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DIVISION OF WASTE MANAGEMENT
SOLID WASTE SECTION
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NC DEPT OF ENVIRONMENT
AND NATURAL RESOURCES
MOORESVILLE REGIONAL OFFICE

Duke Energy

Marshall Steam Station

Catawba County, NC

Flue Gas Desulfurization (FGD) Residue Landfill

Permit Application

.0503(2)(d)(ii)(A) Compliance Demonstration Report

Addendum, Revision 1

December 15, 2005

Prepared by:

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Fac/Perm/Co ID #	Date	Doc ID#
18-09	~~1/25/12~~ 2/2/12	DIN

December 28, 2005

NC Department of Environment and Natural Resources
Division of Waste Management
610 East Center Avenue – Suite 301
Mooresville, NC 28115

Attention: Mr. John Murray
Solid Waste Section

Subject: Duke Power – Marshall Steam Station
Catawba County, NC
Industrial Solid Waste Landfill Permit 18-09
Revisions to Construction Plan Application

Dear Mr. Murray:

Duke Power is herein submitting revised portions of the Construction Plan Application (CPA) for the Flue Gas Desulfurization (FGD) Gypsum Landfill at our Marshall Steam Station. The original CPA was submitted on April 1, 2004 and a Permit to Construct (No. 18-09) was issued on January 15, 2005. The original Marshall FGD landfill was to be constructed as an unlined landfill. Subsequent to the issuance of this Permit to Construct, Duke Power performed additional leaching tests on the clarifier sludge filter cake, an additional waste stream to be placed in this landfill. Testing of this material indicated placement of this material in an unlined landfill was not acceptable and that a synthetic liner would be required for disposal of this material.

This CPA presents information pertaining to the revised design for this landfill. This design calls for an engineered synthetic liner system, a leachate collection and removal system, and an engineered cover system. Certain information and calculations contained in the previous CPA are still accurate and will be referenced in this CPA where appropriate.

In addition, Duke Power is also submitting a revision to the Addendum for the original Compliance Demonstration Report which addresses the change in design of the landfill and the changes in the waste to be placed in the landfill. This revision demonstrates that the revised landfill design will ensure that 2L groundwater standards will not be exceeded at the compliance boundary of the landfill.

If you have any questions or require additional information, please feel free to contact me at (704) 382-7161.

Sincerely,

Patrick J. McCabe, PE
Environmental Support

Attachments: Construction Plan Application (Vol I and II) – 2 copies
Revised Addendum to Compliance Demonstration Report – 2 copies

cc: Ed Mussler, NCDENR (w/ 1 set of attachments)
Division of Waste Management
Solid Waste Section
401 Oberlin Road - Suite 150
Raleigh, NC 27605

Duke Energy

Marshall Steam Station

Catawba County, NC

Flue Gas Desulfurization (FGD) Residue Landfill

Permit Application

.0503(2)(d)(ii)(A) Compliance Demonstration Report

Addendum, Revision 1

December 15, 2005

Prepared by:

NORTH CAROLINA PROFESSIONAL SEAL 17666 ENGINEER WILLIAM M. MILLER

William M. Miller, PE
December 15, 2005

Chas. H. Sells, Inc.
128 Overhill Drive, Suite 105
Mooresville, NC 28117

Executive Summary

This revision to the Addendum for the original compliance demonstration report was prepared to address the changes in design for the Marshall FGD Residue Landfill and to address changes in the waste to be placed in the landfill. This revision provides the demonstration that the revised design for the Marshall Flue Gas Desulfurization (FGD) residue landfill will ensure that 2L groundwater standards are not exceeded at the compliance boundary. This conclusion was reached by review of the site-specific conditions, leaching tests performed on the FGD residue, and by the use of groundwater modeling.

The design evaluated in this demonstration ensures that the ground water standards established under 15A NCAC 2L will not be exceeded.

The design evaluated in this demonstration requires:

1. the landfill be constructed with an engineered liner system consisting of a leachate collection and removal system, 60 mil HDPE liner underlain by a geosynthetic clay liner.
2. the active landfill will receive FGD residue for a 10 year period.
3. an engineered cover will be placed on the completed landfill at the end of the 10 year period.
4. The engineered cover will consist of a textured 40 mil low density polyethylene geomembrane layer beneath a geocomposite drainage net. The cap and geocomposite drainage net will be topped with two feet of soil for vegetative growth. The geomembrane layer will minimize infiltration of precipitation into the waste. The geocomposite drainage net will provide lateral drainage for water that percolates through the vegetative layer.
5. The drainage collected by the geocomposite drainage net will drain to the erosion control benches, as well as draining to the anchor trench. This will limit the drainage length of the geocomposite to no greater than 300 feet.

Other than the engineered liner and cover systems described above, there are no special engineering features or considerations that must be included or maintained in site construction, operation, maintenance and closure.

Description of Revision to the November 2004 Addendum

This revision presents changes to the Addendum to the original Compliance Demonstration Report [Reference 1] .

In general, the changes to the modeling presented in this report are:

1. reduced infiltration rates based on the addition of a leachate collection and removal system, an HDPE liner, and a geosynthetic clay liner underlying the HDPE liner. The infiltration rates for the unlined landfill were 1.55 ft/year during the operational period. The reduced infiltration rates for the lined landfill are 8.3E-7 ft/yr during the operational period.
2. modeling of additional constituents; boron, chloride, and selenium.

The HELP model information is contained in the Construction Plan Application Report, dated December 15, 2005. The revised infiltration values from the HELP analyses are used as input in the MYGRT fate and transport analyses.

The MYGRT fate and transport model results found that the conclusion of the previous Compliance Demonstration Report remains valid.

Notes:

1. *Changes from the original Compliance Demonstration text are marked with a vertical line in the right margin.*
2. *Where there are no changes to discussion due to this revision, the text in these sections is removed and the notation "See November 2004 Addendum" is placed. The reviewer is referred to the November 2004 Addendum for text in these sections. Selected unrevised text relevant to revised material was left in the document.*

Table of Contents

List of Figures

There were no changes to the information shown on these Figures. Refer to the November 2004 Addendum for these figures.

List of Tables

List of Attachments

Attachment 1	*FGD Scrubber Sludge Testing (Revision 1), Duke Power Coal Fired Steam Stations in North Carolina, S&ME Project No. 1264-03-57, February 2004.*
Attachment 2	Geochemical Evaluation of Flue Gas Desulfurization Scrubber Waste, letter from William J, Deutsch, Senior Geochemist, Battelle Pacific Northwest Laboratory to Bill Miller, Duke Energy, dated June 23, 2003.
Attachment 3	HELP Model Results – *See Note below.*
Attachment 4	MYGRT Manual
Attachment 5	Input Data for MYGRT Model Runs
Attachment 6	MYGRT Model Inputs and Results

Note: The information contained in Attachments 1, 2, and 4 was used in the preparation of this report. The parties indicated on the covers of these reports prepared these reports and documents. The engineering certification on the cover page of this report does not imply that the engineering certification of this report includes certification of these particular documents.

There were no changes in the following Attachments: Attachment 1, 2, 4, 5. Copies of these Attachments are not included in this Addendum.

The revised HELP model analysis and results is found in the Appendix of the Construction Plan Application, dated December 15, 2005.

1.0 Regulatory Requirements

The regulatory requirements for the design of a solid waste, industrial landfill are found in North Carolina Administrative Code, Title 15A, Chapter 13 Solid Waste Management, Section .0503 Siting and Design Requirements for Disposal Sites. In particular, Section .0504(2)(d)(ii) requires that:

> *(A) a design that will ensure that the ground water standards established under 15A NCAC 2L will not be exceeded in the uppermost aquifer at the compliance boundary established by the Division in accordance with 15A NCAC 2L. The design shall be based upon modeling methods acceptable to the Division, which shall include, at a minimum, the following factors:*
>
> > *(I) the hydrogeologic characteristics of the facility and surrounding lands;*
> > *(II) the climatic factors of the area; and*
> > *(III) the volume and physical and chemical characteristics of the leachate; or*
>
> *(B) a design with a leachate collection system, a closure cap system, and a composite liner system consisting of two components: the upper component shall consist of a minimum 30-ml flexible membrane (FML), and the lower components shall consist of at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than 1 X 10^{-7}cm/sec. FML components consisting of high density polyethylene (HDPE) shall be at least 60-ml thick. The FML component shall be installed in direct and uniform contact with the compacted soil component.*

This report was prepared to demonstrate that the conceptual design described in the following section will ensure that the ground water standards established under 15A NCAC 2L will not be exceeded in the uppermost aquifer at the compliance boundary established by the Division in accordance with 15A NCAC 2L.

2.0 Description of Flue Gas Desulphurization (FGD) System

See November 2004 Addendum

3.0 Description of Conceptual Design

The design for the proposed gypsum landfill is shown on the drawings included in the construction plan application, dated December 15, 2005. The landfill will consist of a monofill, consisting of a mixture of gypsum and clarifier sludge. The clarifier sludge is a filter cake type material produced from the wastewater treatment system associated with the FGD system. The gypsum will be produced at the Marshall Steam Station and at other Duke plants located within NC.

The landfill will be constructed with a leachate collection and removal system and 60 mil HDPE liner. The liner will be underlain by a geosynthetic clay liner.

The engineered cover will consist of a textured 40 mil low density polyethylene geomembrane layer beneath a geocomposite drainage net. The cap and geocomposite drainage net will be topped with two feet of soil for vegetative growth. The geomembrane layer will minimize infiltration of precipitation into the waste. The geocomposite drainage net will provide lateral drainage for water that percolates through the vegetative layer.

The vegetative layer protects the geomembrane and geocomposite from ultraviolet degradation, desiccation, freeze-thaw, wind, and vectors. The vegetative layer will be stabilized and seeded appropriately to prevent erosion.

Detailed information on the design of the landfill is found in the Construction Plan Application, Document MM6451.00-0000.001, Revision 1. [Reference 2]

4.0 Description of Demonstration Approach

The general approach to demonstrate compliance with 2L standards was:

Step 1. Perform SPLP leaching tests on the FGD residue (gypsum and clarifier sludge) and determine if gypsum leachate constituents exceed the NCAC T15A 2L groundwater standards.

Step 2. Develop conceptual groundwater flow model of site.

Step 3. Use of HELP model to determine the infiltration rates expected at the landfill. These values will be the rate of leachate that will infiltrate into the soil beneath the landfill.

Step 4. Determine the groundwater concentrations of the leachate at the compliance boundary with use of the MYGRT model.

Step 5. Compare the modeled groundwater concentrations to NCAC T15A 2L standards.

5.0 SPLP Leaching Analyses Performed on FGD Residue Samples

5.1.1 Gypsum Samples

The typical parameters for the FGD material produced by the scrubber system to be used at Marshall are:

Typical FGD Residue Parameters

Gypsum	93% to 95%
Sulfite	0.35%
CO_3	1.3%
CaF_2	0.2%
Inerts	2.5% to 3.5%
Fly ash Content	0.5% to 0.8%
pH	6.0 to 8.3
Unit Weight	76 lb/ft^3 to 97 lb/ft^3
Specific Gravity	2.35
Moisture	10% to 12%

FGD residue material that is not suitable for beneficial use will be placed in the landfill. In addition to this material, material will periodically be removed from the clarifier stage of the waste-water treatment system and placed in the landfill. The material from the clarifier stage will be the same composition as the FGD residue, but will consist of smaller particles.

