, physical properties of the test fill material, and the characterization of the construction surface. Holes resulting from the density and moisture content testing and Shelby tube sampling will be filled with dry sodium bentonite.

Upon completion of the 3-foot layer of recompacted barrier layer, the surface will be rolled smooth to facilitate drainage. The top of recompacted barrier layer grades will be surveyed and compared with the test fill subbase grades to document the thickness of the recompacted barrier layer. During the field hydraulic conductivity testing, the test fill will be covered with a plastic tarp to minimize desiccation of the recompacted barrier layer. Moisture will be added to the surface as needed to condition the layer and minimize cracking.

Field Hydraulic Conductivity:

Field hydraulic conductivity (permeability) testing will be performed on the final test fill surface at three locations. Sealed double-ring infiltrometers (SDRI) will be used for this testing.

Sealed Double-Ring Infiltrometers:

Sealed double-ring infiltrometers (SDRI) consist of a sealed inner ring and an open outer ring that are embedded into trenches and sealed with a bentonite grout. The rings are filled with water, and a small flexible bag is attached to the inner ring. The entire SDRI is covered with a tarpaulin. Periodically, the bag is removed and weighed to determine the quantity of flow, and when necessary, the bag is refilled. The sealed inner ring contains the volume of water used to measure the infiltration rate of the water into the liner system. The outer ring of water provides a flow of water to maintain vertical flow beneath the inner ring. Tensiometers are installed within the outer ring to measure the wetting front of the water permeating the liner system.

During the initial start up of each SDRI test, flow through the system will be observed every 3 or 4 hours. Weight measurements of the flexible bag attached to the inner ring will be taken, and the bag will be refilled with water before the bag is allowed to empty.

Initially, flow rates may be high, requiring measurements to be taken often. As the test progresses, the flow rate should slow and the length of time to empty the bag should increase to several days or weeks. Monitoring requirements will be adjusted as the test progresses to correspond to the reduction in the flow rate through the liner.

The acceptance criteria for the field testing will be a maximum hydraulic conductivity of 1×10^{-7} cm/s. Analysis of data collected from the field hydraulic conductivity tests will be performed to compare the results to the maximum hydraulic conductivity requirement.

Laboratory Testing:

Laboratory testing of the low-hydraulic conductivity materials will be performed on samples from the test fill clay borrow area and on in-place–compacted clay soils.

The on-site representative will collect a minimum of two samples from the test fill clay borrow area to determine soil characteristics prior to constructing the 3-foot clay barrier layer test pad. These samples will be part of the testing described in Subsection 6.2 of the Closure Plan to meet the requirements of OAC 3745-30-08(D).

Laboratory testing to determine soil characteristics will include the following:

Parameter	Test Method
Moisture/Density Relationship	ASTM D1557 or ASTM D698
Grain-Size Analysis	ASTM D422
Unified Soil Classification System	ASTM D2487
Moisture Content	ASTM D2216
Atterberg Limits	ASTM D4318
Hydraulic Conductivity	ASTM D5084

A minimum of six undisturbed samples will be taken per lift for each test pad. The samples will be submitted to the Soils Testing Laboratory for testing.

The undisturbed laboratory hydraulic conductivity test results will be compared to the field hydraulic conductivity test results. Laboratory compressive strength values will be compared to the field shear strength test results and will be used to confirm the strength values used in the design stability analysis.

References:

ASTM D5093-90. 1992. Field measurement of infiltration rate using a double-ring infiltrometer with a sealed inner ring. Annual Book of ASTM Standards. Volume 4.08.

Benson, Craig H. 1992. Field Measurement of Hydraulic Conductivity with Sealed Double-Ring Infiltrometers; Envotech Resource Center Landfill. July 1992.

Daniel, D.E., and S.J. Trautwein. 1986. Field permeability test for earthen liners. In: ASCE Specialty Conference on Use of In-Situ Tests in Geotechnical Engineering. Virginia Polytechnical Institute and State University, Blacksburg, Virginia. June 22-26, 1986.

Daniel, D.E. 1989. In-Situ Hydraulic Conductivity Tests for Compacted Clay. In: Journal of Geotechnical Engineering, Vol. 115, No. 9. September 1989.

EPA Technical Guidance Document EPA/530-SW-86-031. Construction Quality Assurance for Hazardous Waste Land Disposal Facilities. October 1986.

EPA Technical Resource Document EPA/530-SW-86-007-F. Design, Construction, and Evaluation of Clay Liners for Waste Management Facilities. November 1988.

EPA Project Summary EPA/600-52-91-002. State-of-the-art field hydraulic conductivity testing of compacted soils. July 1991.

APPENDIX M

SURFACE WATER CONTROL ANALYSIS

POST-DEVELOPMENT SURFACE WATER RUNOFF CALCULATIONS

TABLE OF CONTENTS

- Purpose/Methodologies/Assumptions/Results
- Surface Water Runoff Calculations

APPENDIX M

POST-DEVELOPMENT SURFACE WATER RUNOFF CALCULATIONS

Purpose:

The purpose of the surface water runoff calculations is to determine the peak runoff from the American Steel Foundries (ASF) Sebring Facility Landfill resulting from a 10-year, 24-hour storm event and a 100-year, 24-hour storm event. These peak runoff values will be used to demonstrate that the sedimentation basins are designed to provide storage below the principal spillway for the runoff volume of a 10-year, 24-hour storm event, and will safely discharge the runoff volume from a 100-year, 24-hour storm event without flowing over the maximum basin perimeter elevation. With this design, the surface water from the landfill is collected and discharged in a controlled manner.

Methodologies:

Drainage Area Determinations - For the ASF Landfill, surface water discharge calculations were performed for the post-closure development conditions. Drainage areas for the post-closure conditions were developed based on the flow patterns for each area. The drainage areas for the landfill are shown on Figure 4-1 in Section 4.

Hydrograph Generation Calculations - The hydrograph generation calculations is a process that involves determining rainfall quantities, storm distributions, surface run-off characteristics, drainage paths, time of concentrations, and travel times; and, in conjunction with the computer drainage program Quick TR-55, these calculations are used to estimate a peak flow from a drainage area.

The Quick TR-55 computer program developed by Haestad Methods was used to model the surface water hydrology at the ASF Landfill. The TR-55 methods for computing hydrographs included in the program are based on the methodologies presented in Technical Release No. 55 - "Urban Hydrology for Small Watersheds" by the United States Soil Conservation Service.

The time of concentrations and travel times for the post-development conditions were calculated using the Quick TR-55 program. These calculations combine overland flow time, shallow concentrated flow time, and channel flow time to obtain a total time of concentration for the area being evaluated. The travel time is then calculated as the time for water to flow from the discharge of the individual drainage area to the discharge of the drainage basin (for example, into the sedimentation basin).

Assumptions:

Storm Event - The following assumptions, which were based upon information provided by the Ohio Environmental Protection Agency, the OEPA, and the U.S. Department of Agriculture, Soil Conservation Service Engineering Division (Technical Release No. 55), were used to characterize the storm events:

1. An SCS Type II storm was selected according to SCS storm distribution maps for the United States.

2. For the post-closure landfill conditions, an SCS run-off curve number of 86 was used based on information provided by the OEPA which represents pasture or range land in poor condition, based on values provided by Technical Release No. 55.

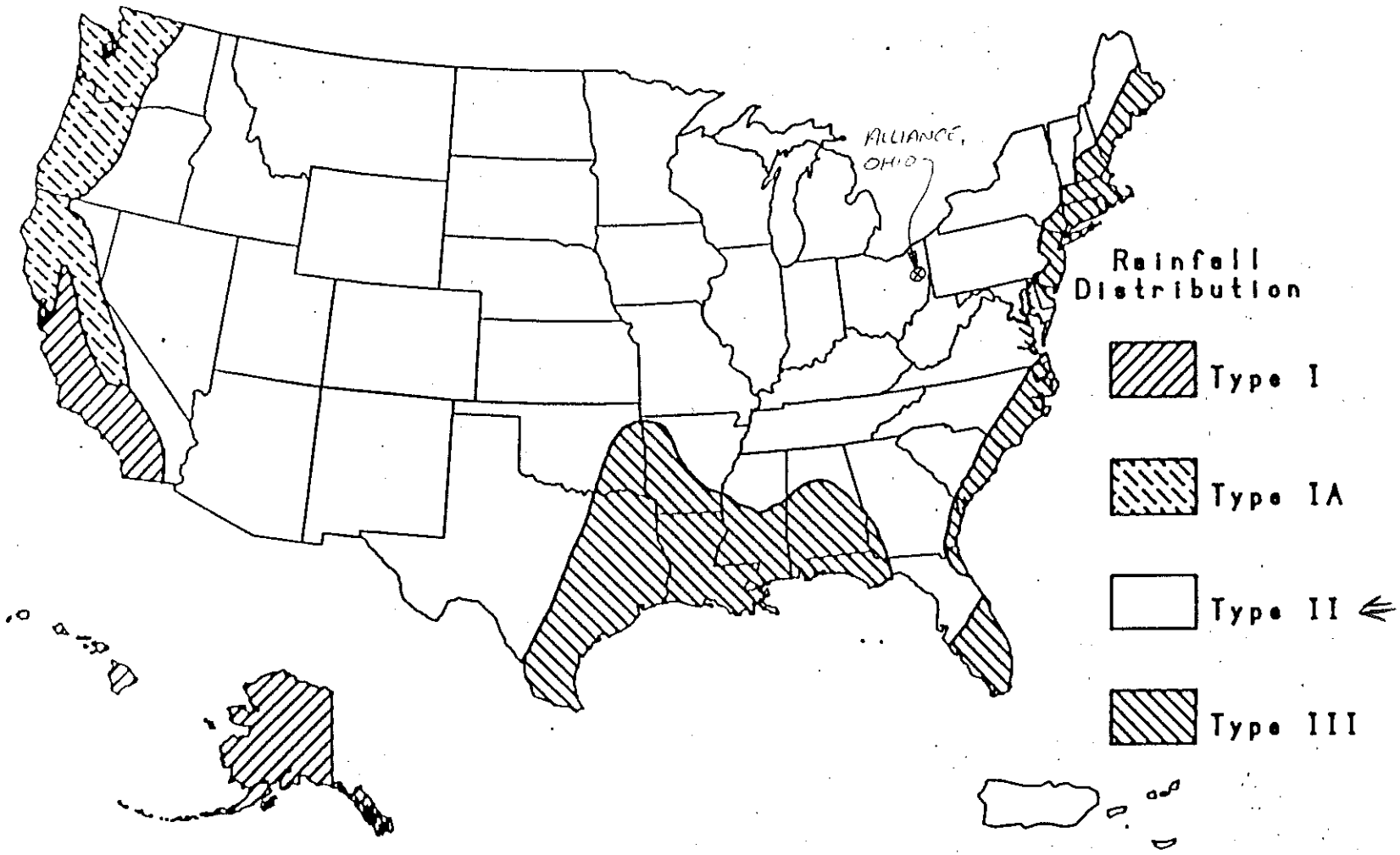
3. A 10-year, 24-hour storm event in the vicinity of the facility equates to 3.6 inches according to figures provided in TR-55.

4. A 100-year, 24-hour storm event in the vicinity of the landfill equates to 4.9 inches according to figures provided in TR-55.

Results:

Based on the surface water run-off analysis, the peak discharge to Sedimentation Basin #1 is 17 cfs for the 10-year, 24-hour storm event and 25 cfs for the 100-year, 24-hour storm event. The peak discharge to the Sedimentation Basin #2 is 6 cfs for the 10-year, 24-hour storm event and 9 cfs for the 100-year, 24-hour storm event. Peak run-off quantities for the individual drainage areas are summarized on Output Sheets 8, 10, 12, and 14 of 42 of the following calculations.

SITE HYDROLOGIC DATA



.—Approximate geographic boundaries for SCS rainfall distributions.

(FROM TR-55 JUNE, 1986)

CONTERMINOUS UNITED STATES

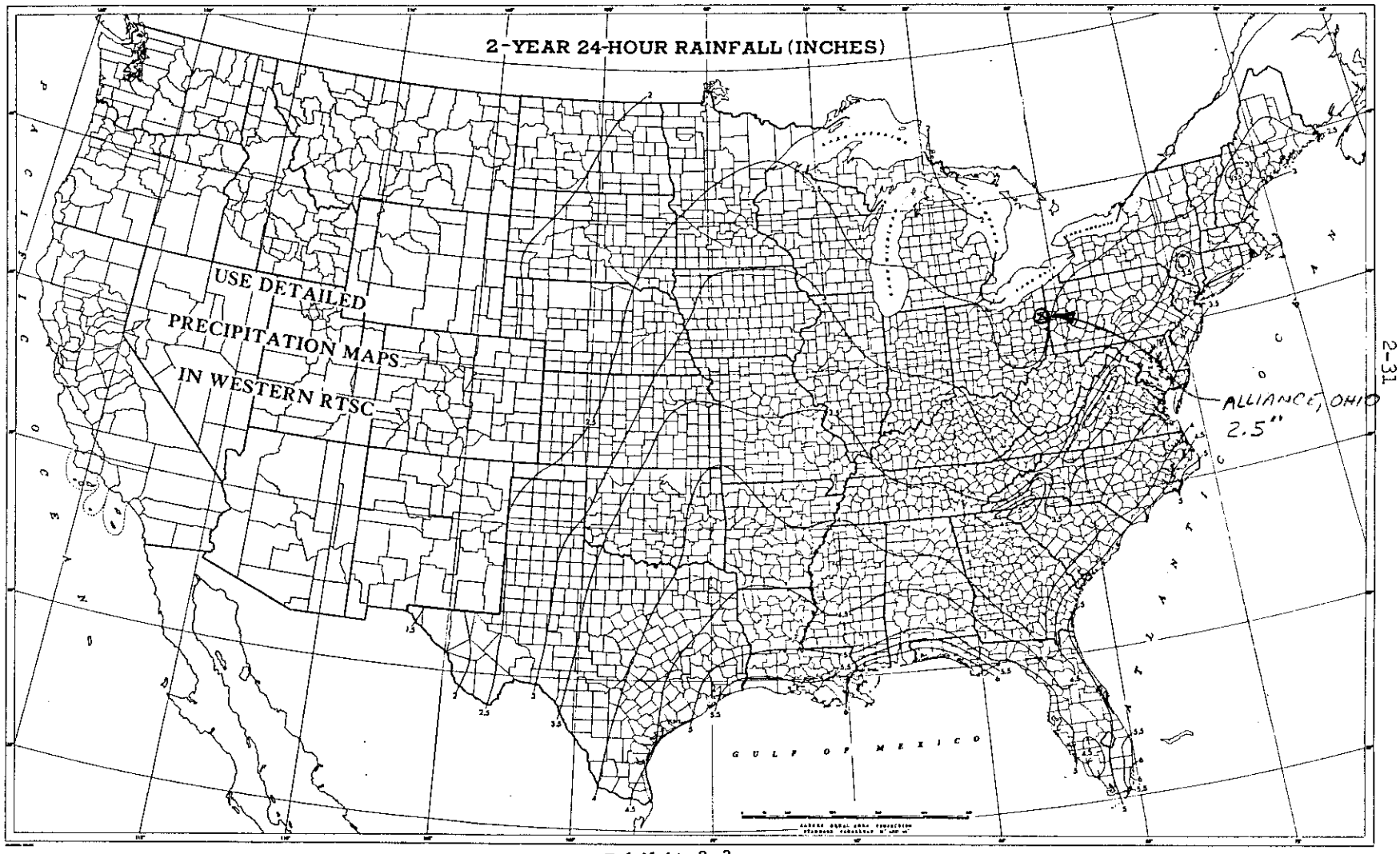
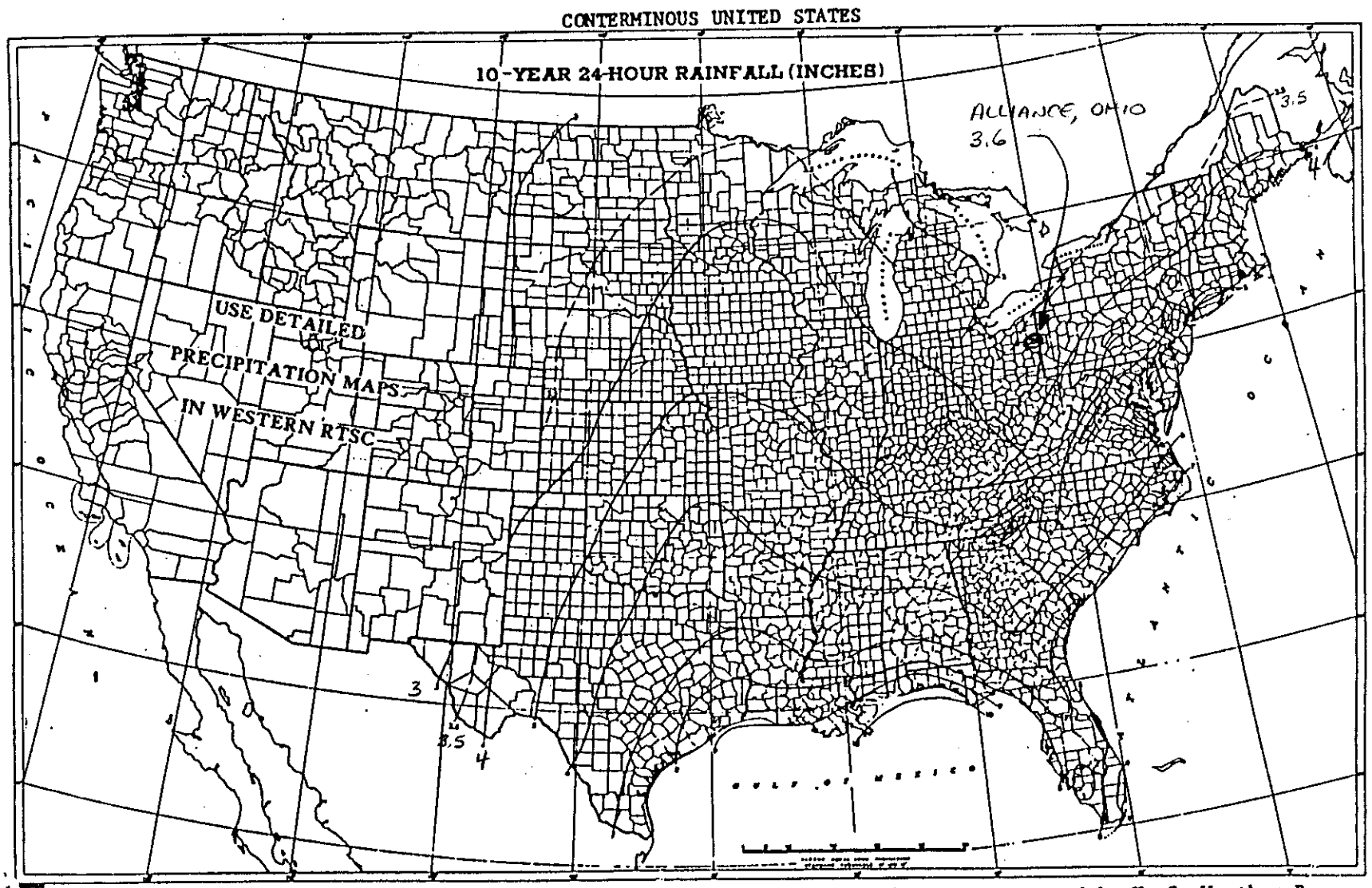


