PREPARED FOR:

BOARD OF COMMISSIONERS
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DIN 17215
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JOHN'S RIVER WASTE MANAGEMENT FACILITY
BURKE COUNTY, NORTH CAROLINA
PERMIT NUMBER 12-03

C&D LANDFILL EXPANSION – PHASE 1
VOLUME 2: PERMIT TO CONSTRUCT

APPENDIX 5:
LANDFILL GAS MONITORING PLAN

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LANDFILL GAS MONITORING PLAN
John's River Landfill
Permit No. 12-03

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1.0 INTRODUCTION

This Landfill Gas Monitoring Plan (LGMP) will serve as a guidance document for collecting and monitoring of landfill gas at Burke County's John's River Waste Management Facility (JRWMF, aka John's River Landfill). Landfill gas will be monitored quarterly to ensure that methane concentrations do not exceed the regulatory limit at the facility boundary or in facility structures. The LGMP was prepared in accordance with the North Carolina Department of Environment and Natural Resources (NC DENR) Division of Waste Management Solid Waste Section Landfill Gas Monitoring Guidance document, to assure performance standards are met and to protect public health and the environment. This LGMP incorporates the previous LGMP for the existing landfill facility dated December 1997 and adds gas monitoring for the proposed C&D landfill expansion at the facility. The proposed new gas monitoring wells associated with the first phase of the C&D landfill expansion will be installed in conjunction with landfill construction after a permit-to-construct is issued by the DENR.

1.1 Background

The JRWMF is located in the north-central portion of Burke County, north of Morganton, North Carolina. The 318-acre facility was permitted in 1987 and the existing landfill began receiving waste in 1988. The existing landfill consists of an unlined waste disposal unit covering 28 acres in the southwest corner of the landfill property. The municipal solid waste (MSW) Landfill began operation in April 1988, but was closed to comply with § .1627(c)(10)(A) of the North Carolina Solid Waste Management Rules (NCSWMR). Burke County has operated a permitted Construction and Demolition (C&D) disposal area on top of the closed portions of the MSW landfill since 1998. A MSW transfer facility is located in the eastern half of the property. A site plan showing all the pertinent features of the facility is provided in Drawing LGMP-1.

1.2 Site Geology and Hydrogeology

The John's River Waste Management Facility is in close proximity to the Brevard Shear Zone, and is underlain by highly metamorphosed rocks including gneiss, schist, as well as calc-silicate rocks, felsic rocks, and metavolcanic rocks. The dominant rock type at the facility is biotite-muscovite schist, as seen in outcrops, boulders, and rock cores located on site. The structures within limited outcrops indicate that these rocks are complexly-folded, with attitudes that vary from vertical to horizontal in most outcrops. The site regolith is typical of the inner piedmont and consists mostly of silty sand, clayey sand, and sandy silt. The regolith itself is up to 100 feet thick and varies in thickness with topography.

The 318-acre landfill property is bounded by Lower Creek to the north and east, and the Catawba River to the south. The Catawba River forms Lake Rhodhiss immediately southeast of the facility. Lake Rhodhiss is a long, narrow lake formed by the Rhodhiss Hydroelectric Dam located approximately 12 miles downstream of the landfill property.

1.3 Regulatory Limits

The closed, unlined MSW landfill at the JRWMF is governed by the North Carolina Solid Waste Management Regulations (NCSWMR) 15A NCAC 13B.1600 rules and regulations for sanitary landfills; however, the active C&D landfill on top of the closed MSW landfill, as well as the proposed C&D landfill expansion, will be governed by the 15A NCAC 13B.0500 rules. Current regulations state that concentration of methane gas generated by the facility should not exceed 25% of the lower explosive limit (LEL) for methane in facility structures or that the concentration of methane gas does not exceed the LEL for methane at the facility property boundary. The LEL for methane equals 5% by volume at standard temperature and pressure. This LGMP prescribes a routine methane monitoring program to ensure standards are met and actions to be taken if methane concentrations exceed specified limits.