Gypsum samples obtained from two power plants were obtained by Duke for analysis. These plants are identified as the CO Plant and the HC Plant.[1] The CO Plant uses a FGD process designed by the same vendor supplying the Marshall FGD system and has similar system design parameters. The CO plant also uses coal that is similar in origin to the coal used by Marshall.

These FGD residue samples were sent to the Pacific Northwest National Laboratory (PNNL)[2] for geochemical evaluation. This evaluation included SPLP[3] leaching studies, analysis of solid samples by x-ray diffraction (XRD), and calculation of saturation indices to identify minerals in equilibrium with the solution phase.

[1] At the time the material was obtained, Duke had not finalized the equipment vendor selection. Therefore material from two different vendors was obtained for these analyses.
[2] PNNL is managed by the US Department of Energy and operated by Battelle.
[3] USEPA Method 1312.

To better understand the changes in leachate over time, sequential leaching tests were performed. The report is provided in Attachment 2. The results from the report are summarized below:

> *The total dissolved solids and sulfate concentrations exceeded the 2L standards for both types of waste in all leachates by factors of about 4 and 6, respectively. The initial leaches of both waste types exceeded the fluoride 2L standard by a factor of about 2; however, the fluoride concentrations decreased with subsequent leaches and either dropped below or were very close to the standard of 2 mg/L by the fifth leach. The arsenic concentrations in all leachates started below the 2L standard of 0.01 mg/L, but the concentrations increased with subsequent leaches and exceeded the standard by a small amount in all cases after the second or third leach. XRD analysis showed that the dominant mineral in the waste was gypsum ($CaSO_4{:}2H_2O$). Saturation index calculations confirm that gypsum is controlling the calcium and sulfate concentrations in the leachate and producing the major ions in solution.*

5.1.2 Comparison of Results of SPLP Leaching Analyses to 2L Standards

The comparison of the results of the leaching analyses to the NCAC T15A 2L Groundwater Standards is presented in Table 5-1. As this table shows, the concentrations of sulfate (SO_4) and fluoride (Fl_2) exceed the 2L groundwater standards in the initial leaches.

As described in the report summary, arsenic was found to leach at concentrations above the 2L standard in subsequent leaches.

Table 5-1 Results of SPLP Analyses of Gypsum Samples from CO and HC Plants

Analyte	Units	NCAC 2L Groundwater Standards	Maximum Value from Initial Leaches	CO Plant Leach #1	CO Plant Leach Dup #1	HC Plant Leach #1
pH	std units	6.5 to 8.5	7.35	7.35	7.31	7.14
Arsenic	mg/L	0.010	<0.010	<0.010	<0.010	<0.010
Barium	mg/L	2.0	0.0507	0.0411	0.0429	0.0507
Boron	mg/L	0.32	0.162	0.149	0.162	0.13
Cadmium	mg/L	0.005	<0.0020	<0.0020	<0.00020	<0.0020
Calcium	mg/L	n/a	614	597	614	612
Chloride	mg/L	250.0	5.33	5.33	4.98	3.67
Chromium	mg/L	0.05	<0.0060	<0.0060	<0.0060	<0.0060
Copper	mg/L	1.0	0.0035	0.0031	0.0035	<0.0030
Fluoride	mg/L	2.0	**4.45**	**4.45**	**4.02**	**3.05**
Iron	mg/L	0.3	0.051	<0.020	0.051	0.026
Lead	mg/L	0.015	<0.0050	<0.0050	<0.0050	<0.0050
Magnesium	mg/L	n/a	1.73	1.6	1.73	1.23
Manganese	mg/L	0.05	0.0292	0.0286	0.0292	0.0187
Mercury	mg/L	0.0011	<0.00020	<0.00020	<0.00020	<0.00020
Nickel	mg/L	0.1	<0.010	<0.010	<0.010	<0.010
Potassium	mg/L	n/a	0	<1.0	<1.0	<1.0
Selenium	mg/L	0.05	<0.010	<0.010	<0.010	<0.010
Silver	mg/L	0.018	<0.0050	<0.0050	<0.0050	<0.0050
Sodium	mg/L	n/a	2.83	0.93	0.94	2.83
Sulfate, SO_4	mg/L	250.0	**1510**	**1,490**	**1,500**	**1,510**
TDS	mg/L	n/a	2200	2,160	2,180	2,200
Zinc	mg/L	2.1	0.0157	0.012	0.0133	0.0157

Bold denotes concentrations greater than NCAC 2L groundwater standards.

5.1.3 Clarifier Filter Cake Samples

Leaching tests were performed on clarifier filter cake material and the results presented to NCDENR in report on the Duke Power Belews Creek FGD landfill. This report is titled:

Assessment of Fate and Transport
Of Constituents of Concern
For the Proposed FGD Scrubber Residue Disposal Site
Belews Creek Steam Station
3195 Pine Hall Road
Belews Creek, North Carolina

Prepared by ES&T, Blacksburg, Virginia, Report 1300309-01-RF1, October 2005 (Reference 3). Duke Power provided this report for use in this demonstration. The constituent composition for the filter cake leached for the Belews report is assumed to be the same as the constituents to be found in the clarifier filter cake at Marshall.

NCDENR has indicated that leaching tests will be required on the actual materials generated by the FGD system.

The values from Table 3 of Reference 2 are presented below. The leaching results presented in this table are for gypsum and for the clarifier filter cake.

Table 5-2 Leachate Concentrations from Gypsum and Filter Cake

Analyte	Units	NCAC 2L Groundwater Standard	Maximum Concentration from All Gypsum Leaches	Maximum Concentration from Filter Cake Leaches
Arsenic	mg/L	0.01	**0.018**	0.008
Boron	mg/L	0.315	0.163	**69.14**
Chloride	mg/L	250.0	5.33	**573.6**
Fluoride	mg/L	2.0	**4.45**	**4.87**
Selenium	mg/L	0.05	< 0.010	**0.1526**
Sulfate	mg/L	250.0	**1,510**	**1,710**

Bold denotes concentrations greater than NCAC 2L groundwater standards.

6.0 Site Conceptual Hydrogeologic Model

See November 2004 Addendum

7.0 Conceptual Description of Modeling Approach

The modeling approach selected to demonstrate compliance of the landfill design was:

1) The Hydrologic Evaluation of Landfill Performance (HELP) model was used to predict quantities of water infiltrating through the landfill and into the soil beneath the landfill during the Operational Period[4]. The HELP model was also used to predict the quantities of water infiltrating through the completed landfill and into the soil beneath the landfill during the Closed Period[5].

2) The MYGRT model was used to predict the fate and transport of constituents leaching into the groundwater during the Operational Period and during the Closed Period.

7.1 HELP Model Results

7.1.1 Infiltration During Operational Period

The HELP model data, discussion, and results are found in the Construction Plan Application, Dated December 15, 2005. The results are presented below.

The HELP model calculated that the average annual infiltration through the landfill and into the saturated zone during the operational period is: 0.00001". For Cell 1, this equates to a volume of 0.528 cubic feet of annual leakage for the entire 14.8 acre footprint. For Cell 2, this equates to a volume of 0.610 cubic feet of annual leakage for the entire 17.1 acre footprint.

Table 7-1 presents the results from the HELP analyses.

7.1.2 Infiltration During Closed Period

The HELP model calculated that the average annual infiltration rate through the liner system (HELP Layer 4) is 0.00000 inches/year. This value will be used in the MYGRT analyses for the infiltration value during the closed period. These results indicate the effectiveness of the engineered cover to reduce infiltration through the landfill and the effectiveness of the leachate collection and removal system and liner system in protecting groundwater.

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[4] The Operational Period refers to the period of landfill operation prior to the placement of the engineered cover.

[5] The Closed Period is the period of time after the placement of the engineered cover.

These values are based on 100 years of simulated weather conditions.

Table 7-1 Percolation/Leakage Values From HELP Analyses

HELP Run Title	Case Description	Number of Years for Analysis	Average Annual Percolation/Leakage Through Liner System (inches)
MSSFGD LF – Cell 1 -10 feet of Waste – 60 mil HDPE+GCL	Cell 1 Open - 10 feet FGD waste placed in cell	100	0.00001
MSSFGD LF – Cell 1 -32 feet of Waste – 60 mil HDPE+GCL	Cell 1 Open - 32 feet FGD waste placed in cell	10	0.00001
MSSFGD LF – Cell 1 - 64 feet of Waste – 60 mil HDPE+GCL	Cell 1 Open - 64 feet FGD waste placed in cell	10	0.00001
MSSFGD LF – Cell 2 – 10 feet of Waste – 60 mil HDPE+GCL	Cell 2 Open - 10 feet FGD waste placed in cell	100	0.00001
MSSFGD LF – Cell 2 - 42 feet of Waste – 60 mil HDPE+GCL	Cell 1 Open - 42 feet FGD waste placed in cell	10	0.00001
MSSFGD LF – Cell 2 – 84 feet of Waste – 60 mil HDPE+GCL	Cell 2 Open – 84 feet FGD waste placed in cell	10	0.00001
MSSFGD LF – Closed W/GCL – Cell 1 and Cell 2	Cell 1 and Cell 2 Closed with final cover in place	100	0.00000

8.0 MYGRT Model Description and Results

The MYGRT software predicts the migration of both inorganic and organic solutes in the unsaturated and saturated zones down gradient of sources. The processes included are advection, dispersion, retardation, and decay. The code can simulate problems in one, two, or three dimensions using either horizontal or vertical views. The model uses inputs such as seepage velocity, dispersion and retardation factors.

The reviewer should refer to the MYGRT manual for detailed definition of the inputs and for the description of the computational processes used by MYGRT.

MYGRT Version 3.0 was used for these analyses. [Reference 4]

8.1 Description of Model Runs

Two cross sections of the site were modeled in MYGRT to evaluate compliance with 2L standards. The groundwater flow at this site is generally from the northwest of the landfill footprint towards the east and southeast in the direction of the Ash Basin arms located east of the landfill. The groundwater flow underneath the landfill footprint is generally defined by two discharge locations: a discharge to the northernmost arm of the Ash Basin, near boring B-1 and by a discharge to the southern arm of the Ash Basin, near boring MS-2.

The groundwater flow along these cross sections, underneath the landfill footprint and towards these two discharge locations was modeled in MYGRT to determine the concentrations of constituents of concern at the compliance boundary.

The borings used to determine the cross section characteristics are listed below.

MYGRT Run 1 - Cross Section 1-1 (See Figure 1 and Figure 2)
MS-11 to MS-7 to B-6 to B-5 to MS-2

MYGRT Run 2 - Cross Section 2-2 (See Figure 1 and Figure 2)
MS-10 to B-2 to B-1

8.2 Model Inputs

The landfill area is represented as a source with an input length and width. The source concentrations are entered as a function of time. For the modeling used in this demonstration, the 3-D modeling scenario was used. Since the FGD material is placed a minimum of 4 feet above the saturated zone, the source (the FGD Residue) was considered to be located at the top of the unsaturated zone. The model calculated the concentrations after the constituents pass through the unsaturated zone and into the saturated zone.

Table 8-3 provides a list of the parameters and provides references to the sources for the MYGRT input parameters.

Boron, Chloride, SO_4 and Fl_2 are generally considered to be conservative substances. Therefore, no attenuation by the site soils is assumed to occur and a K_d value of 0 mL/g is used in the MYGRT analyses. Arsenic and selenium would likely experience some degree of adsorption to site soils, however, the Kd terms for arsenic and selenium are conservatively assumed to be equal to 0 mL/g.