Exhibit 2-3
Sheet 1 of 5

Prepared by U. S. Weather Bureau

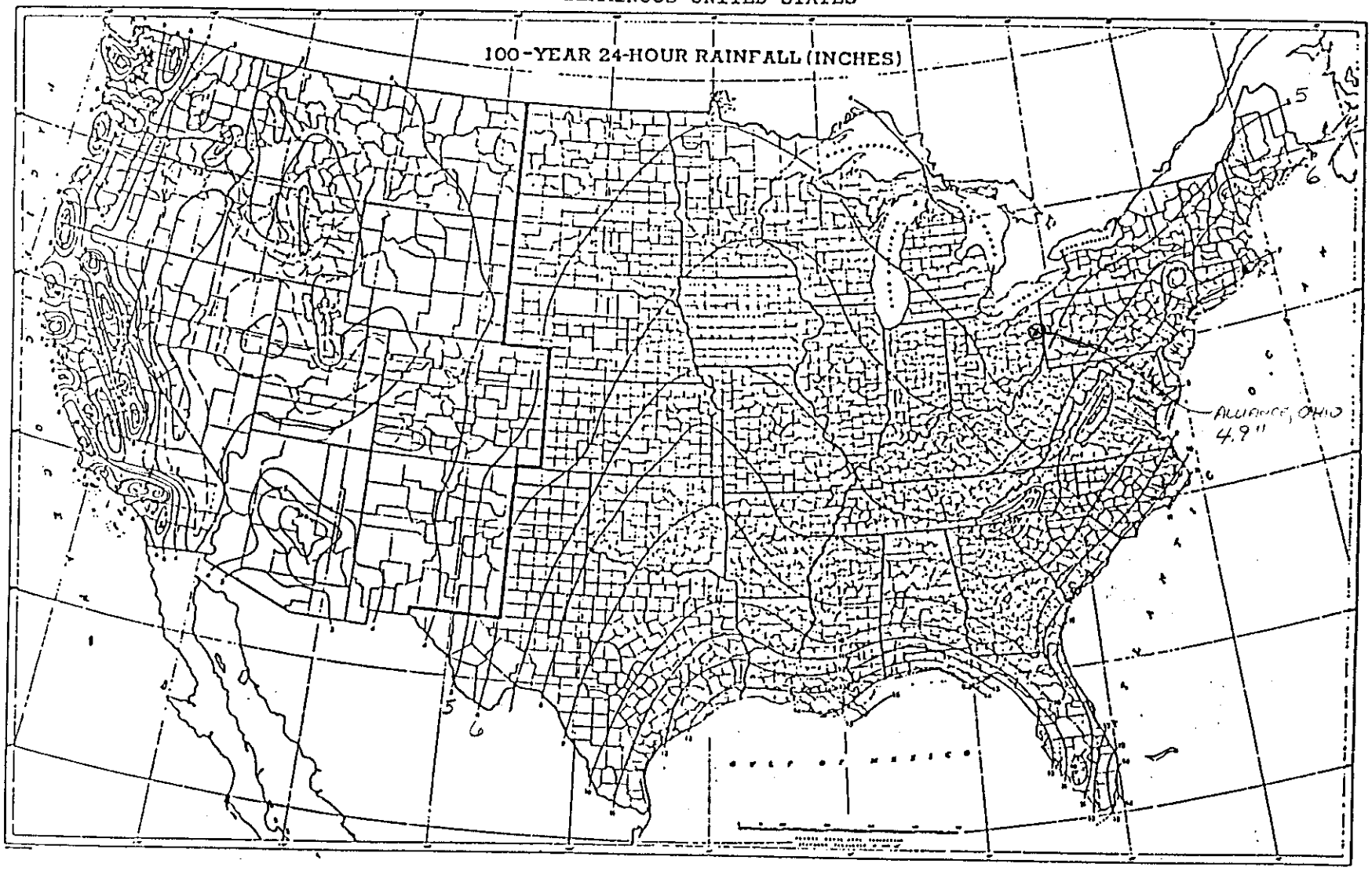
FROM TR NO. 55, 1975, REVISE 1981



Prepared by U. S. Weather Bureau

FROM: Urban Hydrology for Small Watersheds. [n.p.]: U.S. Department of Agriculture. Soil Conservation Service. Engineering Division, (Technical Release No. 55). 1975, as revised 1981.

CONTERMINOUS UNITED STATES



Prepared by U. S. Weather Bureau

FROM: Urban Hydrology for Small Watersheds. [n.p.]: U.S. Department of Agriculture. Soil Conservation Service Engineering Division, (Technical Release No. 55). 1975, as revised 1981.

Table 2-2c.—Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
		RECOMMENDED BY OEPA			
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	[4]30	48	65	73
Woods—grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	[4]30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1]Average runoff condition, and $I_a = 0.2S$.

[2]*Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

[3]*Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

[4]Actual curve number is less than 30; use CN = 30 for runoff computations.

[5]CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

[6]*Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,s^{0.4}} \qquad \text{[Eq. 3-3]}$$

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

where

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1),
L = flow length (ft),
P_2 = 2-year, 24-hour rainfall (in), and
s = slope of hydraulic grade line (land slope, ft/ft).

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

SURFACE WATER RUNOFF CALCULATIONS

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 10 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 11-11-1994 10:02:23
Watershed file: --> A:BASIN-1 .MOP
Hydrograph file: --> A:1-10YR.HYD

VBJK 11/15/94

AMERICAN STEEL FOUNDRIES
SEBRING FACILITIES
ALLIANCE, OHIO
PROJECT # 2169.30

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
1-A	4.30	86.0	0.30	0.00	3.60	2.19	I.09	.10
1-B	4.20	86.0	0.50	0.00	3.60	2.19	I.09	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 8.50 acres or 0.01328 sq.mi
Peak discharge = 17 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
1-A	0.33	0.00	0.30	0.00	No	Computed Ia/p < .1
1-B	0.47	0.00	0.50	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 10 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 11-11-1994 10:02:23
Watershed file: --> A:BASIN-1 .MOP
Hydrograph file: --> A:1-10YR.HYD

VBJK 11/15/94

AMERICAN STEEL FOUNDRIES
SEBRING FACILITIES
ALLIANCE, OHIO
PROJECT # 2169.30

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
1-A	10	12.2
1-B	8	12.4
Composite Watershed	17	12.3

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 100 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 11-11-1994 10:02:23
Watershed file: --> A:BASIN-1 .MOP
Hydrograph file: --> A:1-100YR.HYD

VBJr 11/15/94

AMERICAN STEEL FOUNDRIES
SEBRING FACILITIES
ALLIANCE, OHIO
PROJECT # 2169.30

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
1-A	4.30	86.0	0.30	0.00	4.90	3.37	I.07	.10
1-B	4.20	86.0	0.50	0.00	4.90	3.37	I.07	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 8.50 acres or 0.01328 sq.mi
Peak discharge = 25 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
1-A	0.33	0.00	0.30	0.00	No	Computed Ia/p < .1
1-B	0.47	0.00	0.50	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 100 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 11-11-1994 10:02:23
Watershed file: --> A:BASIN-1 .MOP
Hydrograph file: --> A:1-100YR.HYD

VBJR 11/15/94

AMERICAN STEEL FOUNDRIES
SEBRING FACILITIES
ALLIANCE, OHIO
PROJECT # 2169.30

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
1-A	15	12.2
1-B	12	12.4
Composite Watershed	25	12.3

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 10 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 11-11-1994 10:03:52
Watershed file: --> A:BASIN-2 .MOP
Hydrograph file: --> A:2-10YR.HYD

VBJK 11/15/94

AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
BASIN #2 (PROJECT # 2169.30)

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
2-A	1.00	86.0	0.20	0.00	3.60	2.19	I.09	.10
2-B	1.30	86.0	0.30	0.00	3.60	2.19	I.09	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 2.30 acres or 0.00359 sq.mi
Peak discharge = 6 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
2-A	0.20	0.00	**	**	No	Computed Ia/p < .1
2-B	0.29	0.00	0.30	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Return Frequency: 10 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 11-11-1994 10:03:52
Watershed file: --> A:BASIN-2 .MOP
Hydrograph file: --> A:2-10YR.HYD

AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
BASIN #2 (PROJECT # 2169.30)

VBJL 11/15/94

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
2-A	3	12.1
2-B	3	12.2
Composite Watershed	6	12.2

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 100 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 11-11-1994 10:03:52
Watershed file: --> A:BASIN-2 .MOP
Hydrograph file: --> A:2-100YR.HYD

VBJL 11/15/94

AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
BASIN #2 (PROJECT # 2169.30)

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
2-A	1.00	86.0	0.20	0.00	4.90	3.37	I.07	.10
2-B	1.30	86.0	0.30	0.00	4.90	3.37	I.07	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 2.30 acres or 0.00359 sq.mi
Peak discharge = 9 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
2-A	0.20	0.00	**	**	No	Computed Ia/p < .1
2-B	0.29	0.00	0.30	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 11-11-1994 10:03:52
Watershed file: --> A:BASIN-2 .MOP
Hydrograph file: --> A:2-100YR.HYD

AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
BASIN #2 (PROJECT # 2169.30)

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
2-A	4	12.1
2-B	5	12.2
Composite Watershed	9	12.2

SEDIMENTATION BASIN DESIGN CALCULATIONS

TABLE OF CONTENTS

- Purpose/Methodologies/Assumptions/Results
- Sedimentation Basin Design Calculations
- Sedimentation Basin #1 Contour/Volume Data
- Sedimentation Basin #1 Outlet Structure Data
- Sedimentation Basin #1 Routing Calculations
- Sedimentation Basin #2 Contour/Volume Data
- Sedimentation Basin #2 Outlet Structure Data
- Sedimentation Basin #2 Routing Calculations
- Outlet Pipe Riprap Sizing Calculations
- Ditch Diversion Berm Sizing Calculations
  - Purpose/Methodologies/Assumptions/Results
  - Ditch and Diversion Berm Design Calculations

SEDIMENTATION BASIN DESIGN CALCULATIONS

Purpose:

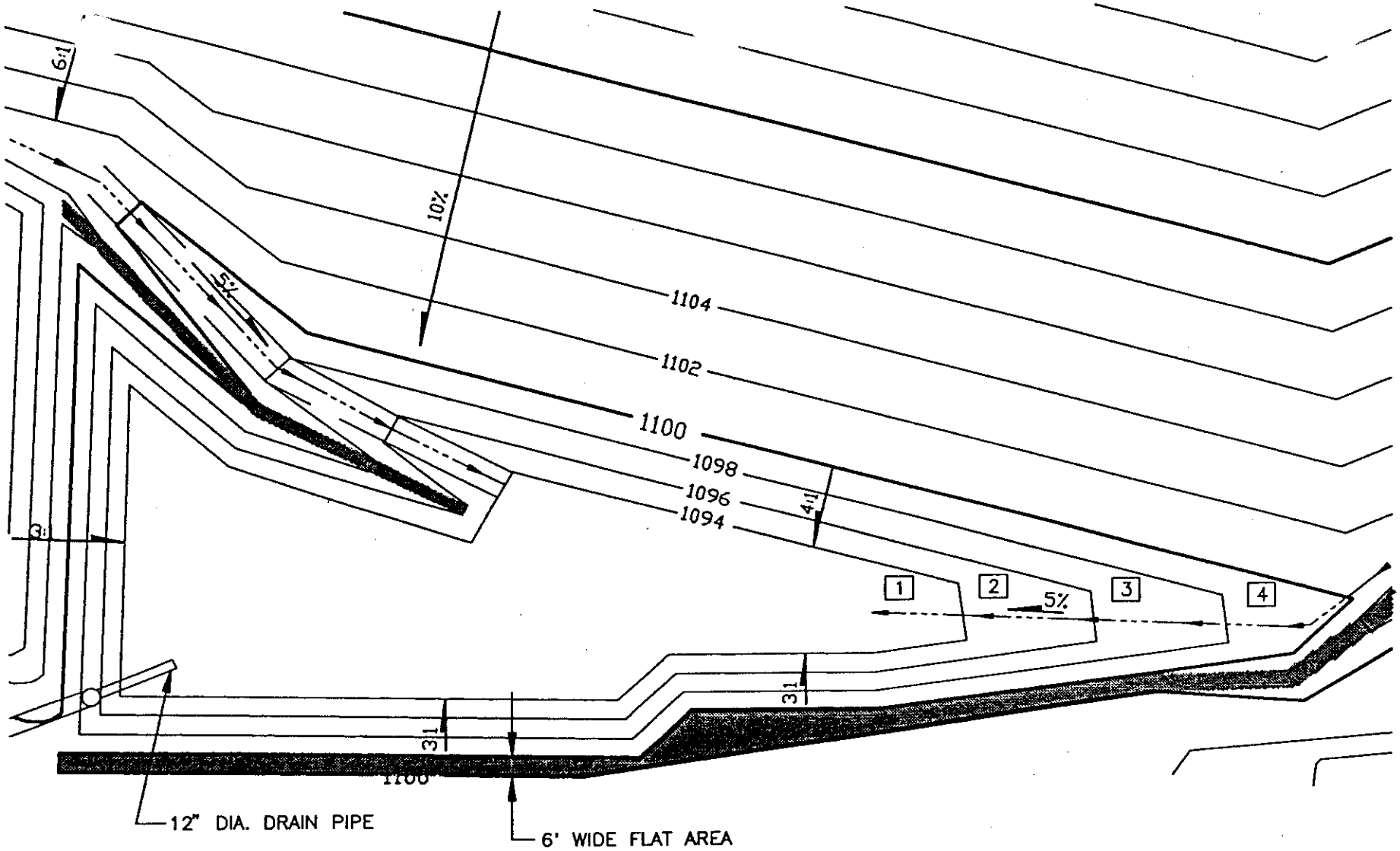
The purpose of the sedimentation design calculations is to demonstrate that the sedimentation basins are designed to adequately provide storage volume and to remove the sediment loads resulting from the design storm event. The sedimentation basins at the ASF Landfill have been sized to store the volume of runoff from a 10-year, 24-hour storm event below the inlet to the principal spillway pipe and to remove a 20-micron particle for the 100-year, 24-hour storm event. The basins evaluated in this analysis include Sedimentation Basin #1 and Sedimentation Basin #2.

Methodologies:

Sedimentation Basin Contour Data and Outlet Structure Data - The volumes of the sedimentation basins were computed using the Pond-2 computer program developed by Haestad Methods. Surface areas were digitized for various basin elevations and input into the program (see Figures P-1 and P-2 of this Appendix). Pond-2 then computes the basin volumes using the conic method to compute the incremental volume between basin contours.

Outlet structures for the sedimentation basins were also evaluated using the Pond-2 program. The program computes an elevation-discharge rating table for each structure defined. The outlet structure data, along with the pond volume data, are used in the routing of storms through the basins.

Sedimentation Basin Routing - The sedimentation basin routing involved routing the design storm through each of the sedimentation basin designs. The storm routing was performed using the Pond-2 computer program. The program routes hydrographs generated during the hydrograph generation calculations (included in this Appendix) through the ponds specified. From the routing calculations, information on the peak flow, peak discharge, high water elevation, and maximum storage of the basins are obtained.



1 =SURFACE AREA AT EL. 1094=13,880 FT. SQ.

2 =SURFACE AREA AT EL. 1096=20,035 FT. SQ.

3 =SURFACE AREA AT EL. 1098=27,316 FT. SQ.

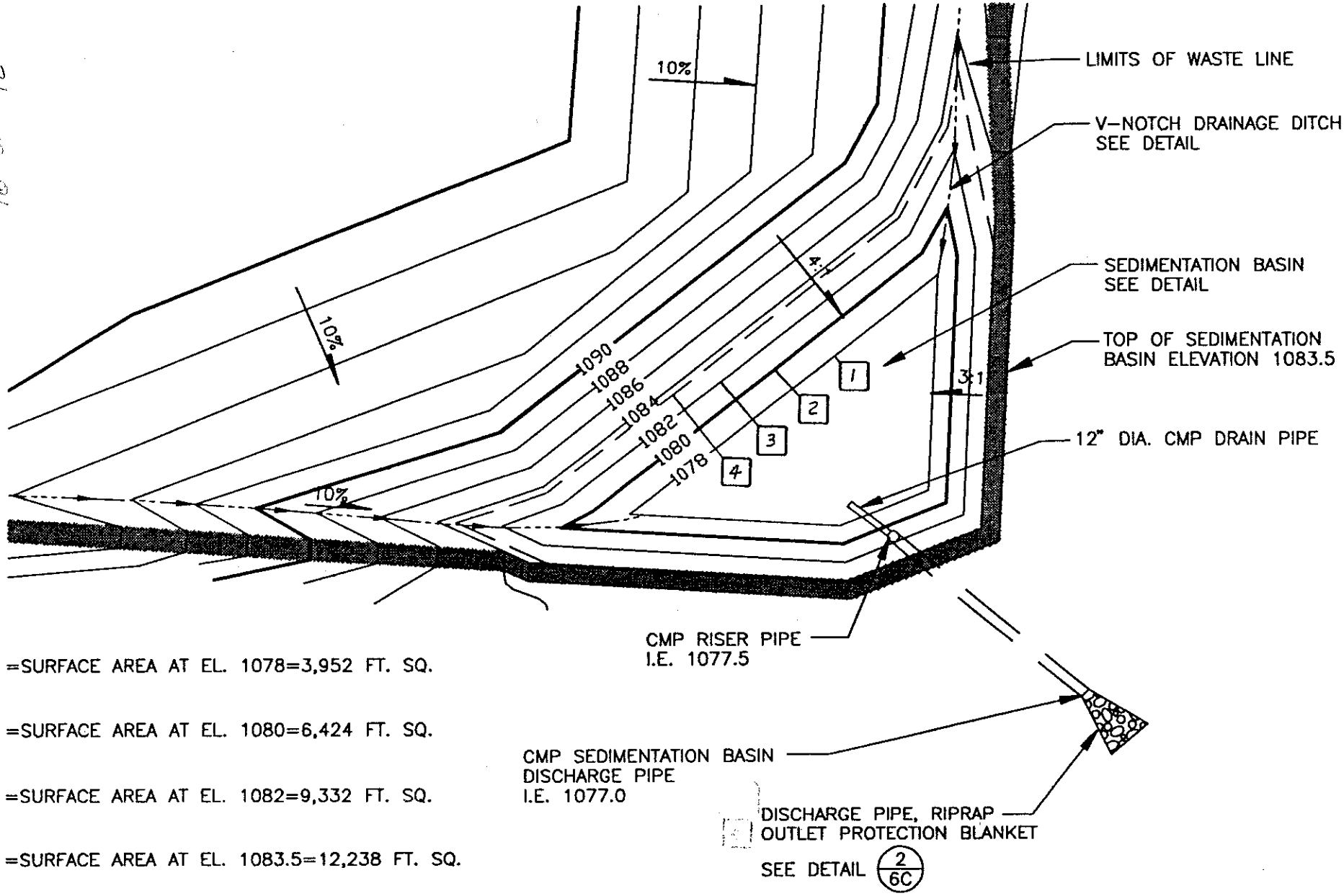
4 =SURFACE AREA AT EL. 1100=35,828 FT. SQ.