2.0 LANDFILL GAS MONITORING

Gas monitoring at the John's River Landfill will be performed throughout the active and post-closure care period. At a minimum, quarterly monitoring will be conducted at all subsurface gas detection wells (gas probes) and in all structures located within 1000 feet of waste on the landfill property. This site is one of three Burke County landfill sites that Joyce Engineering monitors. The East Burke and Kirksey Drive Landfills are closed MSW landfills regulated under the .0500 rules of the NCSWMR. Common practice for the Burke County landfill sites will be to monitor the first and third quarterly gas events on one calendar day and the second and fourth quarterly gas events will occur in conjunction with the semi-annual groundwater monitoring events usually over a two-three day period.

2.1 Landfill Gas Monitoring Network

2.1.1 Existing Facility

The current gas monitoring program for the active landfill includes three gas monitoring wells (gas probes) with multiple screened intervals (GP-1S&D, GP-2S,I,&D, and GP-3S&D), six buildings or structures (GMP-1, GMP-2, GMP-3, GMP-4, GMP-7A, and GMP-13), and eight ambient air monitoring points around the perimeter of the existing landfill (GMP-5, GPM-6, GPM-7, GMP-8, GMP 9, GMP-10, GMP-11, and GMP-12). The structures and ambient air points were first monitored for landfill gas in October 1993. Gas Probes GP-1, GP-2, and GP-3 were installed in 1994 and were first monitored in October 1994.

The locations of the gas probes and monitoring points are shown on the attached drawing (LGMP-1). Note that the GP-2 probes are located near both the existing landfill unit and Phase 1 of the C&D expansion and will be used to monitor gas between the two units. Note also that the GP-3 probes are located within the footprint of Phase 4 of the C&D Expansion and will need to be abandoned prior to construction of Phase 4. The following Table summarizes the locations and screened intervals of the existing gas probes.

Probe ID	Location Description	Screen Interval (feet BGS)
GP-1S	Approximately 200' north of northwest corner of existing landfill unit.	4 - 16
GP-1D		18 - 28
GP-2S	Approximately 90' north of northeast corner of existing landfill unit and 160'southwest of northwest corner of Phase 1 of the C&D Expansion.	4 - 13
GP-2I		14 - 28
GP-2D		29 - 35
GP-3S	Approximately 780' northeast of the existing landfill and in the middle of the C&D expansion.	4 - 11
GP-3D		12 – 18.5

2.1.2 Historical Gas Monitoring Results

While there have been a few isolated detections in site structures and/or at ambient air points, all have been less than 1% methane by volume, and there have been no detections in exceedance of 25% of the LEL. An apparent detection of approximately 20% methane in a vehicle maintenance pit in the shop (GMP-3) on May 29, 2008 was determined to be the result of a leak from a propane line, not landfill gas.

There have been consistent detections of methane above the LEL in the three GP-2 gas probes (S, I, & D) since the 1990's, often in excess of 50% methane by volume. There have been no exceedances of the LEL for methane in any of the GP-1 or GP-3 probes. The GP-2 probes are located very near the former MSW waste unit and are very far from any property boundary. The closest property boundary to GP-2 is over 700 feet to the west, and GP-1 is located between GP-2 and the property boundary in this direction. It is over 1500 feet from GP-2 to any other property boundary. A delineation study for the extent of methane exceedances in the vicinity of GP-2, especially as they may impact the Phase 1 area, is planned for the near future.

2.1.3 Proposed C&D Expansion Facility

The locations of the proposed network of landfill gas monitoring wells (gas probes) for the C&D landfill expansion are shown on Drawing LGMP-1. The gas probes will be installed in stages related to the construction of the various phases of the C&D landfill expansion. The following table summarizes the proposed gas probe installation schedule, as well as the proposed target depths for the probes.

Probe ID	Location Description	Target Depth (feet BGS)	Estimated Depth to Bedrock (feet BGS)	Estimated Depth to Water (feet BGS)	Phase for Probe Installation
GP-4	Southwest of Phase 1 and Phase 2, between the old and new landfill units.	63	37	33	Phase 1
GP-5	Northwest of Phase 1.	81	31	38	Phase 1
GP-6	Northeast of Phase 1.	72	61	44	Phase 1
GP-7	Southwest of Phase 3, between the old and new landfill units.	27	75	17	Phase 3
GP-8	Northeast of Phase 4.	63	48	39	Phase 4
GP-9	Northeast of Phases 5 and 8.	35	33	22	Phase 5

The target depths are based on the lowest elevation of the proposed base of waste within 1000 feet of the probe. Gas probes will be installed to the target depth, the water table, or bedrock, whichever is encountered first.