MYGRT has the capability to change the infiltration rate at a specified time, so the Operational and the Closed conditions can be modeled in the same MYGRT model run. The infiltration value for the Operational period was used for 10 years (year 2006 through year 2016). The infiltration value was then changed to the infiltration value for the Closed period (for years 2017 and beyond).

8.3 Constituents Requiring Modeling

The comparison of the results of the leaching analyses to the NCAC T15A 2L Groundwater Standards is presented in Table 5-2. As this table shows, the concentrations of arsenic, boron, chloride, fluoride, selenium, and sulfate exceed the 2L groundwater standards.

The landfill design requires that the landfill will be capped with an engineered cover after 10 years.

As described earlier, no attenuation will be used in evaluating the potential impacts to groundwater from any of these constituents. Since no attenuation is considered, the only difference in the analyses performed in MYGRT is the concentration of a particular constituent.

The concentrations of the constituents relative to their respective NCAC 2L standard is shown in the table below.

Table 8-1 Ratios of Maximum Source Concentrations to NCAC 2L Standards

Analyte	Units	NCAC 2L Groundwater Standard (1)	Maximum Concentration from All Gypsum Leaches	Maximum Concentration from Filter Cake Leaches (2)	Ratio of Maximum Source Concentration to NCAC 2L Standard (2)/(1)
Arsenic	mg/L	0.01	**0.018**	0.008	1.8
Boron	mg/L	0.315	0.163	**69.14**	219.5
Chloride	mg/L	250.0	5.33	**573.6**	2.3
Fluoride	mg/L	2.0	**4.45**	**4.87**	2.4
Selenium	mg/L	0.05	< 0.010	**0.1526**	3.1
Sulfate	mg/L	250.0	**1,510**	**1,710**	6.8

As this table shows, the maximum constituent concentration to 2L standard ratio is for boron.

Rather than running MYGRT for both cross sections for each of the 6 constituents, the constituent with the maximum ratio in Table 8-1, boron, will be analyzed for both cross sections in MYGRT. If boron meets the 2L standard, then the other constituents will also meet their respective standards.

An additional factor of safety will be incorporated into the analysis by doubling the input concentration of boron in the MYGRT analysis.

The concentrations of boron used in the MYGRT analyses are presented in Table 8-2.

Table 8-2 Source Concentrations Used in MYGRT Model

Analyte	Units	NCAC 2L Groundwater Standard	Maximum Concentration from All Gypsum Leaches	Maximum Concentration from Filter Cake Leaches	Source Concentration Used in MYGRT Model
Boron	mg/L	0.315	0.163	**69.14**	**140**

Table 8-3 MYGRT Model Input Parameters

Input Parameter	Units	Source of Input	Values for MYGRT Cross Section 1-1	Values for MYGRT Cross Section 2-2
Unsaturated Zone Parameters				
Width of Source	ft	Figures 1, 2	1440	1440
Length of Source Parallel with Aquifer Flow Direction	ft	Figures 1, 2	1300	760
Input Source Concentration, boron	mg/l	Table 8-2	140	140
Infiltration Rate - Operational Period Years 2006 to 2016	ft/year	HELP	8.3E-7	8.3E-7
Infiltration Rate - Closed Period Years 2016 to 3000	ft/year	HELP,	0.00000	0.00000
Volumetric Moisture Content of Soil (Unsaturated)	vol/vol	Attachment 5	0.25	0.25
Depth to water table below source	ft	Attachment 5 See Note 1	4	14.5
Rd, Unsaturated layer, SO_4, Fl_2, As		See Note 2	1	1
Saturated Zone Parameters				
Hydraulic Gradient	ft/ft		0.01	0.03
Hydraulic Conductivity	ft/yr	Attachment 5	219.4	183.9
n_e, effective porosity		Attachment 5	0.28	0.27
Scale Distance for Dispersion Calculation	ft	See Note 3	250	250
Aquifer Thickness	ft	Attachment 5, Note 4	27.8	24.3
Solute Plume Properties				
Bulk Density	g/ml	Note 5	N/A	N/A
K_d for SO_4,Fl_2, As	ml/g	See Note 5	0	0

Table 8-3 MYGRT Model Input Parameters~~Table 8-3 MYGRT Model Input Parameters~~

Notes:

1. As found in Attachment 5, the depths to groundwater (below the excavated bottom of the landfill) are 5' (for Section 1-1) and 14.5' (for Section 2-2). The depth to groundwater used in the MYGRT analyses for Section 1-1 is 4' and 14.5' for Section 2-2.[6]
2. No attenuation due to adsorption onto the soil is assumed to occur with any constituents therefore the K_d term would be = 0 and the Rd, retardation factor, would be equal to 1.
3. The scale distance for dispersion calculations used is 250 feet. The longitudinal, transverse, and vertical coefficients are calculated by MYGRT as follows:

Longitudinal Dispersion Coefficient	1/10th of scale distance multiplied by the seepage velocity
Transverse Dispersion Coefficient	1/10th of horizontal dispersion coefficient
Vertical Dispersion Coefficient	1/100th horizontal dispersion coefficient

4. The geometric mean value for thickness of the aquifer was used for each cross section. This value is based on the minimum measured groundwater elevation for the wells. These groundwater elevations are found in Attachment 5.
5. MYGRT uses the bulk density and K_d to calculate a retardation factor. Since no attenuation due to adsorption onto the soil is assumed to occur with any constituent, the K_d term would be = 0 and the retardation factor would be equal to 1.

[6] The value of 6' for depth to the water table was conservatively used in the original demonstration report for Section 2-2.

9.0 MYGRT Model Results and Comparison to 2L Standards

The resulting concentrations from the MYGRT analyses for boron are presented two ways for each of the two cross sections:

- At mid depth of the aquifer, at downgradient distances of 125' and 250' from the edge of the source. The period of time evaluated for these concentrations was from year 2016 to year 3000.
- At a location of 10 feet from the source, at depths from the upper surface of the aquifer to the full depth of the aquifer, at years 2015, 2020, 2025, 2030, and 2040.

In both of the analyses, the resulting concentrations for boron were found by MYGRT to be 0.0 mg/L at all the distances and times evaluated.

Therefore, the concentrations for the other constituents (arsenic, chloride, fluoride, selenium, sulfate) will also 0.0 mg/L and therefore below the 2L standards.

To verify that these results (the 0 mg/L) are valid, a sensitivity run was performed on Cross Section 1-1. The infiltration for the operational period was increased to 0.0083 ft per year. All other values were unchanged. The analysis was performed for distances of 125' and 250' from the source, at the mid-depth of the aquifer. The maximum concentrations in this analysis were 4×10^{-12} mg/L.

Copies of the MYGRT input data and results are included at the end of this report.

10.0 Conclusions

As shown in Section 9.0, the design evaluated in this demonstration ensures that the ground water standards established under 15A NCAC 2L will not be exceeded.

The design evaluated in this demonstration requires:

1. The landfill will be constructed with a leachate collection and removal system and 60 mil HDPE liner. The liner will be underlain by a geosynthetic clay liner.
2. the active landfill will receive FGD residue for a 10 year period.
3. an engineered cover will be placed on the completed landfill at the end of the 10 year period.
4. The engineered cover will consist of a textured 40 mil low density polyethylene geomembrane layer beneath a geocomposite drainage net. The cap and geocomposite drainage net will be topped with two feet of soil for vegetative growth. The geomembrane layer will minimize infiltration of precipitation into the waste. The geocomposite drainage net will provide lateral drainage for water that percolates through the vegetative layer. A detail showing the cover system is shown on drawing MM 6551.00-0001.001 Revision B.
5. The drainage collected by the geocomposite drainage net will drain to the erosion control benches, as well as draining to the anchor trench. This will limit the drainage length of the geocomposite to no greater than 300 feet.

Other than the engineered cap described above, there are no special engineering features or considerations that must be included or maintained in site construction, operation, maintenance and closure.

11.0 References

Note: The information and sources listed below were used in the preparation of this report. The parties listed in the references prepared these reports and documents. The engineering certification on the cover page of this report does not imply that the engineering certification of this report includes certification of these particular references.

1 *Duke Energy Marshall Steam Station, Catawba County, NC, Flue Gas Desulfurization (FGD) Residue Landfill Permit Application, .0503(2)(d)(ii)(A) Compliance Demonstration Report Addendum, November 12, 2004.*

2 *Construction Plan Application, Duke Power Marshall Steam Station FGD Gypsum Landfill, Catawba County, NC, Document MM6451.00-0000.001, Revision 1, December 15, 2005.*

3 *Assessment of Fate and Transport Of Constituents of Concern For the Proposed FGD Scrubber Residue Disposal Site, Belews Creek Steam Station, 3195 Pine Hall Road, Belews Creek, North Carolina,* Prepared by ES&T, Blacksburg, Virginia, Report 1300309-01-RF1, October 2005.

4 *User's Guide for MYGRT Version 3.0:Software for Simulating Migration of Organic and Inorganic Chemicals in Groundwater*, Electric Power Research Institute, 1998, TR-111748, Prepared by Tetra Tech and Ish Inc.

10 Duke Energy Marshall Steam Station, Catawba County, NC, Flue Gas Desulfurization (FGD) Residue Landfill Permit Application, .0503(2)(d)(ii)(A) Compliance Demonstration Report, March 31, 2004.