PLAN VIEW SEDIMENTATION BASIN NO. 1

(NOT TO SCALE)

RMT.

FIGURE P-1



1 =SURFACE AREA AT EL. 1078=3,952 FT. SQ.

2 =SURFACE AREA AT EL. 1080=6,424 FT. SQ.

3 =SURFACE AREA AT EL. 1082=9,332 FT. SQ.

4 =SURFACE AREA AT EL. 1083.5=12,238 FT. SQ.

PLAN VIEW SEDIMENTATION BASIN NO. 2

(NOT TO SCALE)

RMT. INC

FIGURE P-2

Assumptions:

The following assumptions were used to perform the sedimentation basin sizing computations:

1. A 20-micron particle size was targeted to be settled out by the sedimentation basins. The 20-micron particle is classified as a medium silt by the AASHTO Soil Classification System. A minimum surface area of 1,250 ft^2 per cfs of discharge is required to settle out a 20-micron particle. Calculations show that Sedimentation Basin #1 has a surface area of 3,704 ft^2 per cfs and that Sedimentation Basin #2 has 4,990 ft^2 per cfs of discharge

2. A minimum freeboard of 1 foot is assumed from the high water elevation to the top of the basin perimeter elevation. No emergency spillway is assumed with this sedimentation basin dug-out design because no berms will be needed.

3. Because no emergency spillway is included in this design, the entire volume of water generated from a 100-year, 24-hour storm event with discharge through the principal spillway will be stored below the top elevation of each sedimentation basin with an additional 1-foot (minimum) freeboard included.

Results:

The peak runoff volume for a 10-year, 24-hour storm event is 2.19 inches per acre (see Sheet 7 of 42). This equates to 1.55 acre-feet per the 8.5 acres draining to Sedimentation Basin #1 and 0.40 acre-feet for the 2.2 acres draining to Sedimentation Basin #2. For Sedimentation Basin #1, the top of the principal spillway is at elevation 1,097.5. This provides 1.67 acre-feet of storage, which is greater than the required 1.55 acre-feet (see Sheet 19 of 42). For Sedimentation Basin #2, the top of the principal spillway is at elevation 1,081.0. This provides 0.42 acre-feet of storage, which is greater than the 0.40 acre-feet required (see Sheet 33 of 42).

To maintain and safely discharge the volume of runoff from a 100-year, 24-hour storm event, the minimum elevation for the perimeter of Sedimentation Basin #1 must be 1,098.64 (see Sheet 28 of 42). The designed perimeter elevation for Sedimentation Basin #1 with this closure plan is 1,100.0, providing 1.36 feet of additional freeboard. The minimum elevation for the perimeter of Sedimentation Basin #2 must be 1,082.18 (see Sheet 38 of 42). The designed perimeter elevation for Sedimentation Basin #2 with this closure plan is 1,083.2, providing 1.02 feet of additional freeboard.

Based on the sedimentation basin sizing calculations, all sedimentation basins are sized adequate to remove a 20-micro particle. Basin layout information and design details are shown on Engineering Plan Sheet 3B and on Detail Sheet 6C. The peak discharges from Sedimentation Basins #1 and #2 are 25.0 and 9.0 cfs, respectively for the 100-year, 24-hour storm event.

SEDIMENTATION BASIN DESIGN CALCULATIONS

COMPUTATION SHEET

RMT INC.

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
ASF	[illegible]	11-14-92	BJK	11-16-94	216930

BASIN # 1 → REQUIRED STORAGE BELOW PRINCIPAL OUTLET PIPE INLET

AREA 1A AND 1B = 368,497 ft² ÷ 43560 = 8.5 ACRES

- STORAGE VOL. = 1.06 AC. ft / YR. (0.125 × 8.5)
- 10 YR/24 HR VOL = 1.55 Ac ft/YR (2.19 ÷ 12) 8.5
  ↑ RUNOFF INCHES

STORAGE → 1.55 > 1.06 USE 1.55 AC. ft

COMPUTATION SHEET

RMT INC.
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
ASF	[illegible]	11-1-94	BJK	11/16/94	2169.30

BASIN #2 → REQUIRED STORAGE BELOW PRINCIPLE OUTLET PIPE INLET

AREA 2A AND AREA 2B = 96,057 ft^2 ÷ 43560 = 2.2 ACRES

- STORAGE VOL. = .28 AC. ft/YR (0.125 × 2.2)
- 10 YR/24 HR. VOL. = .40 AC. ft/YR (2.19 ÷ 12) 2.2

STORAGE → .40 > .28 USE .40 AC. ft

SEDIMENTATION BASIN #1 CONTOUR/VOLUME DATA

POND-2 Version: 5.17
S/N:

AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
PROJECT # 2169.30

CALCULATED 12-09-1994 13:57:00
DISK FILE: b:BASIN-1A.VOL

* STORAGE [illegible] 1.55

Planimeter scale: 1 inch = 1 ft.

Elevation (ft)	Planimeter (sq.in.)	Area (acres)	A1+A2+sqr(A1*A2) (acres)	* Volume (acre-ft)	Volume Sum (acre-ft)
1,093.00	0.00	0.00	0.00	0.00	0.00
1,094.00	13,880.00	0.32	0.32	0.11	0.11
1,095.00	16,958.00	0.39	1.06	0.35	0.46
1,096.00	20,035.00	0.46	1.27	0.42	0.88
1,097.00	23,676.00	0.54	1.50	0.50	1.38
1,097.50	25,496.00	0.59	1.69	0.28	1.67
1,098.00	27,316.00	0.63	1.82	0.30	1.97
1,099.00	31,572.00	0.72	2.03	0.68	2.65
1,100.00	35,828.00	0.82	2.32	0.77	3.42

> 1.55 *

IA = (sq.rt(Area1) + ((Ei-E1)/(E2-E1))*(sq.rt(Area2)-sq.rt(Area1)))^2

where: E1, E2 = Closest two elevations with planimeter data
Ei = Elevation at which to interpolate area
Area1,Area2 = Areas computed for E1, E2, respectively
IA = Interpolated area for Ei

* Incremental volume computed by the Conic Method for Reservoir Volumes.

Volume = (1/3) * (EL2-EL1) * (Area1 + Area2 + sq.rt.(Area1*Area2))

where: EL1, EL2 = Lower and upper elevations of the increment
Area1,Area2 = Areas computed for EL1, EL2, respectively
Volume = Incremental volume between EL1 and EL2

SEDIMENTATION BASIN #1 OUTLET STRUCTURE DATA

Outlet Structure File: BASIN-1A.STR

POND-2 Version: 5.17 S/N:
Date Executed: Time Executed:

OUTLET STRUCTURE DATA

****
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
PROJECT # 2169.30
****

✓BJK 11/16/94

Outflow Rating Table A
Table A = 1 ? 2

Elevation (ft)	Q (cfs)	Contributing Structures
1093.00	0.0	-
1093.50	0.0	-
1094.00	0.0	-
1094.50	0.0	-
1095.00	0.0	-
1095.50	0.0	-
1096.00	0.0	-
1096.50	0.0	-
1097.00	0.0	-
1097.50	0.0	2
1098.00	7.4	2
1098.50	8.0	1
1099.00	8.4	1
1099.50	8.8	1
1100.00	9.1	1

Outlet Structure File: BASIN-1A.STR

POND-2 Version: 5.17 S/N:
Date Executed: Time Executed:

****
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
PROJECT # 2169.30
****

✓BJK
11/16/94

Outlet Structure File: b:BASIN-1A.STR
Planimeter Input File: b:BASIN-1A.VOL
Rating Table Output File: b:BASIN-1A.PND

Min. Elev.(ft) = 1093 Max. Elev.(ft) = 1100 Incr.(ft) = .5

Additional elevations (ft) to be included in table:
* *

****
SYSTEM CONNECTIVITY
****

Structure	No.	Q Table		Q Table
CULVERT-CR	1		->	1
STAND PIPE	2	? 1	->	A

Outflow rating table summary was stored in file:
b:BASIN-1A.PND

Outlet Structure File: BASIN-1A.STR

POND-2 Version: 5.17 S/N:
Date Executed: Time Executed:

****
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
PROJECT # 2169.30
****

VBJK 11/16/94

>>>>>> Structure No. 1 <<<<<<
(Input Data)

CULVERT-CR
Circular Culvert (With Inlet Control)

E1 elev.(ft)?	1097.5
E2 elev.(ft)?	1100.001
Diam. (ft)?	1.00
Inv. el.(ft)?	1093
Slope (ft/ft)?	.0174
T1 ratio?	
T2 ratio?	
K Coeff.?	.0210
M Coeff.?	1.33
c Coeff.?	.0463
Y Coeff.?	.75
Form 1 or 2?	1
Slope factor?	-.5

SEE PAGE 26 OF 42 FOR DESIGN VALUES.

Outlet Structure File: BASIN-1A.STR

POND-2 Version: 5.17 S/N:
Date Executed: Time Executed:

```
************************
AMERICAN STEEL FOUNDRIES
    SEBRING FACILITY
     ALLIANCE, OHIO
    PROJECT # 2169.30
************************
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VBJK 11/16/94

>>>>>> Structure No. 2 <<<<<<
(Input Data)

STAND PIPE
Stand Pipe with weir or orifice flow

E1 elev.(ft)?	1097.5
E2 elev.(ft)?	1100.001
Crest elev.(ft)?	1097.5
Diameter (ft)?	2
Weir coefficient?	3.33
Orifice coefficient?	.63
Start transition elev.(ft) @ ?	
Transition height (ft)?	

Outlet Structure File: BASIN-1A.STR

POND-2 Version: 5.17 S/N:
Date Executed: Time Executed:

****
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
PROJECT # 2169.30
****

Outflow Rating Table for Structure #1
CULVERT-CR Circular Culvert (With Inlet Control)

***** INLET CONTROL ASSUMED *****

Elevation (ft)	Q (cfs)	Computation Messages
1093.00	0.0	E < El=1097.5
1093.50	0.0	E < El=1097.5
1094.00	0.0	E < El=1097.5
1094.50	0.0	E < El=1097.5
1095.00	0.0	E < El=1097.5
1095.50	0.0	E < El=1097.5
1096.00	0.0	E < El=1097.5
1096.50	0.0	E < El=1097.5
1097.00	0.0	E < El=1097.5
1097.50	7.1	Submerged: HW =4.5
1098.00	7.5	Submerged: HW =5.0
1098.50	8.0	Submerged: HW =5.5
1099.00	8.4	Submerged: HW =6.0
1099.50	8.8	Submerged: HW =6.5
1100.00	9.1	Submerged: HW =7.0

Used Unsubmerged Equ. Form (1) for elev. less than 1094.14 ft
Used Submerged Equation for elevations greater than 1094.48 ft
HW=Headwater (ft) dc=Critical depth (ft) Ac=Area (sq.ft) at dc

Transition flows interpolated from the following values:
E1=1094.14 ft; Q1=2.75 cfs; Dc=.71 ft; E2=1094.48 ft; Q2=3.14 cfs

Outlet Structure File: BASIN-1A.STR

POND-2 Version: 5.17 S/N:
Date Executed: Time Executed:

****
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
PROJECT # 2169.30
****

Outflow Rating Table for Structure #2
STAND PIPE Stand Pipe with weir or orifice flow

***** INLET CONTROL ASSUMED *****

Elevation (ft)	Q (cfs)	Computation Messages
1093.00	0.0	E < Inv.El.= 1097.5
1093.50	0.0	E < El=1097.5
1094.00	0.0	E < El=1097.5
1094.50	0.0	E < El=1097.5
1095.00	0.0	E < El=1097.5
1095.50	0.0	E < El=1097.5
1096.00	0.0	E < El=1097.5
1096.50	0.0	E < El=1097.5
1097.00	0.0	E < El=1097.5
1097.50	0.0	Weir: H =0.0
1098.00	7.4	Weir: H =.5
1098.50	15.9	Orifice: H =1.0
1099.00	19.5	Orifice: H =1.5
1099.50	22.5	Orifice: H =2.0
1100.00	25.1	Orifice: H =2.5

Weir Cw = 3.33 Weir length = 6.283186 ft
Orifice Co = .63 Orifice area = 3.141593 sq.ft.
Q (cfs) = (Cw * L * H**1.5) or (Co * A * sqr(2*g*H))
No transition used, transition height = 0.0
Weir equation = Orifice equation @ elev.= 1098.259 ft

Table 9

Constants for inlet control design equations.

CHART NO.	SHAPE AND MATERIAL	NOMOGRAPH SCALE	INLET EDGE DES ON	UNSUBMERGED EQUATION FORM	UNSUBMERGED K	UNSUBMERGED M	SUBMERGED c	SUBMERGED Y	References
1	Circular Concrete	1	Square edge w/headwall	1	0.0098	2.0	0.0398	0.67	(56) (57)
		2	Groove end w/headwall		.0078	2.0	.0292	.74	(56) (57)
		3	Groove end projecting		.0045	2.0	.0317	.69	(56) (57)
2	Circular CMP	1	Headwall	1	.0078	2.0	.0379	.69	(56) (57)
		2	Mitered to slope		.0210	1.33	.0463	.75	(57)
		3	Projecting		.0340	1.50	.0553	.54	(57)
3	Circular	A	Beveled ring, 45° bevels	1	.0018	2.50	.0300	.74	(57)
		B	Beveled ring, 33.7° bevels*		.0018	2.50	.0243	.83	(57)
8	Rectangular Box	1	30° to 75° wingwall flares	-	.026	1.0	.0385	.81	(56)
		2	90° and 15° wingwall flares	1	.061	0.75	.0400	.80	(56)
		3	0° wingwall flares		.061	0.75	.0423	.82	(8)
9	Rectangular Box	1	45° wingwall flare d=.0430	2	.510	.667	.0309	.80	(8)
		2	18° to 33.7° wingwall flare d=.0830		.486	.667	.0249	.83	(8)
10	Rectangular Box	1	90° headwall w/3/4" chamfers	2	.515	.667	.0375	.79	(8)
		2	90° headwall w/45° bevels		.495	.667	.0316	.82	(8)
		3	90° headwall w/33.7° bevels		.486	.667	.0252	.865	(8)
11	Rectangular Box	1	3/4" chamfers; 45° skewed headwall	2	.522	.667	.0402	.73	(8)
		2	3/4" chamfers; 30° skewed headwall		.533	.667	.0425	.705	(8)
		3	3/4" chamfers; 15° skewed headwall		.545	.667	.04505	.68	(8)
		4	45° bevels; 10°-45° skewed headwall		.498	.667	.0327	.75	(8)
12	Rectangular Box 3/4" chamfers	1	45° non-offset wingwall flares	2	.497	.667	.0339	.803	(8)
		2	18.4° non-offset wingwall flares		.493	.667	.0361	.806	(8)
		3	18.4° non-offset wingwall flares 30° skewed barrel		.495	.667	.0386	.71	(8)
13	Rectangular Box Top Bevels	1	45° wingwall flares - offset	2	.497	.667	.0302	.835	(8)
		2	33.7° wingwall flares - offset		.495	.667	.0252	.881	(8)
		3	18.4° wingwall flares - offset		.493	.667	.0227	.887	(8)
16-19	C M Boxes	1	90° headwall	1	.0083	2.0	.0379	.69	(57)
		2	Thick wall projecting		.0145	1.75	.0419	.64	(57)
		3	Thin wall projecting		.0340	1.5	.0496	.57	(57)

27 OF 42

HYDRAULIC DESIGN OF HIGHWAY CULVERTS

U.S. Department of Transportation
Federal Highway Administration

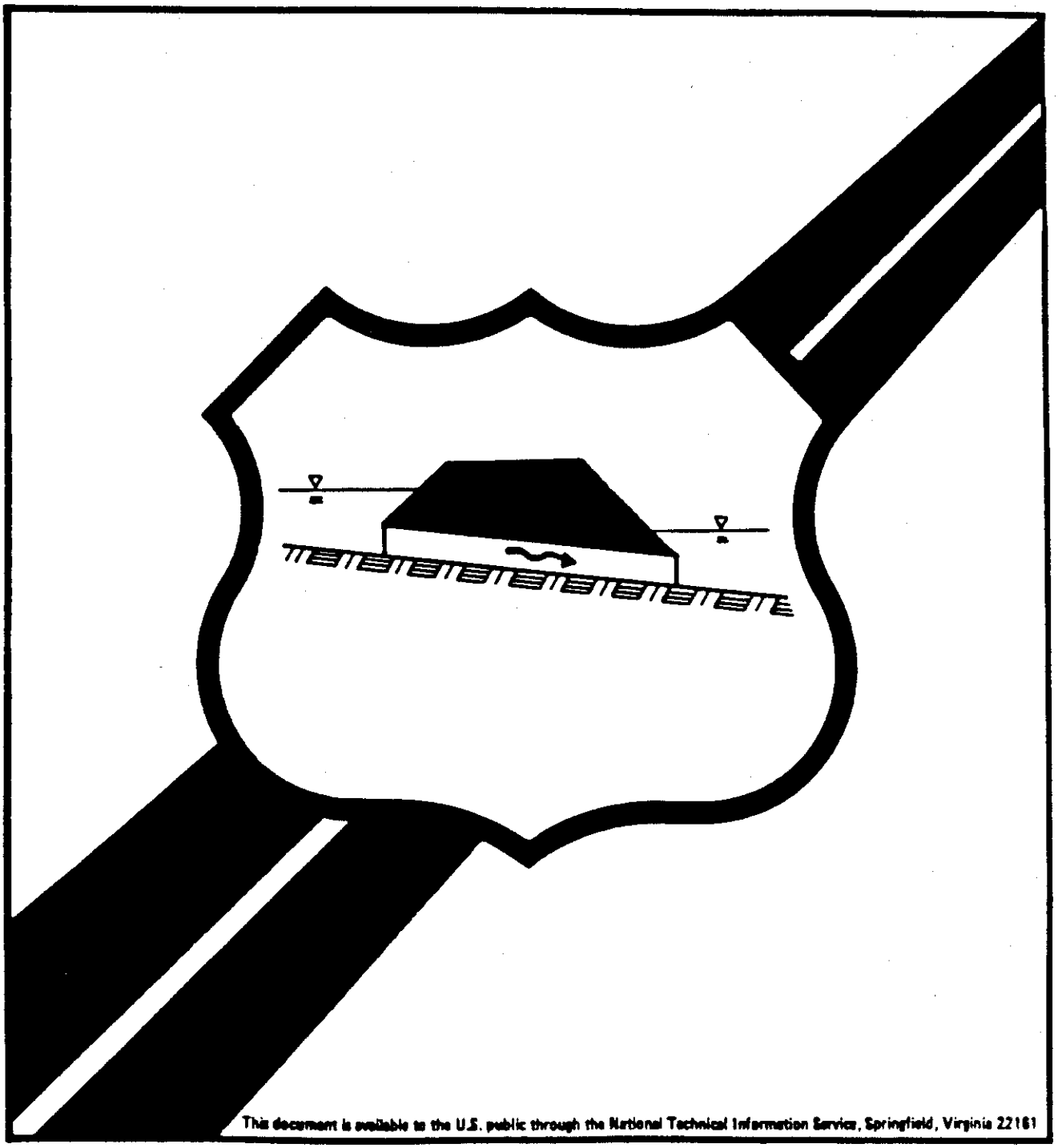
Research, Development, and Technology

Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101

Hydraulic Design Series No. 5

Report No. FHWA-IP-85-15

September 1985



This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

SEDIMENTATION BASIN #1 ROUTING CALCULATIONS

********** SUMMARY OF ROUTING COMPUTATIONS **********

✓BJK 11/94

Pond File: b:BASIN-1A.PND
Inflow Hydrograph: b:1-100YR .HYD
Outflow Hydrograph: b:B1-OUT .HYD

Starting Pond W.S. Elevation = 1097.50 ft

***** Summary of Peak Outflow and Peak Elevation *****

Peak Inflow = 25.00 cfs ✓
Peak Outflow = 8.11 cfs ✓
Peak Elevation = 1098.64 ft ✓

***** Summary of Approximate Peak Storage *****

Initial Storage = 1.67 ac-ft
Peak Storage From Storm = 0.73 ac-ft

Total Storage in Pond = 2.39 ac-ft

NOTES

CHECK FOR SETTLING OUT A 20-MICRON PARTICLE → NEED 1,250 ft^2 PER cfs

– SURFACE AREA AT ELEV. 1098.64 = $(31,572\ ft^2 - 27,316\ ft^2/1.0)\,0.64 + 27,316$
(SEE SHEET 19 OF 42) = 30,040 ft^2 ✓

– PEAK OUTFLOW = 8.11 cfs ✓

→ SURFACE AREA PER cfs OF DISCHARGE = 30,040 ft^2 ÷ 8.11 cfs
= 3,704 ft^2 ✓

3,704 ft^2 > 1250 ft^2 ✓

POND-2 Version: 5.17 S/N:
EXECUTED: 11-14-1994 08:12:27 Basin 1A Return Freq: 100 years