Attachment 6

Marshall FGD Residue Landfill

MYGRT Analyses
Input and Results

Marshall FGD Residue Landfill

MYGRT Input and Results

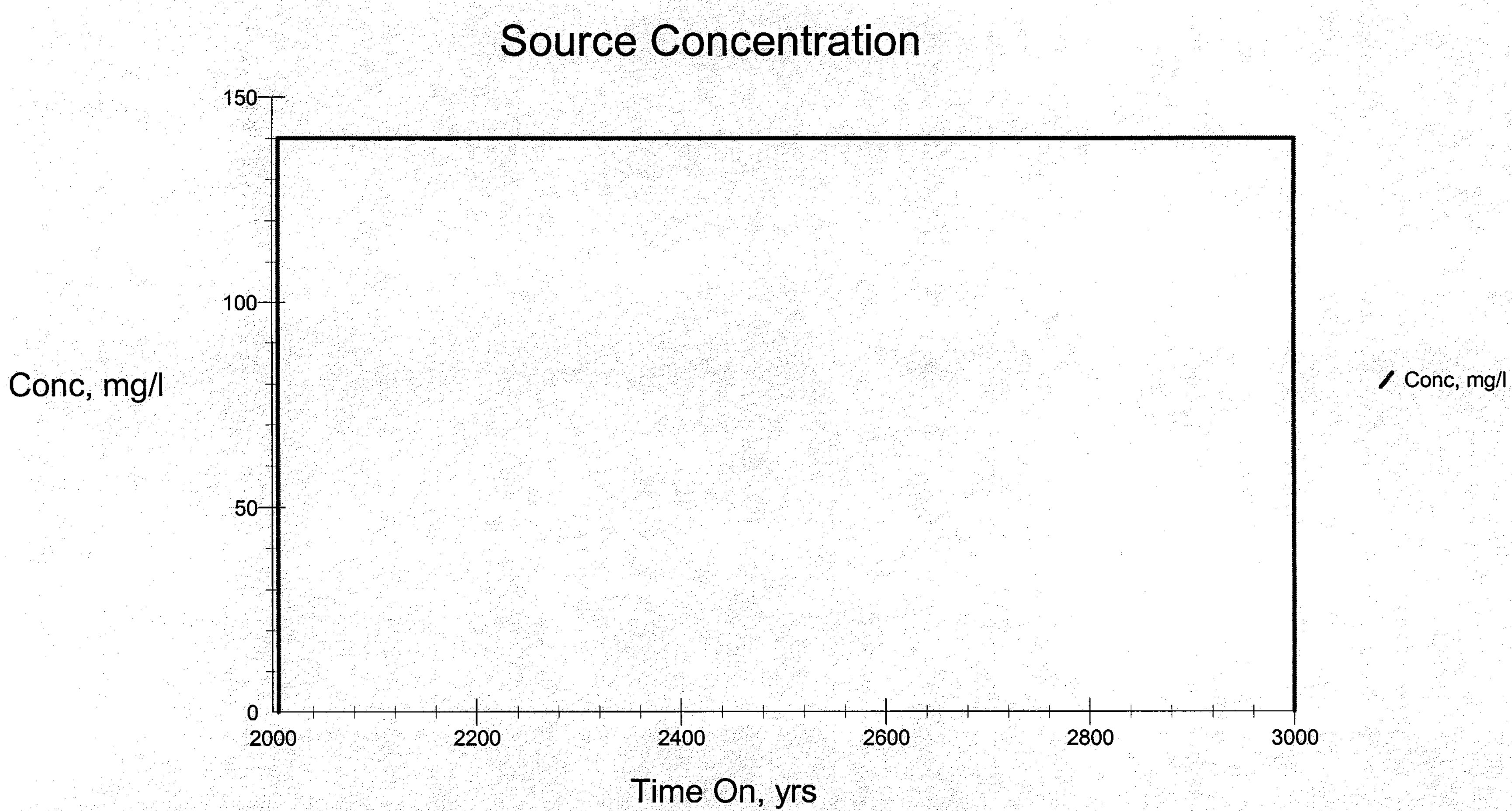
Cross Section 1-1

Input Parameters

Description	Units	Value	Note
General Parameters			
Site		MSS FGD Landfill - Cross Section 1-1 -	
Description		X Sect 1-1 Liner w/GCL - Cap @End of Year 10	
Notes			
Solute Name		Boron	
Organic		No	
Zones Simulated		Unsat/Sat	
Source Location		Unsat	
Saturated Zone Dimension		Sat_3d	
Point or Depth Averaged		Point	
Aquifer Thickness		Finite	
Number of Sat Down Gradient Zones		One	
Unsaturated Zone Parameters			
Unsat Infiltration Rate used in Sat		Yes	
Unsat Infiltration Rate	ft/yr	8.3E-7	
Infiltration Switching		Yes	
Time to Switch Infiltration	yr	2017	
Unsat Infiltration After Switch	ft/yr	0	
Unsat Moisture Content	ft3/ft3	0.25	
Unsat Dispersion Coeff in Z	ft2/yr	1.33E-6	Calc'd
Depth to water table	ft	4	
Unsat Retardation Coeff		1	
Dispersion Calculated		Yes	
Source Parameters			
Width of Source	ft	1440	
Source Length	ft	1300	
Saturated Zone Properties			
Zone Length	ft	32.8084	
Dispersion along X	ft2/yr	196	
Dispersion along Y	ft2/yr	19.6	
Dispersion along Z	ft2/yr	1.96	
Distance for Dispersion	ft	250	
Dispersion calculated		Yes	
Aquifer Thickness	ft	27.8	
Seepage Velocity	ft/yr	7.84	Calc'd
Sat Volumetric Porosity	ft3/ft3	0.28	
Hydraulic Gradient	ft/ft	0.01	
Hydraulic Conductivity	ft/yr	219.4	
Horozontal Velocity calculated		Yes	
Source Penetration Depth	ft	25.5	Calc'd
Source Penetration Depth After S	ft	25.5	Calc'd

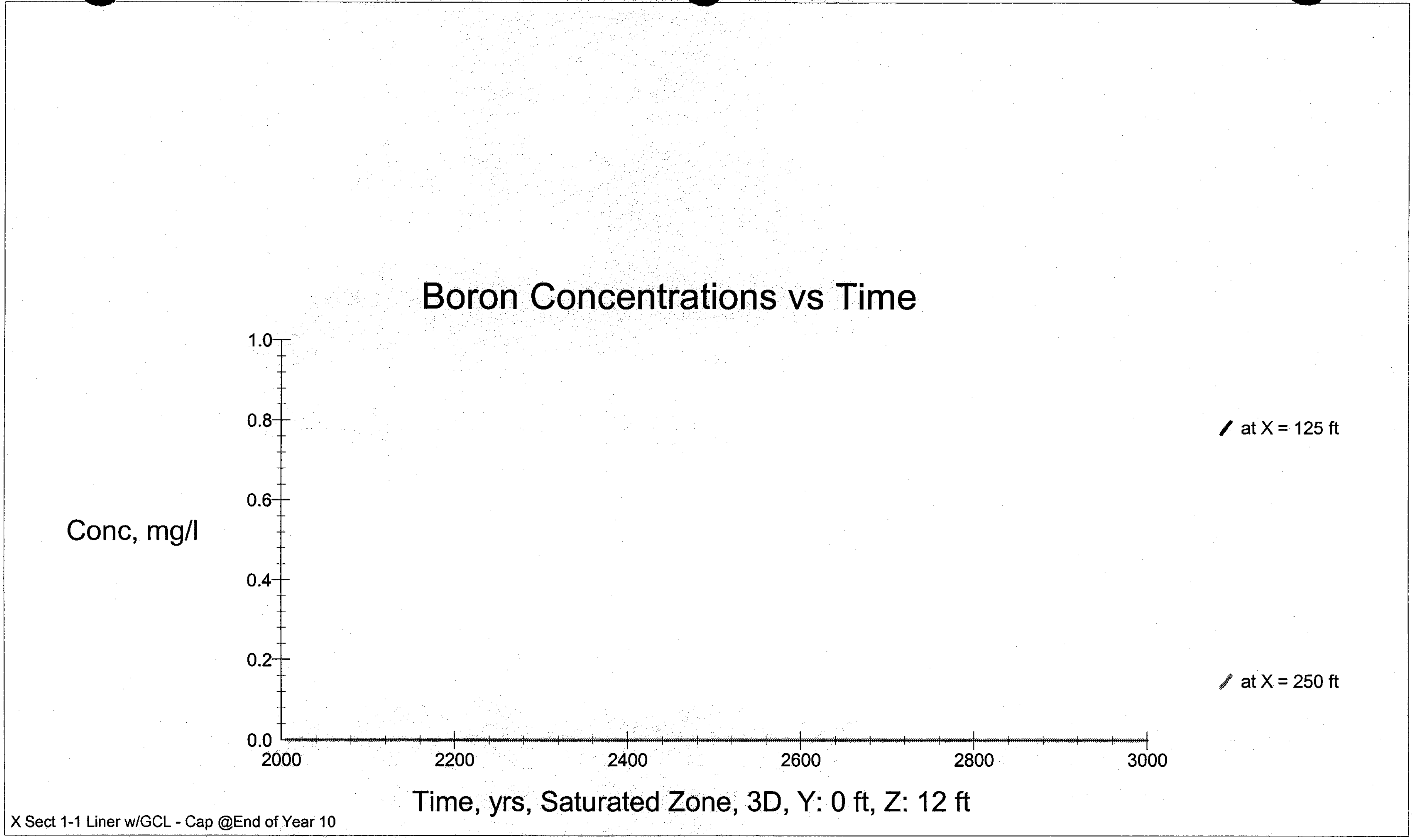
Input Parameters

Description	Units	Value	Note
Mixing Depth Calculated		Yes	
Mixing Depth (2) Calculated		Yes	
Solute Plume Description			
Background Concentration	mg/l	0	
Bulk Density	g/ml	1.6	
pH		7	
Rd (inorganic)		1	Calc'd
Partition Coeff, Kd	ml/g	0	
Rd calculated		Yes	
Distance to Top of Source	ft	0	
Distance to Bottom of Source	ft	16.4042	


Source Concentration
Conc, mg/l
150
100
50
0
2000
2200
2400
2600
2800
3000
Time On, yrs
Conc, mg/l

Source Concentration

	Time On, yrs	Conc, mg/l
1	2006.000	140.000
2	2008.000	140.000
3	2009.000	140.000
4	2010.000	140.000
5	2016.000	140.000
6	3000.000	0.000

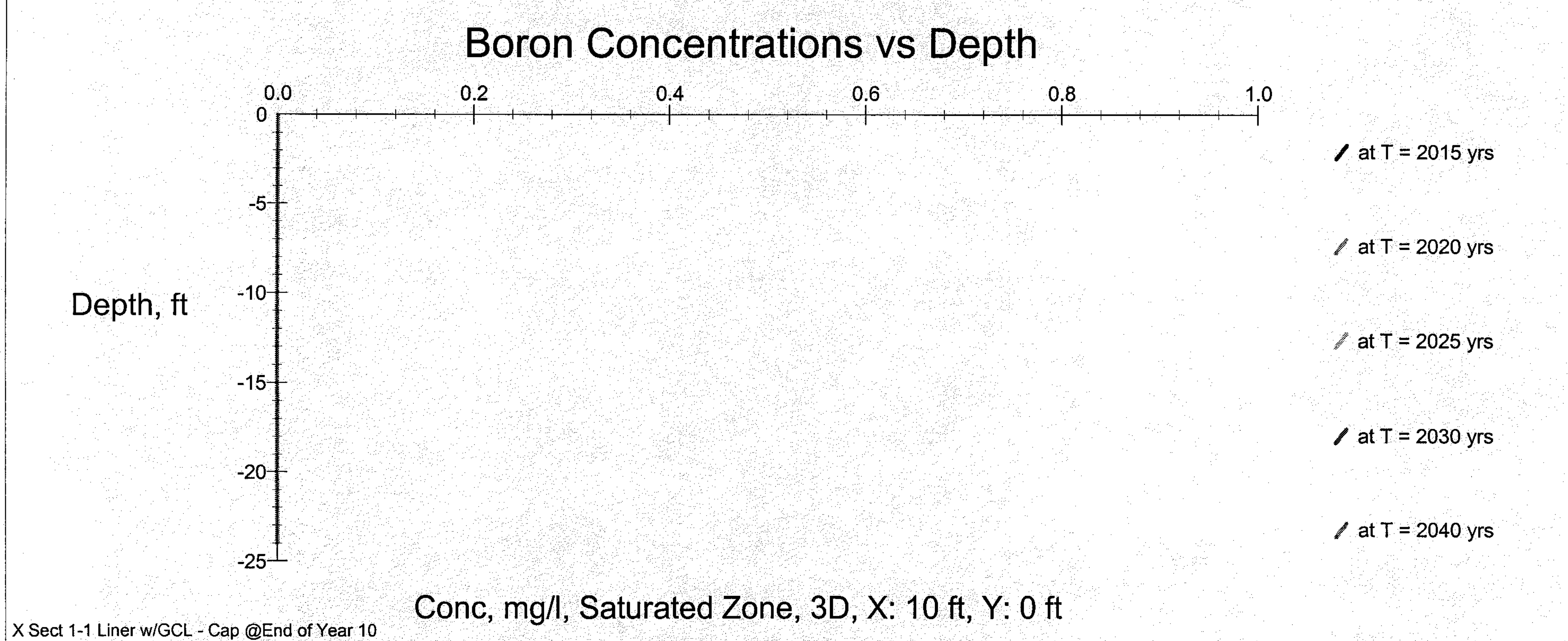


Boron Concentrations vs Time
Conc, mg/l
1.0
0.8
0.6
0.4
0.2
0.0
2000
2200
2400
2600
2800
3000
Time, yrs, Saturated Zone, 3D, Y: 0 ft, Z: 12 ft
at X = 125 ft
at X = 250 ft
X Sect 1-1 Liner w/GCL - Cap @End of Year 10

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
1	2006	0	0
2	2015.94	0	0
3	2025.88	0	0
4	2035.82	0	0
5	2045.76	0	0
6	2055.7	0	0
7	2065.64	0	0
8	2075.58	0	0
9	2085.52	0	0
10	2095.46	0	0
11	2105.4	0	0
12	2115.34	0	0
13	2125.28	0	0
14	2135.22	0	0
15	2145.16	0	0
16	2155.1	0	0
17	2165.04	0	0
18	2174.98	0	0
19	2184.92	0	0
20	2194.86	0	0
21	2204.8	0	0
22	2214.74	0	0
23	2224.68	0	0
24	2234.62	0	0
25	2244.56	0	0
26	2254.5	0	0
27	2264.44	0	0
28	2274.38	0	0
29	2284.32	0	0
30	2294.26	0	0
31	2304.2	0	0
32	2314.14	0	0
33	2324.08	0	0
34	2334.02	0	0
35	2343.96	0	0
36	2353.9	0	0
37	2363.84	0	0
38	2373.78	0	0
39	2383.72	0	0

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
40	2393.66	0	0
41	2403.6	0	0
42	2413.54	0	0
43	2423.48	0	0
44	2433.42	0	0
45	2443.36	0	0
46	2453.3	0	0
47	2463.24	0	0
48	2473.18	0	0
49	2483.12	0	0
50	2493.06	0	0
51	2503	0	0
52	2512.94	0	0
53	2522.88	0	0
54	2532.82	0	0
55	2542.76	0	0
56	2552.7	0	0
57	2562.64	0	0
58	2572.58	0	0
59	2582.52	0	0
60	2592.46	0	0
61	2602.4	0	0
62	2612.34	0	0
63	2622.28	0	0
64	2632.22	0	0
65	2642.16	0	0
66	2652.1	0	0
67	2662.04	0	0
68	2671.98	0	0
69	2681.92	0	0
70	2691.86	0	0
71	2701.8	0	0
72	2711.74	0	0
73	2721.68	0	0
74	2731.62	0	0
75	2741.56	0	0
76	2751.5	0	0
77	2761.44	0	0
78	2771.38	0	0

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
79	2781.32	0	0
80	2791.26	0	0
81	2801.2	0	0
82	2811.14	0	0
83	2821.08	0	0
84	2831.02	0	0
85	2840.96	0	0
86	2850.9	0	0
87	2860.84	0	0
88	2870.78	0	0
89	2880.72	0	0
90	2890.66	0	0
91	2900.6	0	0
92	2910.54	0	0
93	2920.48	0	0
94	2930.42	0	0
95	2940.36	0	0
96	2950.3	0	0
97	2960.24	0	0
98	2970.18	0	0
99	2980.12	0	0
100	2990.06	0	0
101	3000	0	0



Boron Concentrations vs Depth
0.0
0.2
0.4
0.6
0.8
1.0
0
-5
-10
-15
-20
-25
Depth, ft
at T = 2015 yrs
at T = 2020 yrs
at T = 2025 yrs
at T = 2030 yrs
at T = 2040 yrs
Conc, mg/l, Saturated Zone, 3D, X: 10 ft, Y: 0 ft
X Sect 1-1 Liner w/GCL - Cap @End of Year 10

	Depth, ft	Conc, mg/l at T = 2015 yrs	Conc, mg/l at T = 2020 yrs	Conc, mg/l at T = 2025 yrs	Conc, mg/l at T = 2030 yrs	Conc, mg/l at T = 2040 yrs
1	0	0	0	0	0	0
2	0.24	0	0	0	0	0
3	0.48	0	0	0	0	0
4	0.72	0	0	0	0	0
5	0.96	0	0	0	0	0
6	1.2	0	0	0	0	0
7	1.44	0	0	0	0	0
8	1.68	0	0	0	0	0
9	1.92	0	0	0	0	0
10	2.16	0	0	0	0	0
11	2.4	0	0	0	0	0
12	2.64	0	0	0	0	0
13	2.88	0	0	0	0	0
14	3.12	0	0	0	0	0
15	3.36001	0	0	0	0	0
16	3.6	0	0	0	0	0
17	3.83999	0	0	0	0	0
18	4.07999	0	0	0	0	0
19	4.32001	0	0	0	0	0
20	4.56001	0	0	0	0	0
21	4.8	0	0	0	0	0
22	5.03999	0	0	0	0	0
23	5.27999	0	0	0	0	0
24	5.52001	0	0	0	0	0
25	5.76001	0	0	0	0	0
26	6	0	0	0	0	0
27	6.23999	0	0	0	0	0
28	6.47999	0	0	0	0	0
29	6.72001	0	0	0	0	0
30	6.96001	0	0	0	0	0
31	7.2	0	0	0	0	0
32	7.43999	0	0	0	0	0
33	7.67999	0	0	0	0	0
34	7.92001	0	0	0	0	0
35	8.16001	0	0	0	0	0
36	8.4	0	0	0	0	0
37	8.63999	0	0	0	0	0
38	8.87999	0	0	0	0	0

	Depth, ft	Conc, mg/l at T = 2015 yrs	Conc, mg/l at T = 2020 yrs	Conc, mg/l at T = 2025 yrs	Conc, mg/l at T = 2030 yrs	Conc, mg/l at T = 2040 yrs
39	9.12001	0	0	0	0	0
40	9.36001	0	0	0	0	0
41	9.6	0	0	0	0	0
42	9.83999	0	0	0	0	0
43	10.08	0	0	0	0	0
44	10.32	0	0	0	0	0
45	10.56	0	0	0	0	0
46	10.8	0	0	0	0	0
47	11.04	0	0	0	0	0
48	11.28	0	0	0	0	0
49	11.52	0	0	0	0	0
50	11.76	0	0	0	0	0
51	12	0	0	0	0	0
52	12.24	0	0	0	0	0
53	12.48	0	0	0	0	0
54	12.72	0	0	0	0	0
55	12.96	0	0	0	0	0
56	13.2	0	0	0	0	0
57	13.44	0	0	0	0	0
58	13.68	0	0	0	0	0
59	13.92	0	0	0	0	0
60	14.16	0	0	0	0	0
61	14.4	0	0	0	0	0
62	14.64	0	0	0	0	0
63	14.88	0	0	0	0	0
64	15.12	0	0	0	0	0
65	15.36	0	0	0	0	0
66	15.6	0	0	0	0	0
67	15.84	0	0	0	0	0
68	16.08	0	0	0	0	0
69	16.32	0	0	0	0	0
70	16.56	0	0	0	0	0
71	16.8	0	0	0	0	0
72	17.04	0	0	0	0	0
73	17.28	0	0	0	0	0
74	17.52	0	0	0	0	0
75	17.76	0	0	0	0	0
76	18	0	0	0	0	0

	Depth, ft	Conc, mg/l at T = 2015 yrs	Conc, mg/l at T = 2020 yrs	Conc, mg/l at T = 2025 yrs	Conc, mg/l at T = 2030 yrs	Conc, mg/l at T = 2040 yrs
77	18.24	0	0	0	0	0
78	18.48	0	0	0	0	0
79	18.72	0	0	0	0	0
80	18.96	0	0	0	0	0
81	19.2	0	0	0	0	0
82	19.44	0	0	0	0	0
83	19.68	0	0	0	0	0
84	19.92	0	0	0	0	0
85	20.16	0	0	0	0	0
86	20.4	0	0	0	0	0
87	20.64	0	0	0	0	0
88	20.88	0	0	0	0	0
89	21.12	0	0	0	0	0
90	21.36	0	0	0	0	0
91	21.6	0	0	0	0	0
92	21.84	0	0	0	0	0
93	22.08	0	0	0	0	0
94	22.32	0	0	0	0	0
95	22.56	0	0	0	0	0
96	22.8	0	0	0	0	0
97	23.04	0	0	0	0	0
98	23.28	0	0	0	0	0
99	23.52	0	0	0	0	0
100	23.76	0	0	0	0	0
101	24	0	0	0	0	0