```
*****************************
*                           *
*  AMERICAN STEEL FOUNDRIES *
*      SEBRING FACILITY     *
*       ALLIANCE, OHIO      *
*      pROJECT # 2169.30    *
*                           *
*****************************
```

Inflow Hydrograph: b:1-100YR .HYD
Rating Table file: b:BASIN-1A.PND

----INITIAL CONDITIONS----
Elevation = 1097.50 ft
Outflow = 0.00 cfs
Storage = 1.67 ac-ft

GIVEN POND DATA			INTERMEDIATE ROUTING COMPUTATIONS	
ELEVATION (ft)	OUTFLOW (cfs)	STORAGE (ac-ft)	2S/t (cfs)	2S/t + O (cfs)
1093.00	0.0	0.000	0.0	0.0
1093.50	0.0	0.013	3.2	3.2
1094.00	0.0	0.106	25.7	25.7
1094.50	0.0	0.274	66.3	66.3
1095.00	0.0	0.460	111.2	111.2
1095.50	0.0	0.663	160.4	160.4
1096.00	0.0	0.884	213.9	213.9
1096.50	0.0	1.124	272.0	272.0
1097.00	0.0	1.385	335.1	335.1
1097.50	0.0	1.667	403.4	403.4
1098.00	7.4	1.970	476.8	484.2
1098.50	8.0	2.296	555.5	563.5
1099.00	8.4	2.645	640.2	648.6
1099.50	8.8	3.020	730.8	739.6
1100.00	9.1	3.419	827.3	836.4

Time increment (t) = 0.100 hrs.

POND-2 Version: 5.17 S/N:
EXECUTED: 11-14-1994 08:12:27 Basin 1A

Return Freq: 100 years

Pond File: b:BASIN-1A.PND
Inflow Hydrograph: b:1-100YR .HYD
Outflow Hydrograph: b:B1-OUT .HYD

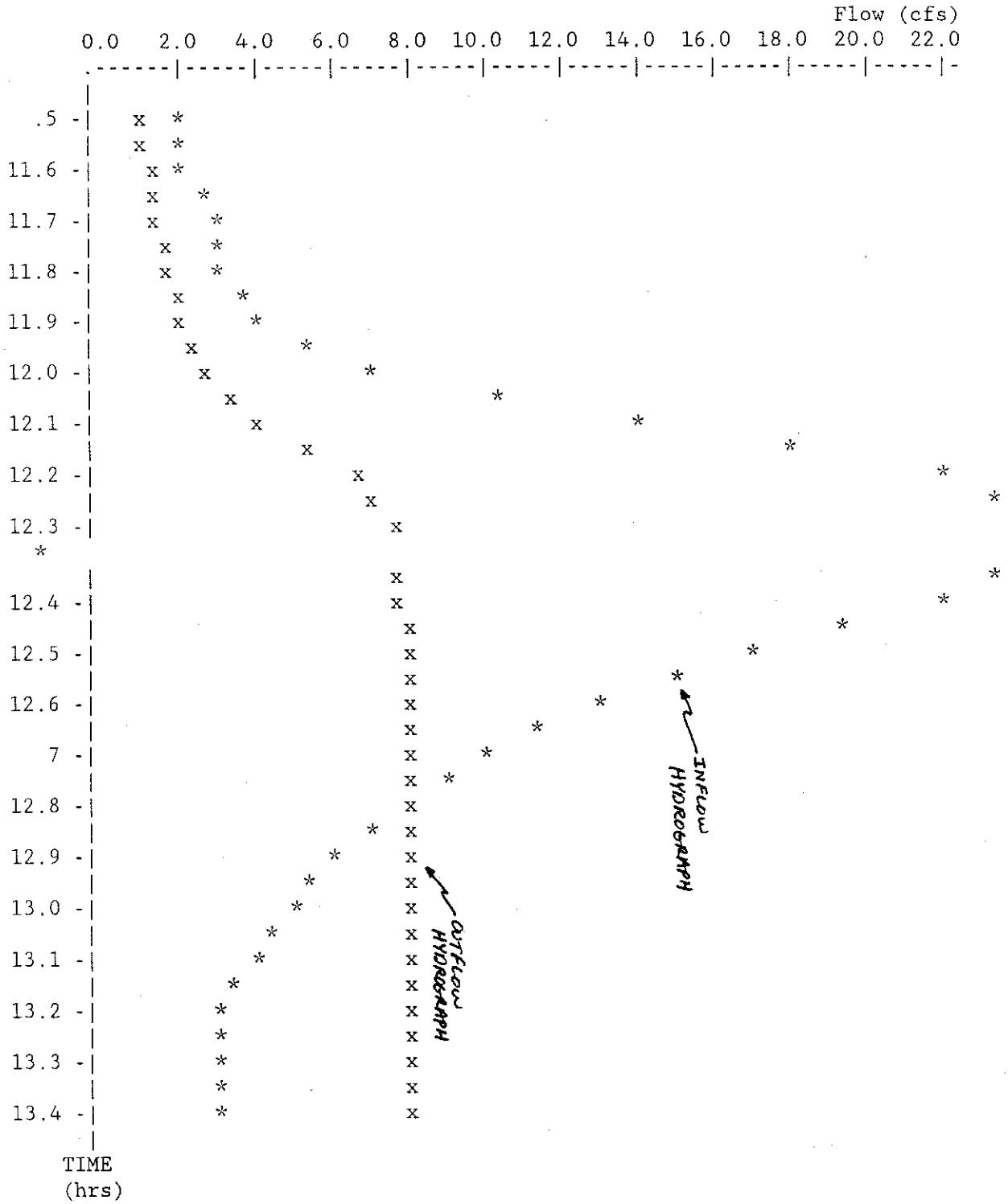
INFLOW HYDROGRAPH		ROUTING COMPUTATIONS				
TIME (hrs)	INFLOW (cfs)	I1+I2 (cfs)	2S/t - O (cfs)	2S/t + O (cfs)	OUTFLOW (cfs)	ELEVATION (ft)
11.000	0.00	-----	403.4	403.4	0.00	1097.50
11.100	1.00	1.0	404.2	404.4	0.09	1097.51
11.200	1.00	2.0	405.7	406.2	0.26	1097.52
11.300	2.00	3.0	407.7	408.7	0.49	1097.53
11.400	2.00	4.0	410.2	411.7	0.76	1097.55
11.500	2.00	4.0	412.2	414.2	0.99	1097.57
11.600	2.00	4.0	413.9	416.2	1.18	1097.58
11.700	3.00	5.0	416.1	418.9	1.42	1097.60
11.800	3.00	6.0	418.6	422.1	1.71	1097.62
11.900	4.00	7.0	421.6	425.6	2.04	1097.64
12.000	7.00	11.0	427.2	432.6	2.67	1097.68
12.100	14.00	21.0	440.0	448.2	4.11	1097.78
12.200	22.00	36.0	462.7	476.0	6.65	1097.95
12.300	25.00	47.0	494.5	509.7	7.59	1098.16
12.400	22.00	47.0	525.8	541.5	7.83	1098.36
12.500	17.00	39.0	548.8	564.8	8.01	1098.51
2.600	13.00	30.0	562.7	578.8	8.07	1098.59
12.700	10.00	23.0	569.5	585.7	8.10	1098.63
12.800	8.00	18.0	571.3	587.5	8.11	1098.64
12.900	6.00	14.0	569.1	585.3	8.10	1098.63
13.000	5.00	11.0	563.9	580.1	8.08	1098.60
13.100	4.00	9.0	556.8	572.9	8.04	1098.56
13.200	3.00	7.0	547.8	563.8	8.00	1098.50
13.300	3.00	6.0	538.0	553.8	7.93	1098.44
13.400	3.00	6.0	528.2	544.0	7.85	1098.38
13.500	3.00	6.0	518.7	534.2	7.78	1098.32
13.600	2.00	5.0	508.3	523.7	7.70	1098.25
13.700	2.00	4.0	497.1	512.3	7.61	1098.18
13.800	2.00	4.0	486.0	501.1	7.53	1098.11
13.900	2.00	4.0	475.1	490.0	7.44	1098.04
14.000	2.00	4.0	465.2	479.1	6.94	1097.97
14.100	2.00	4.0	457.2	469.2	6.03	1097.91
14.200	2.00	4.0	450.6	461.2	5.29	1097.86
14.300	2.00	4.0	445.2	454.6	4.69	1097.82
14.400	2.00	4.0	440.8	449.2	4.20	1097.78
14.500	2.00	4.0	437.2	444.8	3.79	1097.76
14.600	2.00	4.0	434.3	441.2	3.47	1097.73
14.700	2.00	4.0	431.9	438.3	3.20	1097.72
14.800	2.00	4.0	429.9	435.9	2.98	1097.70
14.900	2.00	4.0	428.4	433.9	2.80	1097.69
15.000	2.00	4.0	427.0	432.4	2.65	1097.68
15.100	2.00	4.0	426.0	431.0	2.53	1097.67
15.200	2.00	4.0	425.1	430.0	2.43	1097.66
15.300	2.00	4.0	424.4	429.1	2.36	1097.66
15.400	2.00	4.0	423.8	428.4	2.29	1097.65

POND-2 Version: 5.17 S/N:
EXECUTED: 11-14-1994 08:12:27 Basin 1A Return Freq: 100 years

Pond File: b:BASIN-1A.PND
Inflow Hydrograph: b:1-100YR .HYD
Outflow Hydrograph: b:B1-OUT .HYD

INFLOW HYDROGRAPH ROUTING COMPUTATIONS

TIME (hrs)	INFLOW (cfs)	I1+I2 (cfs)	2S/t - O (cfs)	2S/t + O (cfs)	OUTFLOW (cfs)	ELEVATION (ft)
15.500	2.00	4.0	423.3	427.8	2.24	1097.65
15.600	2.00	4.0	423.0	427.3	2.19	1097.65
15.700	2.00	4.0	422.6	427.0	2.16	1097.65
15.800	2.00	4.0	422.4	426.6	2.13	1097.64
15.900	2.00	4.0	422.2	426.4	2.11	1097.64
16.000	2.00	4.0	422.0	426.2	2.09	1097.64
16.100	2.00	4.0	421.9	426.0	2.07	1097.64
16.200	2.00	4.0	421.8	425.9	2.06	1097.64
16.300	1.00	3.0	420.8	424.8	1.96	1097.63
16.400	1.00	2.0	419.3	422.8	1.78	1097.62
16.500	1.00	2.0	418.0	421.3	1.64	1097.61
16.600	1.00	2.0	417.0	420.0	1.52	1097.60
16.700	1.00	2.0	416.1	419.0	1.42	1097.60
16.800	0.00	1.0	414.6	417.1	1.26	1097.58
16.900	0.00	0.0	412.6	414.6	1.03	1097.57
17.000	0.00	0.0	410.9	412.6	0.84	1097.56
7.100	0.00	0.0	409.5	410.9	0.68	1097.55
17.200	0.00	0.0	408.4	409.5	0.56	1097.54
17.300	0.00	0.0	407.5	408.4	0.46	1097.53
17.400	0.00	0.0	406.7	407.5	0.37	1097.53
17.500	0.00	0.0	406.1	406.7	0.30	1097.52
17.600	0.00	0.0	405.6	406.1	0.25	1097.52
17.700	0.00	0.0	405.2	405.6	0.20	1097.51
17.800	0.00	0.0	404.9	405.2	0.17	1097.51
17.900	0.00	0.0	404.6	404.9	0.14	1097.51
18.000	0.00	0.0	404.4	404.6	0.11	1097.51
18.100	0.00	0.0	404.2	404.4	0.09	1097.51
18.200	0.00	0.0	404.1	404.2	0.07	1097.50
18.300	0.00	0.0	404.0	404.1	0.06	1097.50
18.400	0.00	0.0	403.9	404.0	0.05	1097.50
18.500	0.00	0.0	403.8	403.9	0.04	1097.50
18.600	0.00	0.0	403.7	403.8	0.03	1097.50
18.700	0.00	0.0	403.7	403.7	0.03	1097.50
18.800	0.00	0.0	403.6	403.7	0.02	1097.50
18.900	0.00	0.0	403.6	403.6	0.02	1097.50
19.000	0.00	0.0	403.5	403.6	0.01	1097.50
19.100	0.00	0.0	403.5	403.5	0.01	1097.50
19.200	0.00	0.0	403.5	403.5	0.01	1097.50
19.300	0.00	0.0	403.5	403.5	0.01	1097.50
19.400	0.00	0.0	403.5	403.5	0.01	1097.50
19.500	0.00	0.0	403.5	403.5	0.01	1097.50
19.600	0.00	0.0	403.5	403.5	0.00	1097.50
9.700	0.00	0.0	403.5	403.5	0.00	1097.50
19.800	0.00	0.0	403.4	403.5	0.00	1097.50
19.900	0.00	0.0	403.4	403.4	0.00	1097.50
20.000	0.00	0.0	403.4	403.4	0.00	1097.50



* File: b:1-100YR .HYD Qmax = 25.0 cfs
x File: b:B1-OUT .HYD Qmax = 8.1 cfs

SEDIMENTATION BASIN #2 CONTOUR/VOLUME DATA

POND-2 Version: 5.17
S/N:

POND FILE

AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
PROJECT # 2169.30

CALCULATED 11-14-1994 09:22:29 JBOK 11/16/94
DISK FILE: b:BASIN-2A.VOL

* STORAGE FOR 10YR/24HR STORM BELOW TOP OF RISER PIPE, REQUIRED = .40

Planimeter scale: 1 inch = 1 ft.

Elevation (ft)	Planimeter (sq.in.)	Area (acres)	A1+A2+sqr(A1*A2) (acres)	* Volume (acre-ft)	Volume Sum (acre-ft)
1,077.50	0.00	0.00	0.00	0.00	0.00
1,078.00	3,952.00	0.09	0.09	0.02	0.02
1,079.00	5,188.00	0.12	0.31	0.10	0.12
1,080.00	6,424.00	0.15	0.40	0.13	0.25
1,081.00	7,878.00	0.18	0.49	0.16	0.42 >.40*
1,082.00	9,332.00	0.21	0.59	0.20	0.61
1,083.00	11,269.00	0.26	0.71	0.24	0.85

IA = (sq.rt(Area1) + ((Ei-E1)/(E2-E1))*(sq.rt(Area2)-sq.rt(Area1)))^2

where: E1, E2 = Closest two elevations with planimeter data
Ei = Elevation at which to interpolate area
Area1,Area2 = Areas computed for E1, E2, respectively
IA = Interpolated area for Ei

* Incremental volume computed by the Conic Method for Reservoir Volumes.

Volume = (1/3) * (EL2-EL1) * (Area1 + Area2 + sq.rt.(Area1*Area2))

where: EL1, EL2 = Lower and upper elevations of the increment
Area1,Area2 = Areas computed for EL1, EL2, respectively
Volume = Incremental volume between EL1 and EL2

SEDIMENTATION BASIN #2 OUTLET STRUCTURE DATA

Outlet Structure File: **BASIN-2A.STR**

POND-2 Version: 5.17 S/N:
Date Executed: Time Executed:

OUTLET STRUCTURE DATA

****
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
PROJECT # 2169.30
****

✓BJK 11/16/94

***** COMPOSITE OUTFLOW SUMMARY ****

Elevation (ft)	Q (cfs)	Contributing Structures
1077.50	0.0	
1078.00	0.0	
1078.50	0.0	
1079.00	0.0	
1079.50	0.0	
1080.00	0.0	
1080.50	0.0	
1081.00	0.0	2
1081.50	1.7	1
1082.00	1.9	1
1082.50	2.0	1
1083.00	~~0.0~~	

Outlet Structure File: BASIN-2A.STR

POND-2 Version: 5.17 S/N:
Date Executed: Time Executed:

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************************
AMERICAN STEEL FOUNDRIES
    SEBRING FACILITY
     ALLIANCE, OHIO
    PROJECT # 2169.30
************************
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Outlet Structure File: b:BASIN-2A.STR
Planimeter Input File: b:BASIN-2A.VOL
Rating Table Output File: b:BASIN-2A.PND

Min. Elev.(ft) = 1077.5 Max. Elev.(ft) = 1083 Incr.(ft) = .5

Additional elevations (ft) to be included in table:
* *