Marshall FGD Residue Landfill

MYGRT Input and Results

Cross Section 2-2

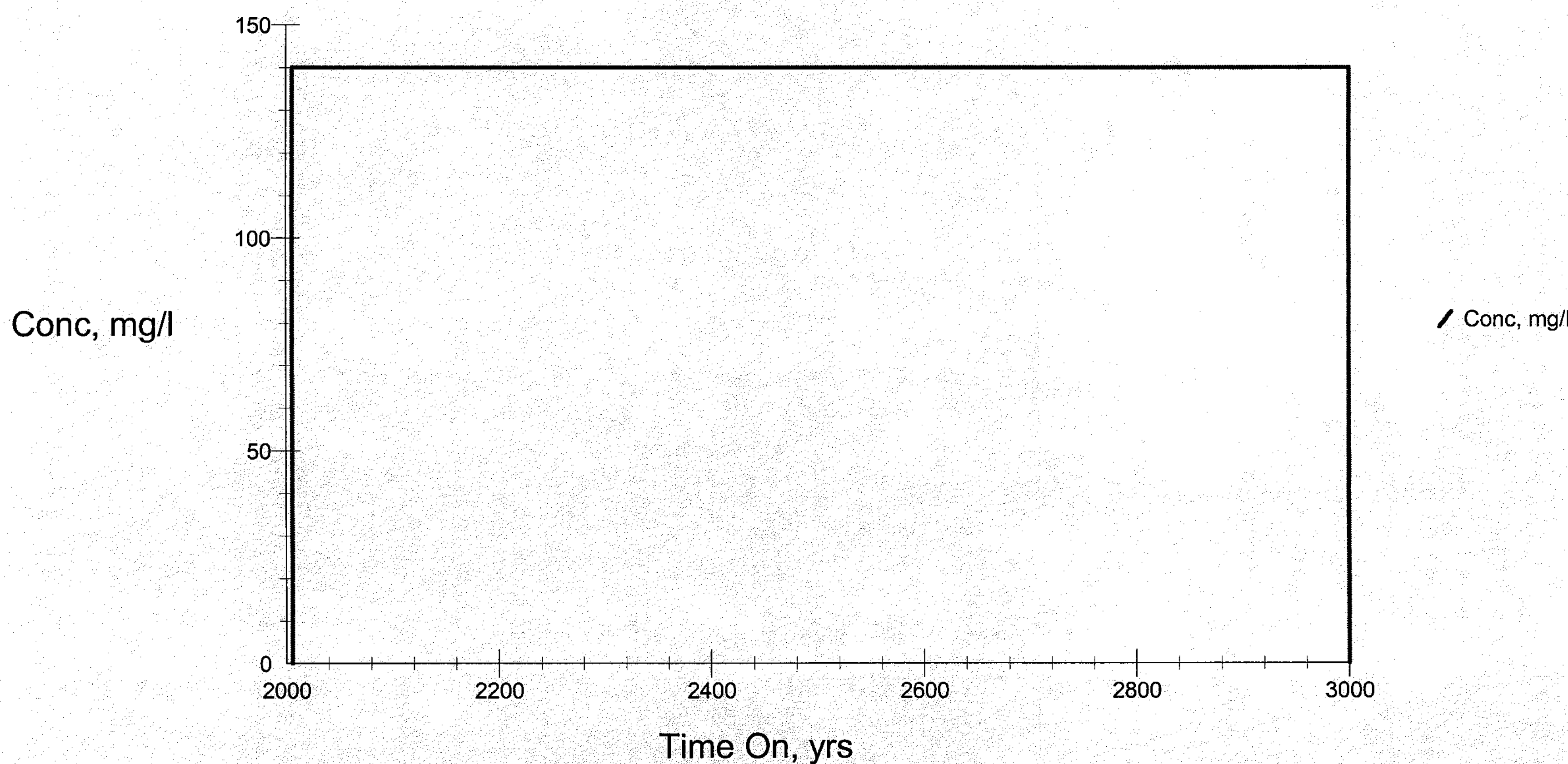
Input Parameters

Description	Units	Value	Note
General Parameters			
Site		MSS FGD Landfill - Cross Section 2-2	
Description		X Sect 2-2 Cap @End of Year 10	
Notes			
Solute Name		Boron	
Organic		No	
Zones Simulated		Unsat/Sat	
Source Location		Unsat	
Saturated Zone Dimension		Sat_3d	
Point or Depth Averaged		Point	
Aquifer Thickness		Finite	
Number of Sat Down Gradient Zones		One	
Unsaturated Zone Parameters			
Unsat Infiltration Rate used in Sat		Yes	
Unsat Infiltration Rate	ft/yr	8.33E-7	
Infiltration Switching		Yes	
Time to Switch Infiltration	yr	2017	
Unsat Infiltration After Switch	ft/yr	0	
Unsat Moisture Content	ft3/ft3	0.25	
Unsat Dispersion Coeff in Z	ft2/yr	4.83E-6	Calc'd
Depth to water table	ft	14.5	
Unsat Retardation Coeff		1	
Dispersion Calculated		Yes	
Source Parameters			
Width of Source	ft	1440	
Source Length	ft	760	
Saturated Zone Properties			
Zone Length	ft	32.8084	
Dispersion along X	ft2/yr	510	
Dispersion along Y	ft2/yr	51	
Dispersion along Z	ft2/yr	5.1	
Distance for Dispersion	ft	250	
Dispersion calculated		Yes	
Aquifer Thickness	ft	24.3	
Seepage Velocity	ft/yr	20.4	Calc'd
Sat Volumetric Porosity	ft3/ft3	0.27	
Hydraulic Gradient	ft/ft	0.03	
Hydraulic Conductivity	ft/yr	183.9	
Horozontal Velocity calculated		Yes	
Source Penetration Depth	ft	19.5	Calc'd
Source Penetration Depth After S	ft	19.5	Calc'd

Input Parameters

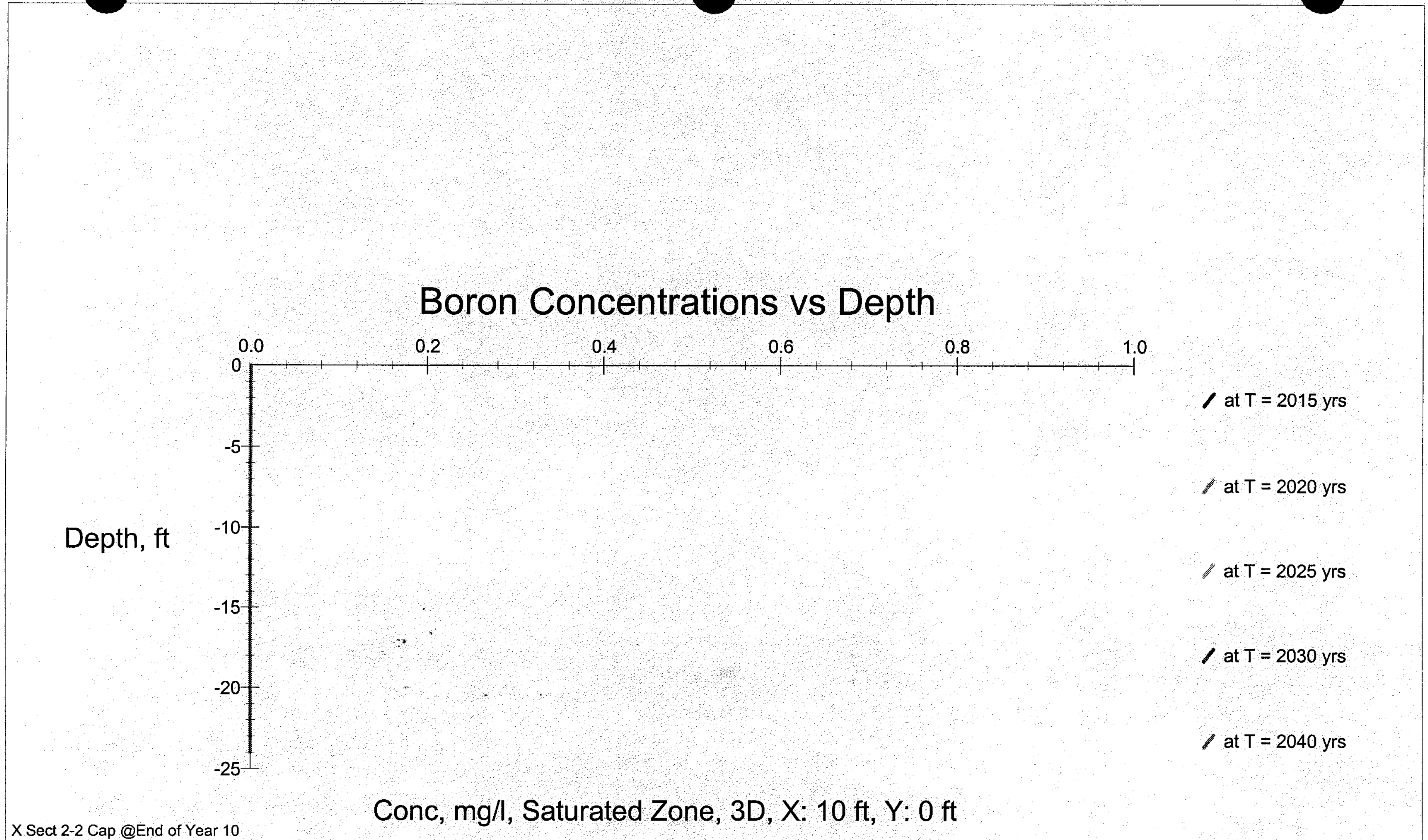
Description	Units	Value	Note
Mixing Depth Calculated		Yes	
Mixing Depth (2) Calculated		Yes	
Solute Plume Description			
Background Concentration	mg/l	0	
Bulk Density	g/ml	1.6	
pH		7	
Rd (inorganic)		1	Calc'd
Partition Coeff, Kd	ml/g	0	
Rd calculated		Yes	
Distance to Top of Source	ft	0	
Distance to Bottom of Source	ft	16.4042	

Source Concentration



Source Concentration

	Time On, yrs	Conc, mg/l
1	2006.000	140.000
2	2007.000	140.000
3	2008.000	140.000
4	2009.000	140.000
5	2010.000	140.000
6	3000.000	0.000

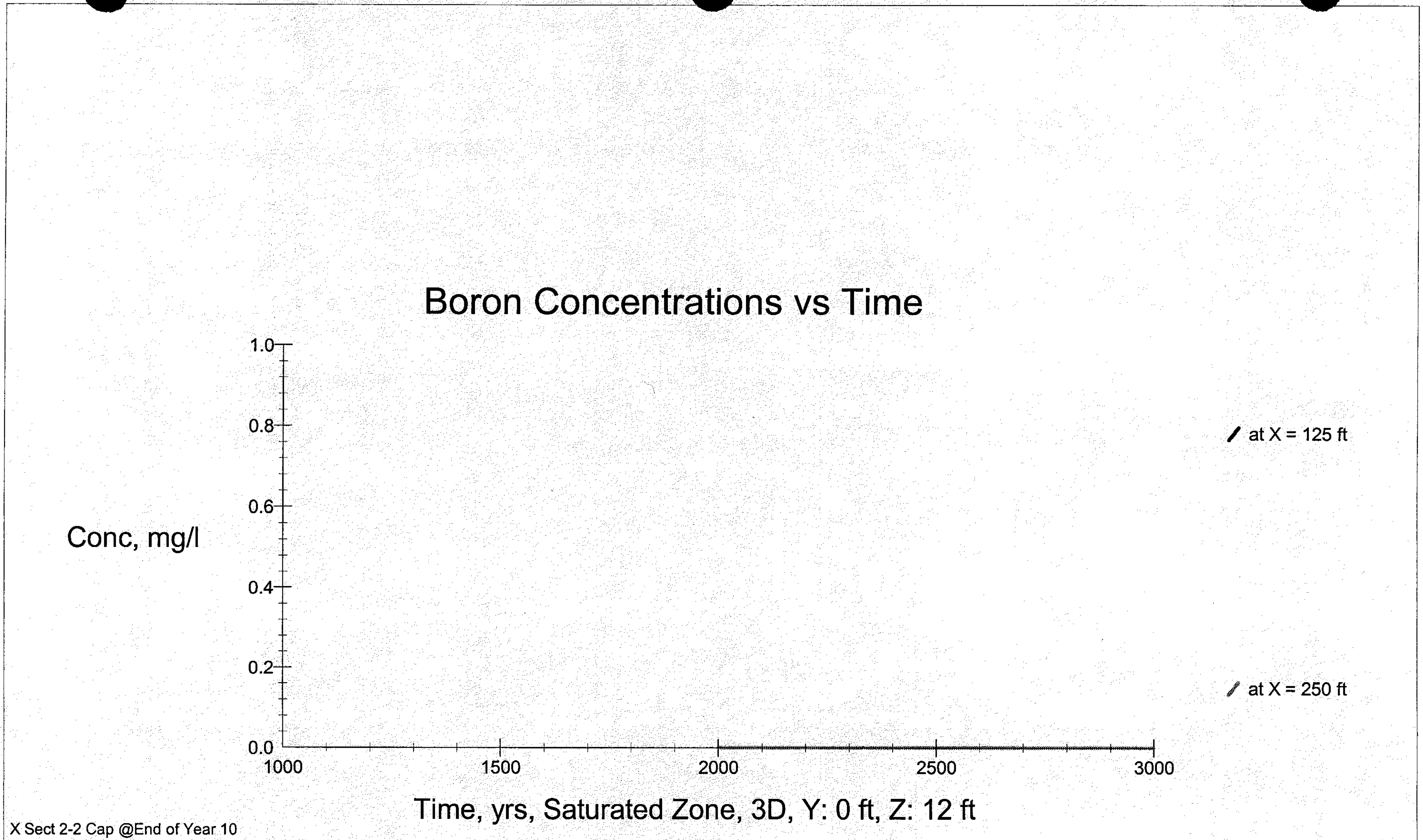


Boron Concentrations vs Depth
0.0
0.2
0.4
0.6
0.8
1.0
0
-5
-10
-15
-20
-25
Depth, ft
at T = 2015 yrs
at T = 2020 yrs
at T = 2025 yrs
at T = 2030 yrs
at T = 2040 yrs
Conc, mg/l, Saturated Zone, 3D, X: 10 ft, Y: 0 ft
X Sect 2-2 Cap @End of Year 10

	Depth, ft	Conc, mg/l at T = 2015 yrs	Conc, mg/l at T = 2020 yrs	Conc, mg/l at T = 2025 yrs	Conc, mg/l at T = 2030 yrs	Conc, mg/l at T = 2040 yrs
1	0	0	0	0	0	0
2	0.24	0	0	0	0	0
3	0.48	0	0	0	0	0
4	0.72	0	0	0	0	0
5	0.96	0	0	0	0	0
6	1.2	0	0	0	0	0
7	1.44	0	0	0	0	0
8	1.68	0	0	0	0	0
9	1.92	0	0	0	0	0
10	2.16	0	0	0	0	0
11	2.4	0	0	0	0	0
12	2.64	0	0	0	0	0
13	2.88	0	0	0	0	0
14	3.12	0	0	0	0	0
15	3.36001	0	0	0	0	0
16	3.6	0	0	0	0	0
17	3.83999	0	0	0	0	0
18	4.07999	0	0	0	0	0
19	4.32001	0	0	0	0	0
20	4.56001	0	0	0	0	0
21	4.8	0	0	0	0	0
22	5.03999	0	0	0	0	0
23	5.27999	0	0	0	0	0
24	5.52001	0	0	0	0	0
25	5.76001	0	0	0	0	0
26	6	0	0	0	0	0
27	6.23999	0	0	0	0	0
28	6.47999	0	0	0	0	0
29	6.72001	0	0	0	0	0
30	6.96001	0	0	0	0	0
31	7.2	0	0	0	0	0
32	7.43999	0	0	0	0	0
33	7.67999	0	0	0	0	0
34	7.92001	0	0	0	0	0
35	8.16001	0	0	0	0	0
36	8.4	0	0	0	0	0
37	8.63999	0	0	0	0	0
38	8.87999	0	0	0	0	0

	Depth, ft	Conc, mg/l at T = 2015 yrs	Conc, mg/l at T = 2020 yrs	Conc, mg/l at T = 2025 yrs	Conc, mg/l at T = 2030 yrs	Conc, mg/l at T = 2040 yrs
39	9.12001	0	0	0	0	0
40	9.36001	0	0	0	0	0
41	9.6	0	0	0	0	0
42	9.83999	0	0	0	0	0
43	10.08	0	0	0	0	0
44	10.32	0	0	0	0	0
45	10.56	0	0	0	0	0
46	10.8	0	0	0	0	0
47	11.04	0	0	0	0	0
48	11.28	0	0	0	0	0
49	11.52	0	0	0	0	0
50	11.76	0	0	0	0	0
51	12	0	0	0	0	0
52	12.24	0	0	0	0	0
53	12.48	0	0	0	0	0
54	12.72	0	0	0	0	0
55	12.96	0	0	0	0	0
56	13.2	0	0	0	0	0
57	13.44	0	0	0	0	0
58	13.68	0	0	0	0	0
59	13.92	0	0	0	0	0
60	14.16	0	0	0	0	0
61	14.4	0	0	0	0	0
62	14.64	0	0	0	0	0
63	14.88	0	0	0	0	0
64	15.12	0	0	0	0	0
65	15.36	0	0	0	0	0
66	15.6	0	0	0	0	0
67	15.84	0	0	0	0	0
68	16.08	0	0	0	0	0
69	16.32	0	0	0	0	0
70	16.56	0	0	0	0	0
71	16.8	0	0	0	0	0
72	17.04	0	0	0	0	0
73	17.28	0	0	0	0	0
74	17.52	0	0	0	0	0
75	17.76	0	0	0	0	0
76	18	0	0	0	0	0

	Depth, ft	Conc, mg/l at T = 2015 yrs	Conc, mg/l at T = 2020 yrs	Conc, mg/l at T = 2025 yrs	Conc, mg/l at T = 2030 yrs	Conc, mg/l at T = 2040 yrs
77	18.24	0	0	0	0	0
78	18.48	0	0	0	0	0
79	18.72	0	0	0	0	0
80	18.96	0	0	0	0	0
81	19.2	0	0	0	0	0
82	19.44	0	0	0	0	0
83	19.68	0	0	0	0	0
84	19.92	0	0	0	0	0
85	20.16	0	0	0	0	0
86	20.4	0	0	0	0	0
87	20.64	0	0	0	0	0
88	20.88	0	0	0	0	0
89	21.12	0	0	0	0	0
90	21.36	0	0	0	0	0
91	21.6	0	0	0	0	0
92	21.84	0	0	0	0	0
93	22.08	0	0	0	0	0
94	22.32	0	0	0	0	0
95	22.56	0	0	0	0	0
96	22.8	0	0	0	0	0
97	23.04	0	0	0	0	0
98	23.28	0	0	0	0	0
99	23.52	0	0	0	0	0
100	23.76	0	0	0	0	0
101	24	0	0	0	0	0


Boron Concentrations vs Time
Conc, mg/l
1.0
0.8
0.6
0.4
0.2
0.0
1000
1500
2000
2500
3000
Time, yrs, Saturated Zone, 3D, Y: 0 ft, Z: 12 ft
at X = 125 ft
at X = 250 ft
X Sect 2-2 Cap @End of Year 10

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
1	2000	0	0
2	2010	0	0
3	2020	0	0
4	2030	0	0
5	2040	0	0
6	2050	0	0
7	2060	0	0
8	2070	0	0
9	2080	0	0
10	2090	0	0
11	2100	0	0
12	2110	0	0
13	2120	0	0
14	2130	0	0
15	2140	0	0
16	2150	0	0
17	2160	0	0
18	2170	0	0
19	2180	0	0
20	2190	0	0
21	2200	0	0
22	2210	0	0
23	2220	0	0
24	2230	0	0
25	2240	0	0
26	2250	0	0
27	2260	0	0
28	2270	0	0
29	2280	0	0
30	2290	0	0
31	2300	0	0
32	2310	0	0
33	2320	0	0
34	2330	0	0
35	2340	0	0
36	2350	0	0
37	2360	0	0
38	2370	0	0
39	2380	0	0

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
40	2390	0	0
41	2400	0	0
42	2410	0	0
43	2420	0	0
44	2430	0	0
45	2440	0	0
46	2450	0	0
47	2460	0	0
48	2470	0	0
49	2480	0	0
50	2490	0	0
51	2500	0	0
52	2510	0	0
53	2520	0	0
54	2530	0	0
55	2540	0	0
56	2550	0	0
57	2560	0	0
58	2570	0	0
59	2580	0	0
60	2590	0	0
61	2600	0	0
62	2610	0	0
63	2620	0	0
64	2630	0	0
65	2640	0	0
66	2650	0	0
67	2660	0	0
68	2670	0	0
69	2680	0	0
70	2690	0	0
71	2700	0	0
72	2710	0	0
73	2720	0	0
74	2730	0	0
75	2740	0	0
76	2750	0	0
77	2760	0	0
78	2770	0	0

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
79	2780	0	0
80	2790	0	0
81	2800	0	0
82	2810	0	0
83	2820	0	0
84	2830	0	0
85	2840	0	0
86	2850	0	0
87	2860	0	0
88	2870	0	0
89	2880	0	0
90	2890	0	0
91	2900	0	0
92	2910	0	0
93	2920	0	0
94	2930	0	0
95	2940	0	0
96	2950	0	0
97	2960	0	0
98	2970	0	0
99	2980	0	0
100	2990	0	0
101	3000	0	0