```
**********************************************
                SYSTEM CONNECTIVITY
**********************************************
```

Structure	No.	Q Table		Q Table
CULVERT-CR	1		->	1
STAND PIPE	2	? 1	->	A

Outflow rating table summary was stored in file:
b:BASIN-2A.PND

Outlet Structure File: BASIN-2A.STR

POND-2 Version: 5.17 S/N:
Date Executed: Time Executed:

****
AMERICAN STEEL FOUNDRIES
SEBRING FACILITY
ALLIANCE, OHIO
PROJECT # 2169.30
********** ✓BJK 11/16/94

>>>>>> Structure No. 1 <<<<<<
(Input Data)

CULVERT-CR
Circular Culvert (With Inlet Control)

E1 elev.(ft)?	1081
E2 elev.(ft)?	1083 OK ✓
Diam. (ft)?	.5
Inv. el.(ft)?	1077.5
Slope (ft/ft)?	.006
T1 ratio?	
T2 ratio?	
K Coeff.?	.0210
M Coeff.?	1.33
c Coeff.?	.0463
Y Coeff.?	.75
Form 1 or 2?	1
Slope factor?	-.5

SEE PAGE 26 of 42 FOR DESIGN VALUES.

Outlet Structure File: BASIN-2A.STR

POND-2 Version: 5.17 S/N:
Date Executed: Time Executed:

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*************************
AMERICAN STEEL FOUNDRIES
    SEBRING FACILITY
     ALLIANCE, OHIO
    PROJECT # 2169.30
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VBJK 11/16/94

>>>>>> Structure No. 2 <<<<<<
(Input Data)

STAND PIPE
Stand Pipe with weir or orifice flow

E1 elev.(ft)?	1081.0
E2 elev.(ft)?	1083.001 ✓
Crest elev.(ft)?	1081
Diameter (ft)?	1
Weir coefficient?	3.33
Orifice coefficient?	.63
Start transition elev.(ft) @ ?	
Transition height (ft)?	

SEDIMENTATION BASIN #2 ROUTING CALCULATIONS

********** SUMMARY OF ROUTING COMPUTATIONS **********

Pond File: b:BASIN-2A.PND
Inflow Hydrograph: b:2-100YR .HYD
Outflow Hydrograph: b:2A-OUT .HYD

BJK 11/16/94

Starting Pond W.S. Elevation = 1081.00 ft

***** Summary of Peak Outflow and Peak Elevation *****

Peak Inflow = 9.00 cfs
Peak Outflow = 1.94 cfs
Peak Elevation = 1082.18 ft

***** Summary of Approximate Peak Storage *****

Initial Storage = 0.42 ac-ft
Peak Storage From Storm = 0.24 ac-ft

Total Storage in Pond = 0.65 ac-ft

NOTES

CHECK FOR SETTLING OUT A 20-MICRON PARTICLE → NEED 1,250 ft² PER cfs

- SURFACE AREA AT ELEV. 1082.18 = (11,269 ft² − 9,332 ft²/1.0) 0.18 + 9,332
(SEE SHEET 33 OF 42) = 9,681 ft²

- PEAK OUTFLOW = 1.94 cfs

→ SURFACE AREA PER cfs OF DISCHARGE = 9,681 ft² ÷ 1.94 cfs
= 4,990 ft²

4,990 ft² > 1250 ft²

```
*****************************
*                           *
*  AMERICAN STEEL FOUNDRIES *
*      SEBRING FACILITY     *
*       ALLIANCE, OHIO      *
*      PROJECT # 2169.30    *
*                           *
*****************************
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Inflow Hydrograph: b:2-100YR .HYD
Rating Table file: b:BASIN-2A.PND

----INITIAL CONDITIONS----
Elevation = 1081.00 ft
Outflow = 0.00 cfs
Storage = 0.42 ac-ft

GIVEN POND DATA

ELEVATION (ft)	OUTFLOW (cfs)	STORAGE (ac-ft)
1077.50	0.0	0.000
1078.00	0.0	0.015
1078.50	0.0	0.064
1079.00	0.0	0.120
1079.50	0.0	0.183
1080.00	0.0	0.253
1080.50	0.0	0.331
1081.00	0.0	0.417
1081.50	1.7	0.511
1082.00	1.9	0.614
1082.50	2.0	0.726

INTERMEDIATE ROUTING COMPUTATIONS

2S/t (cfs)	2S/t + O (cfs)
0.0	0.0
3.7	3.7
15.5	15.5
29.0	29.0
44.2	44.2
61.2	61.2
80.0	80.0
100.8	100.8
123.7	125.4
148.6	150.5
175.8	177.8

Time increment (t) = 0.100 hrs.

POND-2 Version: 5.17 S/N:
EXECUTED: 11-14-1994 09:31:04 BASIN-2A

Return Freq: 100 years

..ond File: b:BASIN-2A.PND
Inflow Hydrograph: b:2-100YR .HYD
Outflow Hydrograph: b:2A-OUT .HYD

INFLOW HYDROGRAPH / ROUTING COMPUTATIONS

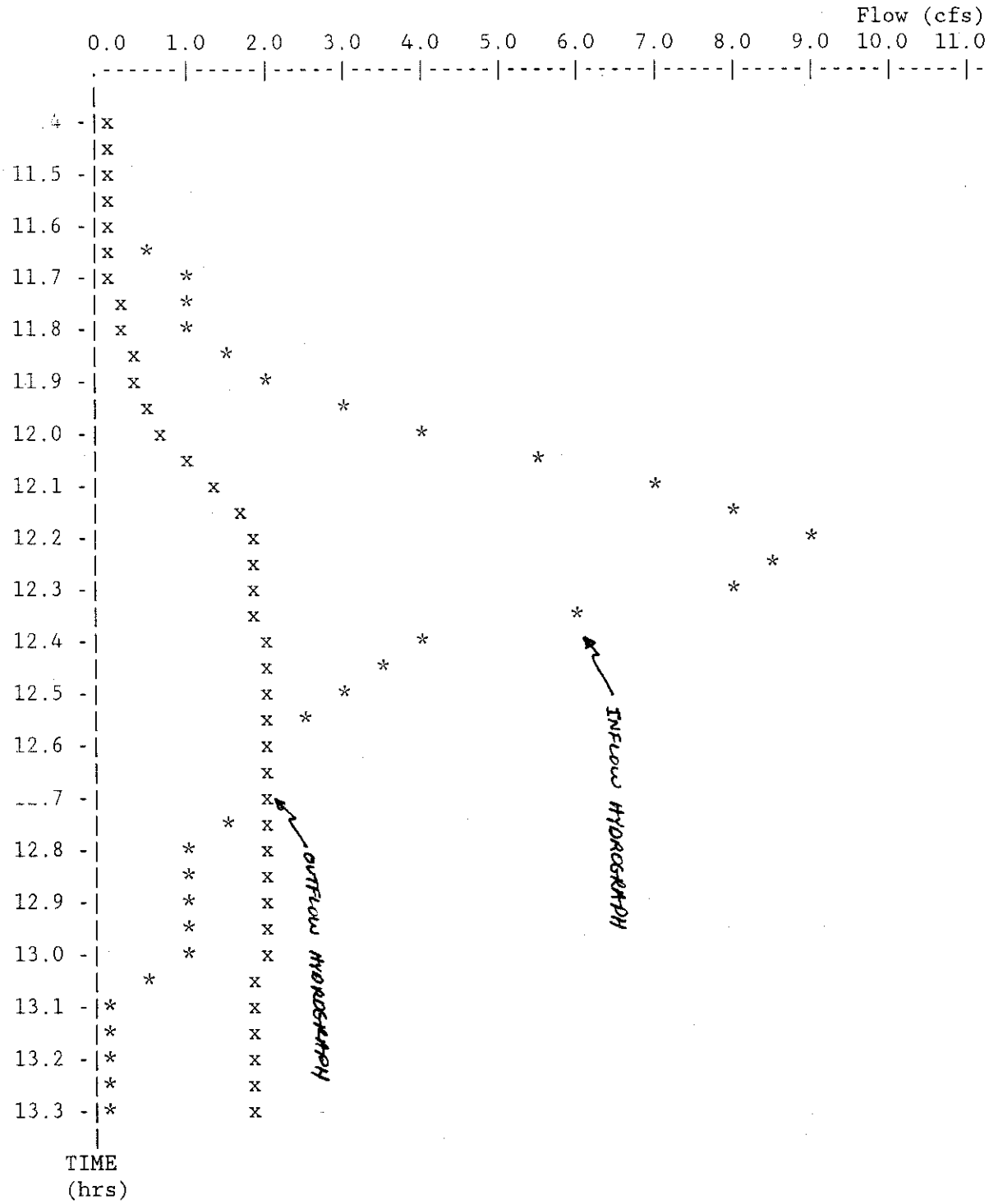
TIME (hrs)	INFLOW (cfs)	I1+I2 (cfs)	2S/t - O (cfs)	2S/t + O (cfs)	OUTFLOW (cfs)	ELEVATION (ft)
11.000	0.00	-----	100.8	100.8	0.00	1081.00
11.100	0.00	0.0	100.8	100.8	0.00	1081.00
11.200	0.00	0.0	100.8	100.8	0.00	1081.00
11.300	0.00	0.0	100.8	100.8	0.00	1081.00
11.400	0.00	0.0	100.8	100.8	0.00	1081.00
11.500	0.00	0.0	100.8	100.8	0.00	1081.00
11.600	0.00	0.0	100.8	100.8	0.00	1081.00
11.700	1.00	1.0	101.7	101.8	0.07	1081.02
11.800	1.00	2.0	103.3	103.7	0.20	1081.06
11.900	2.00	3.0	105.5	106.3	0.38	1081.11
12.000	4.00	6.0	110.1	111.5	0.74	1081.22
12.100	7.00	11.0	118.3	121.1	1.40	1081.41
12.200	9.00	16.0	130.7	134.3	1.77	1081.68
12.300	8.00	17.0	144.0	147.7	1.88	1081.94
12.400	4.00	12.0	152.1	156.0	1.92	1082.10
12.500	3.00	7.0	155.3	159.1	1.93	1082.16
2.600	2.00	5.0	156.4	160.3	1.94	1082.18
12.700	2.00	4.0	156.5	160.4	1.94	1082.18
12.800	1.00	3.0	155.6	159.5	1.93	1082.17
12.900	1.00	2.0	153.8	157.6	1.93	1082.13
13.000	1.00	2.0	151.9	155.8	1.92	1082.10
13.100	0.00	1.0	149.1	152.9	1.91	1082.05
13.200	0.00	0.0	145.4	149.1	1.89	1081.97
13.300	0.00	0.0	141.6	145.4	1.86	1081.90
13.400	0.00	0.0	138.0	141.6	1.83	1081.82
13.500	0.00	0.0	134.4	138.0	1.80	1081.75
13.600	0.00	0.0	130.8	134.4	1.77	1081.68
13.700	0.00	0.0	127.3	130.8	1.74	1081.61
13.800	0.00	0.0	123.9	127.3	1.72	1081.54
13.900	0.00	0.0	120.7	123.9	1.60	1081.47
14.000	0.00	0.0	118.0	120.7	1.38	1081.40
14.100	0.00	0.0	115.6	118.0	1.19	1081.35
14.200	0.00	0.0	113.5	115.6	1.02	1081.30
14.300	0.00	0.0	111.8	113.5	0.88	1081.26
14.400	0.00	0.0	110.3	111.8	0.76	1081.22
14.500	0.00	0.0	109.0	110.3	0.65	1081.19
14.600	0.00	0.0	107.8	109.0	0.56	1081.17
14.700	0.00	0.0	106.9	107.8	0.49	1081.14
14.800	0.00	0.0	106.0	106.9	0.42	1081.12
14.900	0.00	0.0	105.3	106.0	0.36	1081.11
15.000	0.00	0.0	104.7	105.3	0.31	1081.09
15.100	0.00	0.0	104.2	104.7	0.27	1081.08
15.200	0.00	0.0	103.7	104.2	0.23	1081.07
15.300	0.00	0.0	103.3	103.7	0.20	1081.06
15.400	0.00	0.0	103.0	103.3	0.17	1081.05

POND-2 Version: 5.17 S/N:
EXECUTED: 11-14-1994 09:31:04 BASIN-2A Return Freq: 100 years

ond File: b:BASIN-2A.PND
Inflow Hydrograph: b:2-100YR .HYD
Outflow Hydrograph: b:2A-OUT .HYD

INFLOW HYDROGRAPH ROUTING COMPUTATIONS

TIME (hrs)	INFLOW (cfs)	I1+I2 (cfs)	2S/t - O (cfs)	2S/t + O (cfs)	OUTFLOW (cfs)	ELEVATION (ft)
15.500	0.00	0.0	102.7	103.0	0.15	1081.04
15.600	0.00	0.0	102.4	102.7	0.13	1081.04
15.700	0.00	0.0	102.2	102.4	0.11	1081.03
15.800	0.00	0.0	102.0	102.2	0.09	1081.03
15.900	0.00	0.0	101.8	102.0	0.08	1081.02
16.000	0.00	0.0	101.7	101.8	0.07	1081.02
16.100	0.00	0.0	101.6	101.7	0.06	1081.02
16.200	0.00	0.0	101.5	101.6	0.05	1081.02
16.300	0.00	0.0	101.4	101.5	0.04	1081.01
16.400	0.00	0.0	101.3	101.4	0.04	1081.01
16.500	0.00	0.0	101.2	101.3	0.03	1081.01
16.600	0.00	0.0	101.2	101.2	0.03	1081.01
16.700	0.00	0.0	101.1	101.2	0.02	1081.01
16.800	0.00	0.0	101.1	101.1	0.02	1081.01
16.900	0.00	0.0	101.1	101.1	0.02	1081.01
17.000	0.00	0.0	101.0	101.1	0.02	1081.00
17.100	0.00	0.0	101.0	101.0	0.01	1081.00
17.200	0.00	0.0	101.0	101.0	0.01	1081.00
17.300	0.00	0.0	101.0	101.0	0.01	1081.00
17.400	0.00	0.0	100.9	101.0	0.01	1081.00
17.500	0.00	0.0	100.9	100.9	0.01	1081.00
17.600	0.00	0.0	100.9	100.9	0.01	1081.00
17.700	0.00	0.0	100.9	100.9	0.01	1081.00
17.800	0.00	0.0	100.9	100.9	0.00	1081.00
17.900	0.00	0.0	100.9	100.9	0.00	1081.00
18.000	0.00	0.0	100.9	100.9	0.00	1081.00
18.100	0.00	0.0	100.9	100.9	0.00	1081.00
18.200	0.00	0.0	100.9	100.9	0.00	1081.00
18.300	0.00	0.0	100.9	100.9	0.00	1081.00
18.400	0.00	0.0	100.8	100.9	0.00	1081.00
18.500	0.00	0.0	100.8	100.8	0.00	1081.00
18.600	0.00	0.0	100.8	100.8	0.00	1081.00
18.700	0.00	0.0	100.8	100.8	0.00	1081.00
18.800	0.00	0.0	100.8	100.8	0.00	1081.00
18.900	0.00	0.0	100.8	100.8	0.00	1081.00
19.000	0.00	0.0	100.8	100.8	0.00	1081.00
19.100	0.00	0.0	100.8	100.8	0.00	1081.00
19.200	0.00	0.0	100.8	100.8	0.00	1081.00
19.300	0.00	0.0	100.8	100.8	0.00	1081.00
19.400	0.00	0.0	100.8	100.8	0.00	1081.00
19.500	0.00	0.0	100.8	100.8	0.00	1081.00
19.600	0.00	0.0	100.8	100.8	0.00	1081.00
19.700	0.00	0.0	100.8	100.8	0.00	1081.00
19.800	0.00	0.0	100.8	100.8	0.00	1081.00
19.900	0.00	0.0	100.8	100.8	0.00	1081.00
20.000	0.00	0.0	100.8	100.8	0.00	1081.00



* File: b:2-100YR .HYD Qmax = 9.0 cfs
x File: b:2A-OUT .HYD Qmax = 1.9 cfs

OUTLET PIPE RIPRAP APRON SIZING CALCULATIONS

COMPUTATION SHEET

RMT INC.

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
ASF	RM	11-14-94	BJK	11/16/94	2169.30

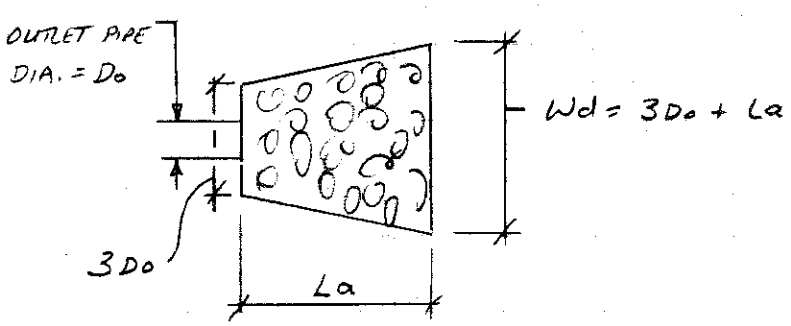
→ DESIGN OUTLET PROTECTION FOR THE SEDIMENTATION BASIN DISCHARGE PIPES AND THE FINAL COVER DRAINAGE LAYER DISCHARGE PIPE OUTLETS.

GIVEN:
- DISCHARGE FLOWS
  - SED. BASIN # 1 = 8.11 CFS
  - SED. BASIN # 2 = 1.94 CFS
  - FINAL COVER DISCHARGE = 1.94 CFS
    PIPES, USE SAME AS BASIN # 2 (CONSERVATIVE)

  (REFER TO POST CLOSURE SURFACE WATER CALCULATIONS FOR BASIN DESIGN)
- DISCHARGE PIPE DIAMETERS
  - BASIN # 1 = 12" DIA.
  - BASIN # 2 = 6" DIA.
  - DRAINAGE LAYER = 6" DIA.
- FLOW DISCHARGE TO UNDEFINED CHANNELS

SOLUTION:
- USE FIGURES 7.45 ATTACHED

  REF.: GOLDMAN, STEVEN J. et al. 1986. EROSION & SEDIMENT CONTROL HANDBOOK. McGRAW-HILL BOOK COMPANY PG. 7-54-7-55.
- USE MINIMUM TAILWATER CONDITIONS FOR UNDEFINED CHANNELS.



SUMMARY

12" PIPE	6" PIPE
Do = 1	Do = 0.5'
3Do = 3'	3Do = 1.5'
La = 14'	La = 5'
Wd = 17'	Wd = 6.5'

USE RIPRAP WITH $d_{50} \geq 0.5$ FEET

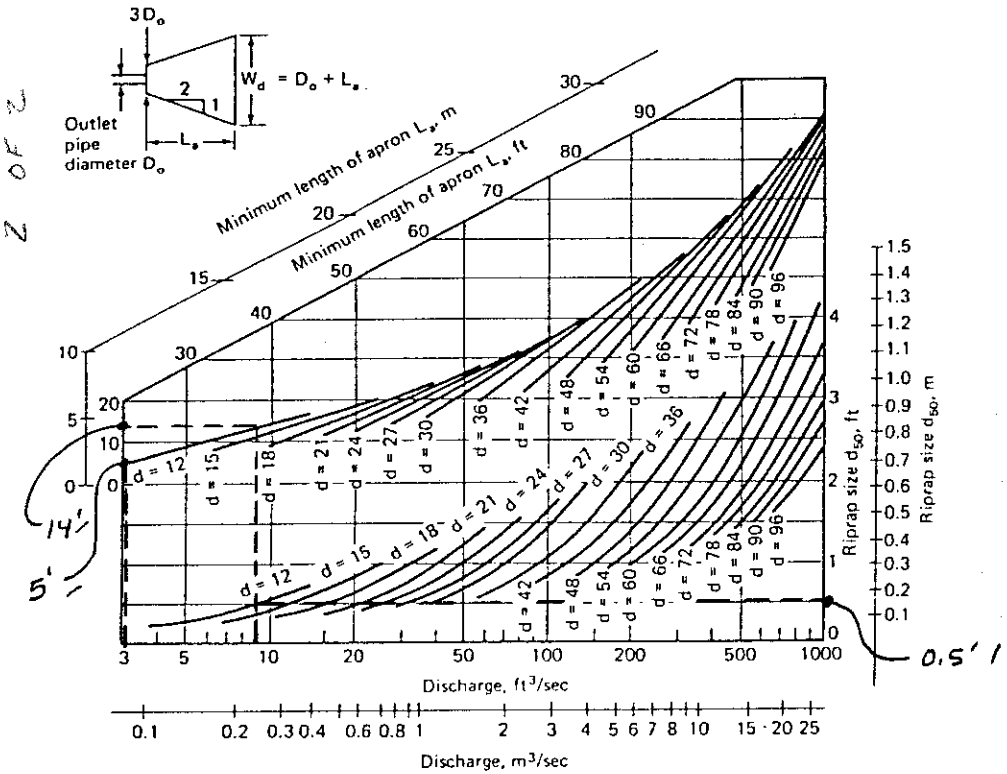


Fig. 7.45 Design of riprap outlet protection from a round pipe flowing full; minimum tailwater conditions. (6, 14)

to find the riprap size and apron length. The apron width at the pipe end should be 3 times the pipe diameter. Where there is a well-defined channel immediately downstream from the apron, the width of the downstream end of the apron should be equal to the width of the channel. Where there is no well-defined channel immediately downstream from the apron, minimum tailwater conditions apply and the width of the downstream end of the apron should be equal to the pipe diameter plus the length of the apron.

EXAMPLE 7.4 Riprap Outlet Protection Design Calculation for Minimum Tailwater Condition

Given: A flow of 6 ft^3/sec (0.17 m^3/sec) discharges from a 12-in (30-cm) pipe onto a 2 percent grassy slope with no defined channel.

Find: The required length, width, and median stone size d_{50} for a riprap apron.

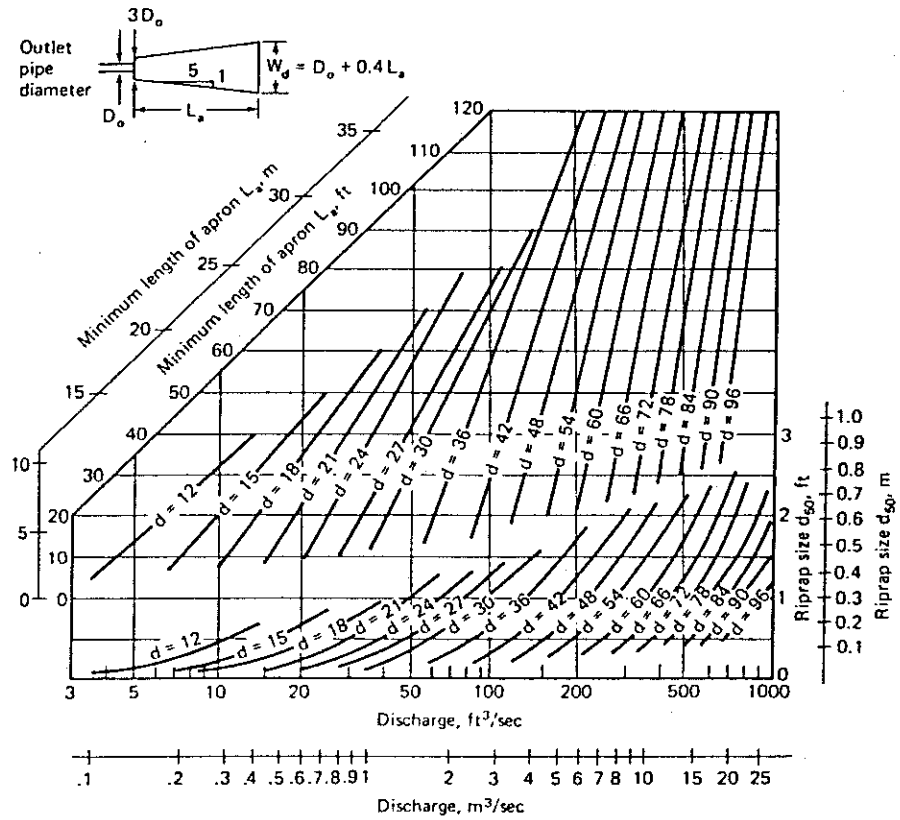


Fig. 7.46 Design of riprap outlet protection from a round pipe flowing full; maximum tailwater conditions. (6, 14)

Solution: Since the pipe discharges onto a flat area with no defined channel, a minimum tailwater condition can be assumed.

By Fig. 7.45, the apron length L_a and median stone size d_{50} are 10 ft (3 m) and 0.3 ft (9 cm), respectively. The upstream apron width W_u equals 3 times the pipe diameter D_o:

$$W_u = 3 \times D_o$$

$$= 3(1 \text{ ft}) = 3 \text{ ft} \qquad [3(0.3 \text{ m}) = 0.9 \text{ m}]$$

The downstream apron width W_d equals the apron length plus the pipe diameter:

$$W_d = D_o + L_a$$

$$= 1 \text{ ft} + 10 \text{ ft} = 11 \text{ ft} \qquad (0.3 \text{ m} + 3.0 \text{ m} = 3.3 \text{ m})$$

Note: When a concentrated flow is discharged onto a slope (as in this example), gullying can occur downhill from the outlet protection. The spreading of concentrated flow

DITCH AND DIVERSION BERM SIZING CALCULATIONS

DITCH AND DIVERSION BERM SIZING CALCULATIONS

TABLE OF CONTENTS

- Purpose/Methodologies/Assumptions/Results
- Ditch and Diversion Berm Design Calculations

DITCH AND DIVERSION BERM SIZING CALCULATIONS

Purpose:

The purpose of the ditches and diversion berms is to control surface water from drainage areas or watersheds (see Figure 4-1 in Section 4). These control structures are sized to channel the peak storm run-off flow to the sedimentation basins in a controlled manner while maintaining low enough velocities to minimize erosion potential. The proposed design incorporates two types of ditch design, a V-notch, and a flat-bottom ditch with a minimum channel slope of 3 percent and a maximum slope of 10 percent. Ditches will be grass-lined and will be seeded, fertilized, and mulched immediately after completion of the finish grade construction.

Methodologies:

An in-house RMT computer program, which incorporates Manning's equation, is used to assist with the design. The program allows the user to enter the ditch geometry, the ditch peak flow (as determined by Quick TR-55), and the vegetative retardance factor. At this point, the program begins an iterative process which adjusts the flow depth and Manning's Coefficient until the Trial Velocity and resultant velocity are within 0.0001 foot per second (fps) of each other. The end result is the peak flow depth and peak velocity for the geometry and peak flow entered.

Assumptions:

Ditching and diversion berms are sized for the post-closure landfill conditions. It is assumed that grass channels are adequate up to a velocity of 5 fps. Manning's numbers were selected for a "low" retardance (Type "D") factor as given by the U.S. Soil Conservation Service.

Results:

Calculations indicate that grass lining will be acceptable for all ditches and diversion berm channels since the "worst-case" ditch velocity is 3.7 fps. For the locations of ditches and diversion berms, refer to Engineering Plan Sheet 3B. Calculations were performed for each ditch and diversion berm draining into the sedimentation basins. For each situation, the area with the steepest slope within the channel was chosen for input into the calculation, making it the "worst-case" situation for each channel design.

DITCH AND DIVERSION BERM DESIGN CALCULATIONS

RMT, Inc.
Grass Channel Sizing Calculations

Site: AMERICAN STEEL FOUNDRIES Date: 11-Nov-94
Project #: 2169.30 User: D.MARSHALL VBJK 11/16/94
Channel: **Drainage ditch** (flat bottom)

SEE FIGURE 4-1 → DITCH IN AREA 1A TO BASIN #1

FOR 100 YEAR STORM

I. Input Parameters.

A. Side slope, Z1 (hor/vert) =	3.000 ft/ft
B. Side slope, Z2 (hor/vert) =	6.000 ft/ft
C. Bottom width, B =	10.000 ft
D. Design channel slope, S =	0.030 ft/ft
E. Channel Peak Flow, Q =	15.000 cfs
F. Enter - 1 - for Type "C" Veg. Retardence - 2 - for Type "D" Veg. Retardence	2

II. Peak Flow Calculations.

A. Trial flow depth, D = (Bisection method until Va=Vb)	0.497 ft
B. Channel flow area, Ac = (.5*Z1*D^2) + (B*D) + (.5*Z2*D^2)	6.079 sq ft
C. Wetted Perimeter, Pw = (D*(Z1^2+1)^.5) + B + (D*(Z2^2+1)^.5)	14.593 ft
D. Hydraulic radius, Rh = (Ac/Pw)	0.417 ft
E. Velocity and hydraulic radius, VR = (Va * Rh)	1.028 sfps
F. Channel flow Manning's coeff, nc = Type "D" Veg. Retardence	0.058
G. Trial velocity, Va = (Q/Ac)	2.468 fps
H. Resultant velocity, Vb = (1.49/nc) * (Rh^.667) * (S^.5)	2.468 fps

RMT, Inc.
Grass Channel Sizing Calculations

Site: AMERICAN STEEL FOUNDRIES Date: 11-Nov-94
Project #: 2169.30 User: D.MARSHALL
Channel: Drainage ditch (flat bottom)

SEE FIGURE 4-1 → DITCH IN AREA 1A TO BASIN #1

FOR 100 YEAR STORM

I. Input Parameters.

A. Side slope, Z1 (hor/vert) =	3.000	ft/ft
B. Side slope, Z2 (hor/vert) =	6.000	ft/ft
C. Bottom width, B =	10.000	ft
D. Design channel slope, S =	0.050	ft/ft
E. Channel Peak Flow, Q =	15.000	cfs
F. Enter - 1 - for Type "C" Veg. Retardence - 2 - for Type "D" Veg. Retardence	2	

II. Peak Flow Calculations.

A. Trial flow depth, D = (Bisection method until Va=Vb)	0.425	ft
B. Channel flow area, Ac = (.5*Z1*D^2) + (B*D) + (.5*Z2*D^2)	5.064	sq ft
C. Wetted Perimeter, Pw = (D*(Z1^2+1)^.5) + B + (D*(Z2^2+1)^.5)	13.930	ft
D. Hydraulic radius, Rh = (Ac/Pw)	0.364	ft
E. Velocity and hydraulic radius, VR = (Va * Rh)	1.077	sfps
F. Channel flow Manning's coeff, nc = Type "D" Veg. Retardence	0.057	
G. Trial velocity, Va = (Q/Ac)	2.962	fps
H. Resultant velocity, Vb = (1.49/nc) * (Rh^.667) * (S^.5)	2.963	fps

RMT, Inc.
Grass Channel Sizing Calculations

Site: AMERICAN STEEL FOUNDRIES Date: 16-Nov-94
Project #: 2169.30 User: D.MARSHALL
Channel: Drainage ditch (flat bottom)
See Figure 4-1, Ditch in Area 1B to Basin #1

FOR 100 YEAR STORM

I. Input Parameters.

A. Side slope, Z1 (hor/vert) =	3.000 ft/ft
B. Side slope, Z2 (hor/vert) =	4.000 ft/ft
C. Bottom width, B =	10.000 ft
D. Design channel slope, S =	0.050 ft/ft
E. Channel Peak Flow, Q =	12.000 cfs
F. Enter - 1 - for Type "C" Veg. Retardence - 2 - for Type "D" Veg. Retardence	2

II. Peak Flow Calculations.

A. Trial flow depth, D = (Bisection method until Va=Vb)	0.390 ft
B. Channel flow area, Ac = (.5*Z1*D^2) + (B*D) + (.5*Z2*D^2)	4.438 sq ft
C. Wetted Perimeter, Pw = (D*(Z1^2+1)^.5) + B + (D*(Z2^2+1)^.5)	12.845 ft
D. Hydraulic radius, Rh = (Ac/Pw)	0.346 ft
E. Velocity and hydraulic radius, VR = (Va * Rh)	0.934 sfps
F. Channel flow Manning's coeff, nc = Type "D" Veg. Retardence	0.061
G. Trial velocity, Va = (Q/Ac)	2.704 fps
H. Resultant velocity, Vb = (1.49/nc) * (Rh^.667) * (S^.5)	2.704 fps

RMT, Inc.
Grass Channel Sizing Calculations

Site: AMERICAN STEEL FOUNDRIES Date: 11-Nov-94
Project #: 2169.30 User: D.MARSHALL VBJK 11/15/94
Channel: **Drainage ditch** (V-Notch bottom)

SEE FIGURE 4-1 → DITCH IN AREA 2A TO BASIN #2

FOR 100 YEAR STORM

I. Input Parameters.

A. Side slope, Z1 (hor/vert) =	3.000 ft/ft
B. Side slope, Z2 (hor/vert) =	4.000 ft/ft
C. Bottom width, B =	0.000 ft
D. Design channel slope, S =	0.100 ft/ft
E. Channel Peak Flow, Q =	4.000 cfs
F. Enter - 1 - for Type "C" Veg. Retardence - 2 - for Type "D" Veg. Retardence	2

II. Peak Flow Calculations.

A. Trial flow depth, D = (Bisection method until Va=Vb)	0.585 ft
B. Channel flow area, Ac = (.5*Z1*D^2) + (B*D) + (.5*Z2*D^2)	1.199 sq ft
C. Wetted Perimeter, Pw = (D*(Z1^2+1)^.5) + B + (D*(Z2^2+1)^.5)	4.263 ft
D. Hydraulic radius, Rh = (Ac/Pw)	0.281 ft
E. Velocity and hydraulic radius, VR = (Va * Rh)	0.938 sfps
F. Channel flow Manning's coeff, nc = Type "D" Veg. Retardence	0.061
G. Trial velocity, Va = (Q/Ac)	3.337 fps
H. Resultant velocity, Vb = (1.49/nc) * (Rh^.667) * (S^.5)	3.338 fps

RMT, Inc.
Grass Channel Sizing Calculations

Site: AMERICAN STEEL FOUNDRIES Date: 11-Nov-94
Project #: 2169.30 User: D.MARSHALL VBJK 11/16/94
Channel: Drainage ditch (V-Notch bottom)

SEE FIGURE 4-1 → DITCH IN AREA 2B TO BASIN #2

FOR 100 YEAR STORM

I. Input Parameters.

A. Side slope, Z1 (hor/vert) =	3.000 ft/ft
B. Side slope, Z2 (hor/vert) =	4.000 ft/ft
C. Bottom width, B =	0.000 ft
D. Design channel slope, S =	0.100 ft/ft
E. Channel Peak Flow, Q =	5.000 cfs
F. Enter - 1 - for Type "C" Veg. Retardence - 2 - for Type "D" Veg. Retardence	2

II. Peak Flow Calculations.

A. Trial flow depth, D = (Bisection method until Va=Vb)	0.621 ft
B. Channel flow area, Ac = (.5*Z1*D^2) + (B*D) + (.5*Z2*D^2)	1.349 sq ft
C. Wetted Perimeter, Pw = (D*(Z1^2+1)^.5) + B + (D*(Z2^2+1)^.5)	4.522 ft
D. Hydraulic radius, Rh = (Ac/Pw)	0.298 ft
E. Velocity and hydraulic radius, VR = (Va * Rh)	1.106 sfps
F. Channel flow Manning's coeff, nc = Type "D" Veg. Retardence	0.057
G. Trial velocity, Va = (Q/Ac)	3.708 fps
H. Resultant velocity, Vb = (1.49/nc) * (Rh^.667) * (S^.5)	3.709 fps

RMT, Inc.
Grass Channel Sizing Calculations

Site: AMERICAN STEEL FOUNDRIES Date: 11-Nov-94
Project #: 2169.30 User: D.MARSHALL VBJL 11/16/94
Channel: **Drainage ditch** (V-Notch bottom)

SEE FIGURE 4-1 → DITCH IN AREA 2B TO BASIN # 2

FOR 100 YEAR STORM

I. Input Parameters.

A. Side slope, Z1 (hor/vert) =	3.000 ft/ft
B. Side slope, Z2 (hor/vert) =	4.000 ft/ft
C. Bottom width, B =	0.000 ft
D. Design channel slope, S =	0.030 ft/ft
E. Channel Peak Flow, Q =	5.000 cfs
F. Enter - 1 - for Type "C" Veg. Retardence - 2 - for Type "D" Veg. Retardence	2

II. Peak Flow Calculations.

A. Trial flow depth, D = (Bisection method until Va=Vb)	0.811 ft
B. Channel flow area, Ac = (.5*Z1*D^2) + (B*D) + (.5*Z2*D^2)	2.305 sq ft
C. Wetted Perimeter, Pw = (D*(Z1^2+1)^.5) + B + (D*(Z2^2+1)^.5)	5.912 ft
D. Hydraulic radius, Rh = (Ac/Pw)	0.390 ft
E. Velocity and hydraulic radius, VR = (Va * Rh)	0.846 sfps
F. Channel flow Manning's coeff, nc = Type "D" Veg. Retardence	0.063
G. Trial velocity, Va = (Q/Ac)	2.170 fps
H. Resultant velocity, Vb = (1.49/nc) * (Rh^.667) * (S^.5)	2.169 fps

APPENDIX N

PIPE STRENGTH CALCULATIONS

APPENDIX N

PIPE STRENGTH CALCULATIONS

TABLE OF CONTENTS

- Purpose/Methodologies/Assumptions/Results
- Calculations

PIPE STRENGTH CALCULATIONS

Purpose:

The purpose of the pipe strength calculations is to demonstrate that the pipes selected for each piping application will be able to withstand the potential worst-case loading conditions without sacrificing the pipes' design performance capabilities.