Marshall FGD Residue Landfill

MYGRT Input and Results

Cross Section 1-1

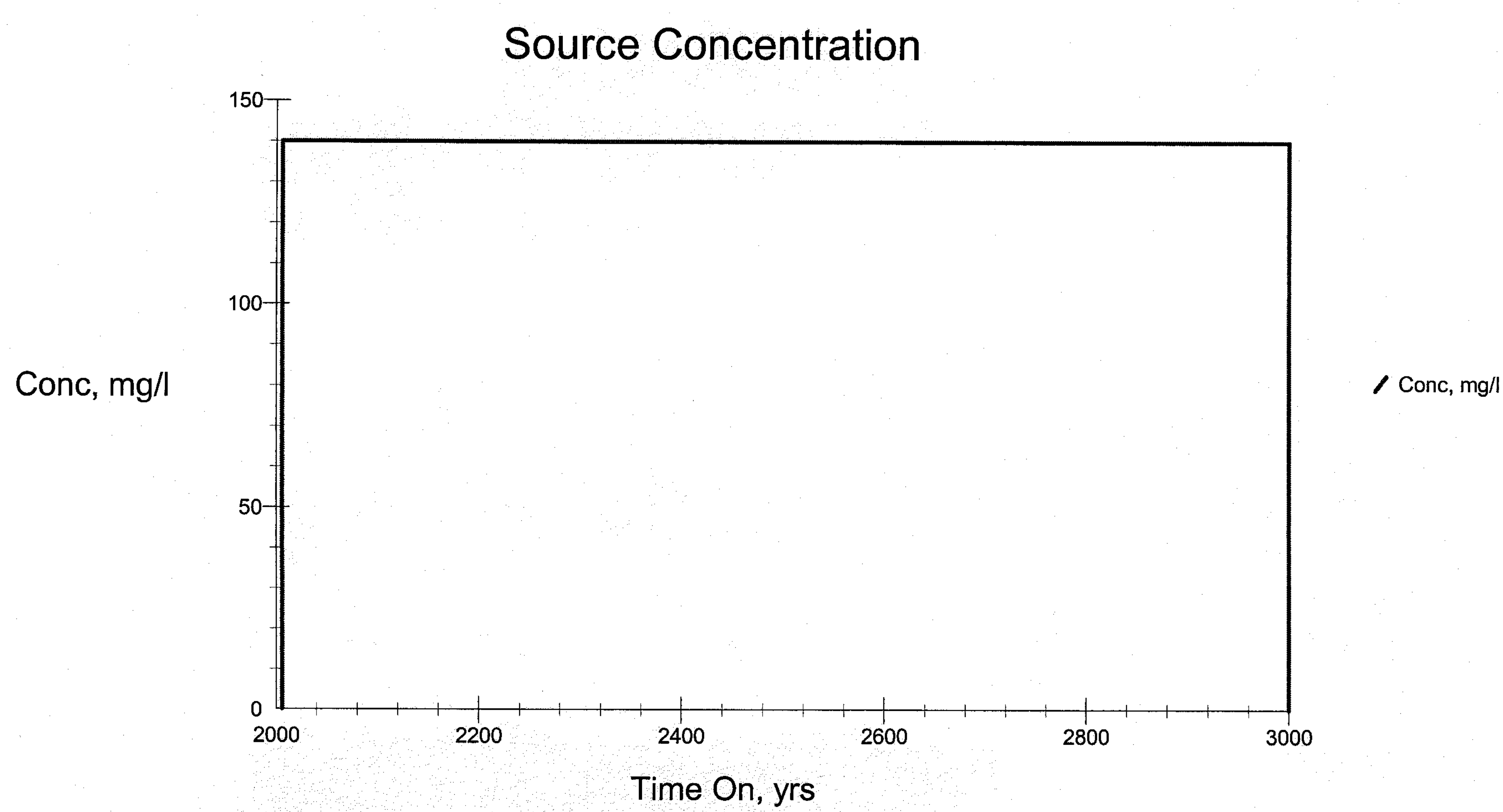
Infiltration Increased to 0.0083ft/yr

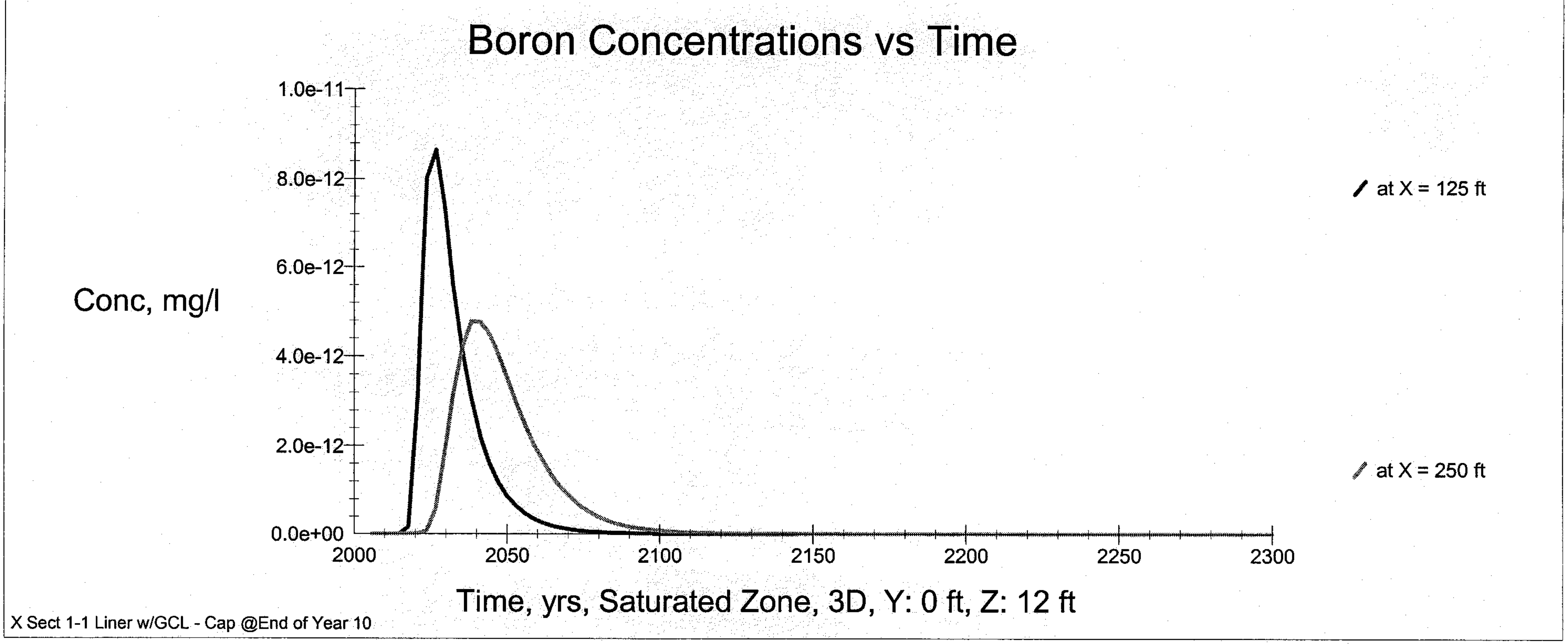
Input Parameters

Description	Units	Value	Note
General Parameters			
Site		MSS FGD Landfill - Cross Section 1-1 -	
Description		X Sect 1-1 Liner w/GCL - Cap @End of Year 10	
Notes			
Solute Name		Boron	
Organic		No	
Zones Simulated		Unsat/Sat	
Source Location		Unsat	
Saturated Zone Dimension		Sat_3d	
Point or Depth Averaged		Point	
Aquifer Thickness		Finite	
Number of Sat Down Gradient Zones		One	
Unsaturated Zone Parameters			
Unsat Infiltration Rate used in Sat		Yes	
Unsat Infiltration Rate	ft/yr	0.0083	
Infiltration Switching		Yes	
Time to Switch Infiltration	yr	2017	
Unsat Infiltration After Switch	ft/yr	0	
Unsat Moisture Content	ft3/ft3	0.25	
Unsat Dispersion Coeff in Z	ft2/yr	0.0133	Calc'd
Depth to water table	ft	4	
Unsat Retardation Coeff		1	
Dispersion Calculated		Yes	
Source Parameters			
Width of Source	ft	1440	
Source Length	ft	1300	
Saturated Zone Properties			
Zone Length	ft	32.8084	
Dispersion along X	ft2/yr	196	
Dispersion along Y	ft2/yr	19.6	
Dispersion along Z	ft2/yr	1.96	
Distance for Dispersion	ft	250	
Dispersion calculated		Yes	
Aquifer Thickness	ft	27.8	
Seepage Velocity	ft/yr	7.84	Calc'd
Sat Volumetric Porosity	ft3/ft3	0.28	
Hydraulic Gradient	ft/ft	0.01	
Hydraulic Conductivity	ft/yr	219.4	
Horozontal Velocity calculated		Yes	
Source Penetration Depth	ft	25.5	Calc'd
Source Penetration Depth After S	ft	25.5	Calc'd

Input Parameters

Description	Units	Value	Note
Mixing Depth Calculated		Yes	
Mixing Depth (2) Calculated		Yes	
Solute Plume Description			
Background Concentration	mg/l	0	
Bulk Density	g/ml	1.6	
pH		7	
Rd (inorganic)		1	Calc'd
Partition Coeff, Kd	ml/g	0	
Rd calculated		Yes	
Distance to Top of Source	ft	0	
Distance to Bottom of Source	ft	16.4042	


Source Concentration
Conc, mg/l
150
100
50
0
2000
2200
2400
2600
2800
3000
Time On, yrs
Conc, mg/l


Boron Concentrations vs Time
Conc, mg/l
1.0e-11
8.0e-12
6.0e-12
4.0e-12
2.0e-12
0.0e+00
2000
2050
2100
2150
2200
2250
2300
Time, yrs, Saturated Zone, 3D, Y: 0 ft, Z: 12 ft
at X = 125 ft
at X = 250 ft
X Sect 1-1 Liner w/GCL - Cap @End of Year 10

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
1	2006	0	0
2	2008.94	3.44564E-52	6.99889E-57
3	2011.88	0	0
4	2014.82	9.60735E-16	2.40132E-18
5	2017.76	1.53179E-13	2.07976E-15
6	2020.7	3.06689E-12	9.86022E-15
7	2023.64	8.03027E-12	7.03837E-14
8	2026.58	8.64889E-12	5.69605E-13
9	2029.52	7.37194E-12	1.80145E-12
10	2032.46	5.58982E-12	3.16829E-12
11	2035.4	4.14209E-12	4.20293E-12
12	2038.34	3.06527E-12	4.78377E-12
13	2041.28	2.2058E-12	4.76771E-12
14	2044.22	1.60694E-12	4.49398E-12
15	2047.16	1.17219E-12	4.03747E-12
16	2050.1	8.55508E-13	3.49818E-12
17	2053.04	6.26153E-13	2.95694E-12
18	2055.98	4.6066E-13	2.45887E-12
19	2058.92	3.38916E-13	2.01032E-12
20	2061.86	2.53872E-13	1.65124E-12
21	2064.8	1.85818E-13	1.30954E-12
22	2067.74	1.38153E-13	1.04562E-12
23	2070.68	1.04347E-13	8.41811E-13
24	2073.62	7.68919E-14	6.56527E-13
25	2076.56	5.82259E-14	5.23804E-13
26	2079.5	4.33101E-14	4.07899E-13
27	2082.44	3.31302E-14	3.25638E-13
28	2085.38	2.44379E-14	2.49636E-13
29	2088.32	1.84227E-14	1.95018E-13
30	2091.26	1.39481E-14	1.52578E-13
31	2094.2	1.06336E-14	1.19914E-13
32	2097.14	8.1822E-15	9.49157E-14
33	2100.08	6.06201E-15	7.21676E-14
34	2103.02	4.60275E-15	5.61467E-14
35	2105.96	3.5099E-15	4.38034E-14
36	2108.9	2.67253E-15	3.407E-14
37	2111.84	2.04183E-15	2.65559E-14
38	2114.78	1.57429E-15	2.08648E-14
39	2117.72	1.18809E-15	1.60265E-14

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
40	2120.66	9.0761E-16	1.24492E-14
41	2123.6	6.94439E-16	9.67682E-15
42	2126.54	5.32402E-16	7.5307E-15
43	2129.48	4.09141E-16	5.8698E-15
44	2132.42	3.20209E-16	4.65775E-15
45	2135.36	2.41105E-16	3.55083E-15
46	2138.3	1.8657E-16	2.78152E-15
47	2141.24	1.44647E-16	2.18154E-15
48	2144.18	1.09549E-16	1.67055E-15
49	2147.12	8.42784E-17	1.29882E-15
50	2150.06	6.49112E-17	1.0104E-15
51	2153	5.0041E-17	7.86615E-16
52	2155.94	3.86398E-17	6.13098E-16
53	2158.88	2.98578E-17	4.77828E-16
54	2161.82	2.30637E-17	3.72171E-16
55	2164.76	1.7976E-17	2.92695E-16
56	2167.7	1.37706E-17	2.25905E-16
57	2170.64	1.0663E-17	1.76188E-16
58	2173.58	8.31081E-18	1.38246E-16
59	2176.52	6.45171E-18	1.08183E-16
60	2179.46	4.89413E-18	8.33892E-17
61	2182.4	3.82519E-18	6.49876E-17
62	2185.34	2.96741E-18	5.06606E-17
63	2188.28	2.29834E-18	3.94964E-17
64	2191.22	1.77875E-18	3.08089E-17
65	2194.16	1.38853E-18	2.39872E-17
66	2197.1	1.07314E-18	1.87928E-17
67	2200.04	5.86907E-19	1.46782E-17
68	2202.98	6.46919E-19	1.14537E-17
69	2205.92	4.97266E-19	8.94246E-18
70	2208.86	3.85628E-19	6.96962E-18
71	2211.8	3.04471E-19	5.46278E-18
72	2214.74	2.36936E-19	4.31302E-18
73	2217.68	1.97372E-19	3.34068E-18
74	2220.62	1.3423E-19	2.60251E-18
75	2223.56	1.05126E-19	2.03618E-18
76	2226.5	9.72552E-20	1.61271E-18
77	2229.44	0	1.25179E-18
78	2232.38	5.11151E-20	9.99754E-19

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
79	2235.32	2.8269E-20	7.65207E-19
80	2238.26	3.0713E-20	6.0457E-19
81	2241.2	2.96643E-20	4.56036E-19
82	2244.14	1.35217E-20	3.60575E-19
83	2247.08	2.05313E-20	3.00464E-19
84	2250.02	8.1618E-20	2.08635E-19
85	2252.96	4.0824E-21	1.81901E-19
86	2255.9	7.04476E-21	1.33799E-19
87	2258.84	9.54996E-21	9.34662E-20
88	2261.78	0	6.36151E-20
89	2264.72	0	6.48938E-20
90	2267.66	0	6.81144E-20
91	2270.6	0	3.13274E-20
92	2273.54	0	3.43058E-20
93	2276.48	0	2.37416E-20
94	2279.42	6.18107E-21	1.09552E-20
95	2282.36	1.85449E-20	6.8285E-21
96	2285.3	0	8.3773E-22
97	2288.24	1.82335E-20	1.94111E-20
98	2291.18	8.6927E-21	3.55748E-21
99	2294.12	0	1.10466E-21
100	2297.06	0	1.00465E-20
101	2300	0	2.53183E-20

December

NC Department
Division of Wa
Mooresville, NC

Attention

Subject

Duke Power
...due Gas Desulfurization (F...

CP... ents

...ulations contained in the ...

...dition, Duke Power is also ...
...al Compliance Demonstration Report which ... Addendum for ...
...n of the landfill ... the changes ...
...revised ...
...dwater ... be ex...