Methodologies:

For buried flexible pipelines, the controlling design criterion is ring deflection. By limiting ring deflection, the potential for deformation by wall buckling or wall crushing is greatly reduced.

Flexible pipe is evaluated by calculating the expected deflection using the Modified Iowa Formula. The formula combines inherent properties of the pipe and the soil backfill material to determine pipe deflection, given an applied load. The formula is shown in Figure 1.

For the piping application, the most severe (worst-case) loading condition must first be determined before solving the Modified Iowa Formula for deflection. Following the determination of the most severe loading condition, the pipe deflection is then determined. A printout of the calculations performed on a Lotus spreadsheet has also been included.

Based on standard engineering practice for the design of most flexible buried pipes, the allowable defection for all pipes has been limited to 5 percent.

For HDPE pipe, most manufacturers recommend limiting deflection based on a function of the allowable tangential strain in the outer surface of the pipe wall. For landfill applications, the recommended allowable tangential strain is 5 percent. A tangential strain of 5 percent corresponds to an allowable deflection of from 9 to 40 percent depending on the pipe's Standard Dimensional Ratio (SDR). An allowable deflection of 5 percent will meet and exceed tangential strain requirements and will also provide a safety factor greater than 4.

Assumptions:

Piping Applications

- 6-inch-diameter (SDR 17) HDPE Drain Pipe

Loading Conditions

The structural stability of each pipe was analyzed for severe loading conditions. The severe loading conditions assumed are as follows:

- Maximum equipment loaded on the pipe with a minimum soil cover (typically 24 inches).
- Maximum height of soil placed over the pipe.

After the severe loads are determined, the maximum load for the piping configuration is entered into the Modified Iowa Formula to check ring deflection values.

In determining the severe live load conditions, the following equipment was assumed to cause the highest live load condition during construction or operation of the landfill:

- Cat 637E Scraper
- Cat 826C Landfill Compactor
- Cat D400D Articulated Dump Truck
- Cat D9N WDA Dozer

The vehicle specifications were determined from the Caterpillar Performance Handbook (Edition 20), and a concrete pipe handbook.

Unit weights for the cover soils of 125 lb/ft^3 for the cover soil load and 120 lb/ft^3 for the pipe bedding material were used as conservative values.

Results:

The 6-inch-diameter (SDR 17) HDPE drain pipe was tested using the Modified Iowa Formula for deflection. Calculations for the drainage layer collection pipe indicate that the maximum pipe deflection with a loaded Cat 637E Scraper would be 4.2 percent. The factor of safety for this situation would be approximately 4.7.

CALCULATIONS

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
ASF - ALLIANCE	By BLP	Date 10/31/94	By RDP	Date 11/16/94	2169.30

LOADING CONDITIONS

THE STRUCTURAL STABILITY OF EACH PIPE NEEDS TO BE ANALYZED FOR SEVERE LOADING CONDITIONS. THE SEVERE LOADING CONDITIONS ARE AS FOLLOWS:

- MAXIMUM EQUIPMENT LOAD ON THE PIPE WITH A MINIMUM SOIL COVER (TYPICALLY 24").
- MAXIMUM HEIGHT OF SOIL AND/OR WASTE PLACED OVER THE PIPE.

AFTER THE SEVERE LOADS ARE DETERMINED, THE MAXIMUM LOAD FOR EACH PIPE CONFIGURATION IS ENTERED INTO THE MODIFIED IOWA FORMULA TO CHECK RING DEFLECTION AND TANGENTIAL STRAIN VALUES.

EQUIPMENT LOADS

FROM UNI-BELL HANDBOOK OF PVC PIPE - DESIGN AND CONSTRUCTION (1986),

$$W_{sc} = C_s \frac{PF'}{L}$$ ← FOR CONCENTRATED LOADS

WHERE: W_{sc} = THE LOAD ON THE PIPE, lb/unit length
P = THE CONCENTRATED LOAD, lbs
F' = THE IMPACT FACTOR ← USE 1.5 (FROM UNI-BELL BOOK)
L = THE EFFECTIVE LENGTH OF THE CONDUIT (3' OR LESS), ft
C_s = THE LOAD COEFFICIENT WHICH IS A FUNCTION OF $B_c/(2H)$ AND $L/(2H)$, WHERE:
H = THE HEIGHT OF THE FILL FROM THE TOP OF THE PIPE TO GROUND SURFACE, ft.
B_c = THE DIAMETER OF THE PIPE, ft.

COMPUTATION SHEET

RMT INC.

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX. (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED	CHECKED	PROJECT/PROPOSAL NO.
ASF - ALLIANCE	BLP 10/31/94	KDP 11/16/94	2169.30

$$W_{SD} = C_s P F' B_c$$ ← FOR DISTRIBUTED LOADS

WHERE: W_{SD} = THE LOAD ON THE PIPE, lb/unit length
P = THE INTENSITY OF THE DISTRIBUTED LOAD, lb/ft²
F' = THE IMPACT FACTOR ← USE 1.5 (FROM UNI-BELL BOOK)
B_c = THE DIAMETER OF THE PIPE, ft.
C_s = THE LOAD COEFFICIENT WHICH IS A FUNCTION OF $D/(2H)$ AND $M/(2H)$ WHERE D AND M ARE THE WIDTH AND LENGTH, RESPECTIVELY, OF THE AREA OVER WHICH THE DISTRIBUTED LOAD ACTS, ft.

The values of C_s can be determined by use of Table 25:

TABLE 25 – VALUES OF C_s

Values of Load Coefficients, C_s, for Concentrated and Distributed Superimposed Loads Vertically Centered Over Conduit*

$\frac{D}{2H}$ or $\frac{B_c}{2H}$	$\frac{M}{2H}$ or $\frac{L}{2H}$													
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	5.0
0.1	0.019	0.037	0.053	0.067	0.079	0.089	0.097	0.103	0.108	0.112	0.117	0.121	0.124	0.128
0.2	0.037	0.072	0.103	0.131	0.155	0.174	0.189	0.202	0.211	0.219	0.229	0.238	0.244	0.248
0.3	0.053	0.103	0.149	0.190	0.224	0.252	0.274	0.292	0.306	0.318	0.333	0.345	0.355	0.360
0.4	0.067	0.131	0.190	0.241	0.284	0.320	0.349	0.373	0.391	0.405	0.425	0.440	0.454	0.460
0.5	0.079	0.155	0.224	0.284	0.336	0.379	0.414	0.441	0.463	0.481	0.505	0.525	0.540	0.548
0.6	0.089	0.174	0.252	0.320	0.379	0.428	0.467	0.499	0.524	0.544	0.572	0.596	0.613	0.624
0.7	0.097	0.189	0.274	0.349	0.414	0.467	0.511	0.546	0.584	0.597	0.628	0.650	0.674	0.688
0.8	0.103	0.202	0.292	0.373	0.441	0.499	0.546	0.584	0.615	0.639	0.674	0.703	0.725	0.740
0.9	0.108	0.211	0.306	0.391	0.463	0.524	0.574	0.615	0.647	0.673	0.711	0.742	0.766	0.784
1.0	0.112	0.219	0.318	0.405	0.481	0.544	0.597	0.639	0.673	0.701	0.740	0.774	0.800	0.816
1.2	0.117	0.229	0.333	0.425	0.505	0.572	0.628	0.674	0.711	0.740	0.783	0.820	0.849	0.868
1.5	0.121	0.238	0.345	0.440	0.525	0.596	0.650	0.703	0.742	0.774	0.820	0.861	0.894	0.916
2.0	0.124	0.244	0.355	0.454	0.540	0.613	0.674	0.725	0.766	0.800	0.849	0.894	0.930	0.956

**Influence coefficients for solution of Holl's and Newmark's integration of the Boussinesq equation for vertical stress.*

SOURCE: DESIGN & CONSTRUCTION OF SANITARY & STORM SEWERS, "MANUALS & REPORTS ON ENGINEERING PRACTICE NO. 37", AMERICAN SOCIETY OF CIVIL ENGINEERS AND "MANUAL OF PRACTICE NO. 9", WATER POLLUTION CONTROL FEDERATION, 1969, P. 300.

USING THE FORMULAS, DETERMINE THE MAXIMUM EQUIPMENT LOADS FOR THE 6" DIAMETER PIPES TO BE USED IN THE LANDFILL DESIGN.

RMT INC.
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX (608) 831-3334

COMPUTATION SHEET

PROJECT / PROPOSAL NAME	PREPARED	CHECKED	PROJECT/PROPOSAL NO.
ASF - ALLIANCE	BLP 10/31/94	KDP 11/16/94	2169.30

CONSIDER THE FOLLOWING TYPES OF EQUIPMENT WHICH ARE LIKELY TO BE USED DURING CONSTRUCTION OR OPERATION OF THE LANDFILL: CAT 637E SCRAPER, CAT D9N WDA DOZER, CAT D400D ARTICULATED DUMP TRUCK, AND CAT 826C LANDFILL COMPACTOR.

— CAT 637E SCRAPER *

OPERATING WEIGHT (LOADED) = 195,000 lbs

50/50 WEIGHT DISTRIBUTION

$\Longrightarrow$ WEIGHT PER WHEEL = $\frac{195,000}{4}$ = 48,750 lbs = P

— CAT 826C LANDFILL COMPACTOR *

OPERATING WEIGHT = 69,700 lbs

50/50 WEIGHT DISTRIBUTION

$\Longrightarrow$ WEIGHT PER WHEEL = $\frac{69,700}{4}$ = 17,425 lbs = P

— CAT D400D ARTICULATED DUMP TRUCK *

34/33/33 WEIGHT DISTRIBUTION (3) GROSS VEHICLE WEIGHT = 141,700 lbs.

$\Longrightarrow$ WEIGHT PER WHEEL = $\frac{141,700}{6}$ = 23,617 lbs = P

FOR WHEELED VEHICLES, THE SCRAPER LOAD IS THE LARGEST. USE THIS VALUE TO DETERMINE W_{sc}.

— CAT D9N WDA DOZER *

OPERATING WEIGHT = 94,000 lbs.

GROUND CONTACT AREA = 6571 in² (3285.5 in²/track) → width = 2' length = 11.

WEIGHT PER TRACK = 94,000 lbs./2 = 47,000 lbs.

INTENSITY OF LOAD = 47,000 lbs./3285.5 in² = 14 psi = 2060 psf = P

↳ used to f W_{sD}

* VALUES FROM CATERPILLAR PERFORMANCE HANDBOOK EDITION 20.

ESTIMATED DEFLECTION

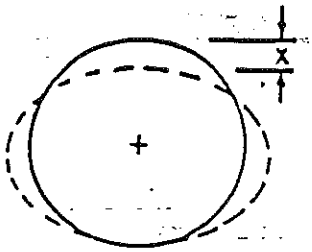
$$\% \text{ deflection} = \frac{\text{Calculated deflection} \times 100}{\text{Outside diameter of pipe}}$$

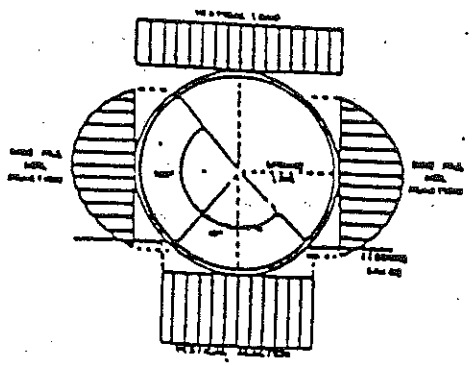
X = Calculated deflection

$$X = \frac{K \times D \times W}{(0.149 \times PS + 0.061 \times E')}$$ ← MODIFIED IOWA FORMULA

$$W = \frac{DC \times OD \times SD}{144}$$

$$PS = \frac{E \times I}{0.149 \times R^3}$$





Where
- OD = Outside diameter of pipe (inch)
- K = Bedding Factor = 0.1
- D = Deflection Lag Factor = 1.5
- W = Weight per Lineal Inch (#/inch)
- PS = Pipe Stiffness (PSI)
- E' = Soil Modulus (See Figure 1)
- E = Flexural Modulus (PSI)
  - = 133,000 PSI for PE 3408
  - = 100,000 PSI for PE 2406
- DC = Depth of cover (feet)
- SD = Soil Density (#/ft³)
- SDR = Standard Dimentional Ratio
- I = Average Wall Thickness (inch)

$$I = \frac{OD \times 1.06}{SDR}$$

- I = Moment of Inertia = $I^3/12$
- R = Mean Radii of the pipe (inch)

$$R = \frac{(OD - I)}{2}$$

Figure 1
BUREAU OF RECLAMATION VALUES OF E' FOR IOWA FORMULA
(For Initial Flexible Pipe Deflection)

Soil type-pipe bedding material (Unified Classification System 1/)	E' for degree of compaction of bedding (lb/in²) 2/			
	Dumped	Slight <85% Proctor <40% rel. den.	Moderate 85-95% Proctor 40-70% rel. den.	High >95% Proctor >70% rel. den.
Fine-grained Soils (LL > 50) 2/ Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent Soils Engineer; Otherwise use E' = 0			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with less than 25 percent coarse-grained particles	50	200	400	1,000
Fine-grained Soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with more than 25 percent coarse-grained particles; Coarse-grained Soils with Fines GM, GC, SM, SC 3/ contains more than 12 percent fines	100	400	1,000	2,000
Coarse-grained Soils with Little or No Fines GW, GP, SW, SP 3/ contains less than 12 percent fines	200	1,000	2,000	3,000
Crushed Rock	1,000	3,000		

1/ ASTM Designation D-2487, USBR Designation E-3.

2/ LL = Liquid limit.

3/ Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC).

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PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
ASE - Alliance	BLP	10/31/94	KDP	11/16/94	2169.30

SOIL LOADS

ASSUME UNIT WEIGHTS AS FOLLOWS:

COVER SOILS - 125 pcf

PIPE BEDDING MATERIAL - 120 pcf

• 6-inch-diameter pipe

PIPE BEDDING MATERIAL - (0.5')(120 pcf) = 60 psf
SOIL - (2.5')(125 pcf) = 312.5 psf

TOTAL SOIL LOAD = 60 + 312.5 = 372.5 psf

$$w = (372.5\ psf)\left(\frac{1\ ft^2}{144\ in^2}\right)(6.625\ in) = 17.1\ lb/in$$

EQUIPMENT LOADS

ASSUME 2' MIN. COVER OVER PIPE

• 6-inch-diameter pipe

O.D. = 6.625" = 0.552'

$$\frac{B_c}{2H} = \frac{0.552'}{2(2')} = 0.138$$

$$\frac{L}{2H} = \frac{3'}{2(2')} = 0.75$$

INTERPOLATING FROM TABLE 25, $C_s = 0.136$

$$w = (0.136)\frac{(48{,}750\ lb)(1.5)}{3'} = 3315\ lb/ft = 276\ lb/in$$

∴ EQUIPMENT LOAD POSES WORST-CASE (276 lb/in > 17.1 lb/in)

COMPUTATION SHEET

RMT INC.
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PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
ASF - Alliance	BLP	10/31/94	KDP	11/16/94	2169.30

DEFLECTION CALCULATION

6-inch-diameter (SDR 17) HDPE pipe

PIPE CHARACTERISTICS

O.D. = 6.625"

FLEXURAL MODULUS, $E = 133{,}000$ psi

AVE. WALL THICKNESS, $t = \frac{O.D. \times 1.06}{SDR} = \frac{6.625 \times 1.06}{17} = 0.413$ in.

$w = 276$ lb/in

PIPE STRENGTH, $PS = \frac{EI}{0.149\,R^3}$

$$I = \frac{t^3}{12} = \frac{(0.413\text{ in})^3}{12} = 0.006$$

$$R = \frac{O.D. - t}{2} = \frac{6.625 - 0.413}{2} = 3.106$$

$$PS = \frac{(133{,}000\text{ psi})(0.006)}{(0.149)(3.106)^3} = 178.7\text{ psi}$$

FOR PIPE EMBEDDED IN COARSE-GRAINED SOILS WITH AN ASSUMED DEGREE OF COMPACTION BETWEEN 40-70% OF THE RELATIVE DENSITY, THE CORRESPONDING SOIL MODULUS (E') IS 2000 psi (FIG. 1)

ASSUMING BEDDING CONSTANT, K = 0.10 AND THE DEFLECTION LAG FACTOR, D = 1.5

$$X = \frac{K \times D \times w}{(0.149)(PS) + (0.061)(E')}$$

$$X = \frac{(0.10)(1.5)(276\text{ lb/in})}{(0.149)(178.7\text{ psi}) + (0.061)(2000\text{ psi})} = 0.279\text{ in}$$

$$\%\text{ DEFLECTION} = \frac{X}{O.D.} \times 100 = \frac{0.279\text{ in}}{6.625\text{ in}} \times 100 = 4.2\%$$

4.2% < 5%*, ∴ PIPE STRENGTH IS SUITABLE FOR THESE CONDITIONS

* ALLOWABLE DESIGN DEFLECTION

✓ KPP
11/16/94

***** MODIFIED IOWA FORMULA FOR HDPE PIPE DESIGN BY RING DEFLECTION *****

PROJECT NAME:ASF-ALLIANCE
PROJECT NO. : 08-Dec-05
USER NAME :BLP
DATE : 31-Oct-94

PIPE DESCRIPION: 6" DIA. (SDR 17) HDPE DRAIN PIPE

<<< VARIABLES >>>

STANDARD DIMENSION RATIO	17.0
OUTSIDE DIAMETER (inches)	6.625
WEIGHT / LINEAL INCH (lbs/in)	276
SOIL MODULUS (psi)	2000

<<< CONSTANTS >>>

BEDDING FACTOR	0.10
DEFLECTION LAG FACTOR	1.5
FLEXURAL MODULUS (psi)	133,000

<<< CALCULATED VALUES >>>

AVERAGE WALL THICKNESS (inches)	0.413
MOMENT OF INERTIA (inch^3)	0.006
MEAN RADII (inches)	3.106
PIPE STIFFNESS (psi)	175
DEFLECTION (inches)	0.280
% DEFLECTION	4.22%
% TANGENTIAL STRAIN	1.05%
TANGENTIAL STRAIN ALLOWABLE	5.00%
FACTOR OF SAFETY	4.75

PE 3408 Industrial Piping System
Pipe Data and Pressure Ratings

(Pipe weights are calculated in accordance with PPI TR-7)

PRESSURE RATING		255 psi SDR 7.3		200 psi SDR 9		160 psi SDR 11		130 psi SDR 13.5		110 psi SDR 15.5		100 psi SDR 17		80 psi SDR 21		65 psi SDR 26		50 psi SDR 32.5	
IPS* PIPE SIZE	O.D. SIZE (INCHES)	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT
1¼"	1.660	—	—	—	—	.151	.31	—	—	—	—	—	—	—	—	—	—	—	—
2"	2.375	.325	.91	.264	.76	.216	.64	—	—	—	—	—	—	—	—	—	—	—	—
3"	3.500	.479	1.98	.389	1.65	.318	1.39	.259	1.15	.226	1.02	.206	.93	—	—	—	—	—	—
4"	4.500	.616	3.27	.500	2.74	.409	2.30	.333	1.90	.290	1.67	.265	1.54	.214	1.26	—	—	—	—
5"	5.563	.762	5.00	.618	4.18	.506	3.51	.412	2.91	.359	2.57	.327	2.35	.265	1.93	.214	1.58	—	—
6"	6.625	.908	7.09	.736	5.93	.602	4.97	.491	4.13	.427	3.64	.390	3.34	.316	2.74	.255	2.23	.204	1.80
7"	7.125	—	—	—	—	—	—	—	—	—	—	.420	3.87	.340	3.17	.274	2.58	.220	2.09
8"	8.625	1.182	12.01	.958	10.05	.785	8.43	.639	7.00	.556	6.16	.508	5.66	.411	4.64	.332	3.79	.265	3.05
10"	10.750	1.473	18.66	1.194	15.62	.978	13.10	.797	10.89	.694	9.59	.633	8.80	.512	7.21	.413	5.87	.331	4.75
12"	12.750	1.747	26.25	1.417	21.97	1.160	18.43	.945	15.31	.823	13.47	.750	12.36	.608	10.14	.490	8.26	.392	6.67
14"	14.000	1.918	31.64	1.556	26.49	1.273	22.20	1.037	18.44	.903	16.24	.824	14.91	.667	12.22	.538	9.96	.431	8.05
16"	16.000	2.192	41.34	1.778	34.61	1.455	29.00	1.185	24.09	1.032	21.21	.941	19.46	.762	15.97	.615	13.02	.492	10.51
18"	18.000	2.466	52.31	2.000	43.79	1.636	36.69	1.333	30.48	1.161	26.85	1.059	24.65	.857	20.19	.692	16.48	.554	13.29
20"	20.000	2.740	64.57	2.222	54.05	1.818	45.30	1.481	37.64	1.290	33.13	1.176	30.42	.952	24.92	.769	20.34	.615	16.41
22"	22.000	*	*	2.444	65.41	2.000	54.82	1.630	45.56	1.419	40.09	1.294	36.81	1.048	30.19	.846	24.62	.677	19.87
24"	24.000	*	*	2.667	77.85	2.182	65.24	1.778	54.22	1.548	47.72	1.412	43.82	1.143	35.92	.923	29.29	.738	23.62
†26"	26.000	—	—	2.889	91.35	2.364	76.58	1.926	63.63	1.677	56.02	1.529	51.40	1.238	42.13	1.000	34.39	.800	27.74
28"	28.000	—	—	—	—	2.545	88.79	2.074	73.76	1.806	64.94	1.647	59.62	1.333	48.86	1.077	39.89	.862	32.20
30"	30.000	—	—	—	—	2.727	101.94	2.222	84.68	1.935	74.56	1.765	68.45	1.429	56.13	1.154	45.78	.923	36.92
32"	32.000	—	—	—	—	2.909	115.99	2.370	96.35	2.065	84.88	1.882	77.86	1.524	63.83	1.231	52.10	.985	42.04
†34"	34.000	—	—	—	—	—	—	2.519	108.80	2.194	95.83	2.000	87.91	1.619	72.06	1.308	58.79	1.046	47.44
36"	36.000	—	—	—	—	—	—	2.667	121.98	2.323	107.40	2.118	98.56	1.714	80.79	1.385	65.93	1.108	53.18

*Industrial PE (polyethylene) pipe sizes are identified by IPS (iron pipe size) diameters which designate the nominal diameter for 12" IPS AND SMALLER PIPE, AND O.D. (outside diameter) for 14" IPS and larger pipe.

**Check with your PLEXCO sales office for availability of this item or other sizes not listed.

† Subject to minimum order quantities.

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1990 ANNUAL BOOK OF ASTM STANDARDS

SECTION 8

Plastics

ASTM

VOLUME

08.04 Plastic Pipe and Building Products

Revision issued annually

000382

TABLE 1 Outside Diameters and Tolerances for PVC Plastic Pipe Schedules 40, 80, and 120, in. (mm)

Nominal Pipe Size	Outside Diameter	Tolerances		
		Average	For Max and Min Diameter (Out-of-Roundness)	
			Schedule 40 sizes 3½ in. and over; Schedule 80 sizes 8 in. and over	Schedule 40 sizes 3 in. and less; Schedule 80 sizes 6 in. and less; Schedule 120 sizes all
⅛	0.405 (10.29)	±0.004 (±0.10)	...	±0.008 (±0.20)
¼	0.540 (13.72)	±0.004 (±0.10)	...	±0.008 (±0.20)
⅜	0.675 (17.14)	±0.004 (±0.10)	...	±0.008 (±0.20)
½	0.840 (21.34)	±0.004 (±0.10)	...	±0.008 (±0.20)
¾	1.050 (26.67)	±0.004 (±0.10)	...	±0.010 (±0.25)
1	1.315 (33.40)	±0.005 (±0.13)	...	±0.010 (±0.25)
1¼	1.660 (42.16)	±0.005 (±0.13)	...	±0.012 (±0.30)
1½	1.900 (48.26)	±0.006 (±0.15)	...	±0.012 (±0.30)
2	2.375 (60.32)	±0.006 (±0.15)	...	±0.012 (±0.30)
2½	2.875 (73.02)	±0.007 (±0.18)	...	±0.015 (±0.38)
3	3.500 (88.90)	±0.008 (±0.20)	...	±0.015 (±0.38)
3½	4.000 (101.60)	±0.008 (±0.20)	±0.050 (±1.27)	±0.015 (±0.38)
4	4.500 (114.30)	±0.009 (±0.23)	±0.050 (±1.27)	±0.015 (±0.38)
5	5.563 (141.30)	±0.010 (±0.25)	±0.050 (±1.27)	±0.030 (±0.76)
6	6.625 (168.28)	±0.011 (±0.28)	±0.050 (±1.27)	±0.035 (±0.89)
8	8.625 (219.08)	±0.015 (±0.38)	±0.075 (±1.90)	±0.045 (±1.14)
10	10.750 (273.05)	±0.015 (±0.38)	±0.075 (±1.90)	±0.050 (±1.27)
12	12.750 (323.85)	±0.015 (±0.38)	±0.075 (±1.90)	±0.060 (±1.52)

TABLE 2 Wall Thicknesses and Tolerances for PVC Plastic Pipe, Schedules 40, 80, and 120,[A,B] in. (mm)

Nominal Pipe Size	Wall Thickness[A]					
	Schedule 40		Schedule 80		Schedule 120	
	Min	Tolerance	Min	Tolerance	Min	Tolerance
⅛	0.068 (1.73)	+0.020 (+0.51)	0.095 (2.41)	+0.020 (+0.51)	...	...
¼	0.088 (2.24)	+0.020 (+0.51)	0.119 (3.02)	+0.020 (+0.51)	...	...
⅜	0.091 (2.31)	+0.020 (+0.51)	0.126 (3.20)	+0.020 (+0.51)	...	...
½	0.109 (2.77)	+0.020 (+0.51)	0.147 (3.73)	+0.020 (+0.51)	0.170 (4.32)	+0.020 (+0.51)
¾	0.113 (2.87)	+0.020 (+0.51)	0.154 (3.91)	+0.020 (+0.51)	0.170 (4.32)	+0.020 (+0.51)
1	0.133 (3.38)	+0.020 (+0.51)	0.179 (4.55)	+0.021 (+0.53)	0.200 (5.08)	+0.024 (+0.61)
1¼	0.140 (3.56)	+0.020 (+0.51)	0.191 (4.85)	+0.023 (+0.58)	0.215 (5.46)	+0.026 (+0.66)
1½	0.145 (3.68)	+0.020 (+0.51)	0.200 (5.08)	+0.024 (+0.61)	0.225 (5.72)	+0.027 (+0.68)
2	0.154 (3.91)	+0.020 (+0.51)	0.218 (5.54)	+0.026 (+0.66)	0.250 (6.35)	+0.030 (+0.76)
2½	0.203 (5.16)	+0.024 (+0.61)	0.276 (7.01)	+0.033 (+0.84)	0.300 (7.62)	+0.036 (+0.91)
3	0.216 (5.49)	+0.026 (+0.66)	0.300 (7.62)	+0.036 (+0.91)	0.350 (8.89)	+0.042 (+1.07)
3½	0.226 (5.74)	+0.027 (+0.68)	0.318 (8.08)	+0.038 (+0.96)	[illegible]50 (8.89)	+0.042 (+1.07)
4	0.237 (6.02)	+0.028 (+0.71)	0.337 (8.56)	+0.040 (+1.02)	[illegible]37 (11.10)	+0.052 (+1.32)
5	0.258 (6.55)	+0.031 (+0.79)	0.375 (9.52)	+0.045 (+1.14)	[illegible]00 (12.70)	+0.060 (+1.52)
6	0.280 (7.11)	+0.034 (+0.86)	0.432 (10.97)	+0.052 (+1.32)	[illegible]62 (14.27)	+0.067 (+1.70)
8	0.322 (8.18)	+0.039 (+0.99)	0.500 (12.70)	+0.060 (+1.52)	[illegible]18 (18.24)	+0.086 (+2.18)
10	0.365 (9.27)	+0.044 (+1.12)	0.593 (15.06)	+0.071 (+1.80)	[illegible]43 (21.41)	+0.101 (+2.56)
12	0.406 (10.31)	+0.049 (+1.24)	0.687 (17.45)	+0.082 (+2.08)	[illegible]000 (25.40)	+0.120 (+3.05)

[A] The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.

[B] These dimensions conform to nominal IPS dimensions, with the exception that Schedule 120 wall thickness for pipe sizes ½ to 3½ in. (12.5 to 87.5 mm), inclusive, are special PVC plastic pipe sizes.

000383

APPENDIX O

GEOTEXTILE DESIGN CALCULATIONS

GEOTEXTILE DESIGN CALCULATIONS

TABLE OF CONTENTS

- Purpose/Methodologies/Assumptions/Results

APPENDIX O

GEOTEXTILE DESIGN CALCULATIONS

Purpose:

The purpose of the geotextile design calculations is to demonstrate proper geotextile selection for its intended function. The filters are designed to provide reinforcement, separation, and/or to prevent excessive migration of soil particles while, at the same time, allowing flow of liquid from the soil.

Methodologies:

The design methodology utilized in selecting geotextiles is based on methods described in the Nicolon Corporation "Geotextile Filter Design Manual," which was developed by Geosyntec Consultants. The geotextiles were analyzed by evaluating the materials anticipated to be used adjacent to one another. The following geotextile applications were analyzed:

1. General Soil/Geotextile - This configuration occurs in the final cover. A geotextile is used to separate the 1.5-foot general fill layer from the select granular fill drainage layer (see Detail 1 on Plan Sheet 6B).

2. Perimeter Drainage Layer Collection Pipe - This configuration occurs along the perimeter of the final cover. A geotextile is used to separate the select granular fill soil and compacted barrier layer soil from the aggregate pipe bedding material (see Detail 6 on Plan Sheet 6B).

3. Decontamination Pad/Geotextile - This configuration occurs under the decontamination pad. A geotextile is used to separate the select aggregate from the waste (see Detail 7 on Plan Sheet 6D).

The geotextile design calculations have been performed using a series of steps which include defining the filter requirements, defining boundary conditions, determining the geotextile characteristics, and then selecting the appropriate geotextile.

Assumptions:

Assumptions regarding material characteristics adjacent to the geotextile were made for each of the design computations. The materials selected were determined to be the most likely material to be used for the application.

The following assumptions regarding material properties have been made (see computations for references):

Soil Fines Content

- All soil adjacent to geotextiles is assumed to conservatively have fines contents exceeding 20 percent. Upon actual selection of construction material source, this assumption may be re-evaluated. Since the survivability component of the geotextile sizing is likely the controlling factor, any adjustments to fines content will likely have no effect on geotextile sizing requirements.

Minimum Hydraulic Conductivities of Soil

- Select granular fill, $K_s = 1.0 \times 10^{-3}$ cm/s
- Select aggregate fill, $K_s = 1.0 \times 10^{-2}$ cm/s
- General soils, $K_s = 5.2 \times 10^{-4}$ cm/s (from HELP model, Appendix D)

Hydraulic Gradients Across Geotextiles

- General soil/geotextile - $i = 1.5$
- Perimeter drain - $i = 1.0$
- Decontamination pad - $i = 1.5$

Results:

The following table contains the recommended characteristics of the proposed geotextiles. These requirements are minimum allowable values except in the case of apparent opening size (O_{95}).

GEOTEXTILE APPLICATION[1] (Continued)				
Property	Units	General Soil	Perimeter Fill Drain[2]	Decontamination Pad[2]
Apparent opening size (O_{95})	mm	0.21	0.21	0.21
Grab tensile strength	lbs	180	180	200
Grab elongation	%	20	20	20

GEOTEXTILE APPLICATION[1] (Continued)				
Property	Units	General Soil	Perimeter Fill Drain[2]	Decontamination Pad[2]
Puncture strength	lbs	80	80	80
Burst Strength	psi	290	290	320
Permeability	cm/s	0.015	0.015	0.015

NOTES:

[1] Engineer may require a letter from the supplier certifying that its geotextile meets specification requirements.

[2] Minimum. Use value in weaker principal direction. All numerical values represent minimum average roll value (i.e., test results from any sampled roll in a lot shall meet or exceed the minimum values in the Table). Stated values are for non-critical, non-severe applications. Lots sampled according to ASTM D4354.

Geotextile Sizing Calculations

Applications (see Methodologies)

1. General soil/geotextile application should be designed to provide adequate control of the migration of fines while providing large enough openings to allow free flow.

2. The perimeter drainage layer collection pipe application should be designed to prevent migration of fines from the select granular fill layer into the pipe backfill. Migration of fines from the barrier layer is not considered to be significant due to the lack of hydraulic gradient.

3. The decontamination pad geotextile primarily serves as a separation layer between the select aggregate fill and waste. Flow capacity is also a significant design consideration.

Soil Retention Requirements (steady-state)

Assuming retained soil has >20 percent clay, the most conservative soil retention requirements will be defined by:

$$O_{95} < 0.21 \text{ mm (\#70 sieve)}$$

Provided the other geotextile sizing criteria are met, the geotextile meeting the above soil retention requirement will also be appropriate for coarser grained soil.

Geotextile Permeability Requirements

Soil hydraulic conductivities are assumed as follows:

- Select granular fill, $K_s = 1.0 \times 10^{-3}$ cm/s
- Select aggregate fill, $K_s = 1.0 \times 10^{-2}$ cm/s
- General soil, $K_s = 5.2 \times 10^{-4}$ cm/s (from HELP model, Appendix D)

Hydraulic gradients are assumed from Figure 3 (attached).

1. General soil/geotextile - $i = 1.5$
2. Perimeter drain - $i = 1.0$
3. Decontamination pad - $i = 1.5$

Minimum geotextile permeability, $kg = iK_s$

1. $kg = 1.5\ (1 \times 10^{-3}) = 1.5 \times 10^{-3}$ cm/s
2. $kg = 1.0\ (1 \times 10^{-2}) = 1.0 \times 10^{-2}$ cm/s
3. $kg = 1.5\ (1 \times 10^{-2}) = 1.5 \times 10^{-2}$ cm/s

Use $kg > 1.5 \times 10^{-2}$ cm/s to cover all applications.

Anti-Clogging

Use largest O_{95} that satisfies retention criteria ($O_{95} = 0.21$ or greater, depending on actual site soil).

Survivability Requirements (see attached Figure 4)

All applications will have moderate installation conditions with low- or high-contact stresses. As a conservative assumption, at a minimum assume all geotextiles must meet survivability requirements for moderate installation conditions with high-contact stresses.

In addition, the decontamination pad geotextile will be subjected to heavy equipment traffic. For this case, assume sever installation conditions with high-contact stresses.

Selected Geotextile

A geotextile meeting the requirements presented in the Table in the Results section of this appendix will be acceptable. An example of a geotextile meeting the requirements for all three applications is as follows:

Nicolon N-70 7.1 oz/yd^2 geotextile

FIGURE 3

TYPICAL HYDRAULIC GRADIENTS[a]

DRAINAGE APPLICATION	TYPICAL HYDRAULIC GRADIENT
STANDARD DEWATERING TRENCH	1.0
VERTICAL WALL DRAIN	1.5
PAVEMENT EDGE DRAIN	1[b]
LANDFILL LCDRS	1.5
LANDFILL LCRS	1.5
LANDFILL SWCRS	1.5
DAMS	10[b]
INLAND CHANNEL PROTECTION	1[b]
SHORELINE PROTECTION	10[b]
LIQUID IMPOUNDMENTS	10[b]

perimeter drain

final cover drainage layer / Decontamination Pad

NOTES: (a) Table developed after Giroud, 1988.

(b) Critical applications may require designing with higher gradients than those given.

FIGURE 4

SURVIVABILITY STRENGTH REQUIREMENTS[a]

		GEOTEXTILE PROPERTY[b]						
		GRAB STRENGTH (lbs)	ELONGATION (%)	SEWN SEAM STRENGTH (lbs)	PUNCTURE STRENGTH (lbs)	BURST STRENGTH (psi)	TRAPEZOID TEAR (lbs)	
MODERATE INSTALLATION CONDITIONS (TYPICAL DRAINAGE APPLICATIONS)	HIGH CONTACT STRESSES (ANGULAR DRAINAGE MEDIA) (HEAVY COMPACTATION) OR (HEAVY CONFINING STRESS)	180	N/A	160	80	290	50	← General Soils/ Perimeter Drain
	LOW CONTACT STRESSES (ROUNDED DRAINAGE MEDIA) (LIGHT COMPACTION) AND (LIGHT CONFINING STRESS)	80	N/A	70	25	130	25	
SEVERE INSTALLATION CONDITIONS (SHORELINE PROTECTION AND ARMOURED SYSTEMS APPLICATIONS)	HIGH CONTACT STRESSES (DIRECT STONE PLACEMENT) (DROP HEIGHT > 3 ft)	200	15	180	80	320	50	← Decontam Pad
	LOW CONTACT STRESSES (SAND OR GEOTEXTILE CUSHION) (DROP HEIGHT < 3 ft)	90	15	80	40	140	30	

NOTE: (a) After FHWA, 1985.

(b) Test methods for determining geotextile properties given in Table 4-6 in 'Geotextile Filter Design Manual'

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Reference:

GEOTEXTILE FILTER DESIGN MANUAL

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