Note that the John's River Landfill is bordered by the Catawba River to the south and southwest. The river will act as a hydraulic barrier to the movement of subsurface landfill gas so that it will not be possible for gas to migrate beyond the property boundary in this direction. Also, there are no structures or potential receptors located between the southeast end of the C&D expansion area and the river; therefore, no gas probes have been proposed for this portion of the property.

The future gas probes will be constructed and installed to the specifications listed in 15A NCAC Subchapter 2C and the Solid Waste Section's Landfill Gas Monitoring Guidance Document. A Professional Engineer (P.E.) or a N.C. Professional Geologist (L.G.) must certify/ supervise the installation of all landfill gas monitoring wells. A detailed example of a typically constructed LFG well is included in Appendix C.

Within thirty (30) days of completion of the landfill monitoring gas wells, a well construction record and/or boring log and a diagram for each well, including but not limited to total depth, screened interval and distance above seasonal table will be submitted to the SWS. The submittal will also include a scaled topographic map showing the surveyed location and identification of new, existing, and abandoned landfill gas monitoring wells.

2.2 Structure and Ambient Sampling

There are currently six structures on the facility property that are monitored for explosive gases GMP-1, GMP-2, GMP-3, GMP-4, GMP-7A, and GMP-13. An additional monitoring point, GMP-14) is proposed to be added after waste is being received in the C&D expansion area. The structures are described below. The locations of these structures are shown on Drawing LGMP-1.

GMP-1	Scale House
GMP-2	Recycling Center
GMP-3	Office & Shop Building
GMP-4	Building behind Shop
GMP-7A	Shed
GMP-13	Firing Range Structure
GMP-14	Transfer Station

Furthermore, there are eight points around the perimeter of the existing landfill unit where ambient air is monitored for landfill gas. These points are designated GMP-5, GPM-6, GPM-7, GMP-8, GMP 9, GMP-10, GMP-11, and GMP-12. The locations of these monitoring points are shown on Drawing LGMP-1.

2.3 Landfill Gas Monitoring Frequency

The landfill gas wells and on-site structures included in this LGMP will be monitored at least quarterly in accordance with current regulations. The first and the third quarterly monitoring events will occur sometime in February-March and August-September. The gas wells will be monitored for the second and fourth quarterly events in conjunction with the semi-annual groundwater monitoring events which usually occur in May-June and November-December.

3.0 LANDFILL GAS SAMPLING PROCEDURES

Landfill gas samples will be collected in accordance with Solid Waste Section's Landfill Gas Monitoring Guidance document. Details of detection equipment and sampling procedures are outlined below.

3.1 Detection Equipment

A portable combustible gas monitor, measuring the concentration of combustible gases in units of percent of LEL, shall be used to conduct gas monitoring. The LEL means the lowest percent by volume of a mixture of combustible gas in air that will propagate a flame at 25 degrees Celsius and atmospheric pressure.

The gas monitor shall be calibrated to methane using the manufacturer's calibration kit and procedure before the monitoring activities begin. The calibration gas to be used is depends on the expected levels of methane in landfill gas monitoring wells. If low level methane is expected 15% CO_2/15% CH_4 calibration gas should be used; while if high level methane is expected, 35% CO_2/ 50% CH_4 calibration gas should be used. Verification that the equipment was calibrated in accordance with the manufacture's specifications is required. Calibration information must be recorded on the Landfill Gas Monitoring Data Form.

3.2 Landfill Gas Sampling Procedure

The portable combustible gas monitor will be turned on and allowed to warm up prior to gas sampling. The static pressure should show a reading of zero before taking the initial sample. The sample tube shall be purged for at least one minute prior to connecting the sample tube to the detection well, and then the initial concentration will be recorded. Gas monitoring will continue until the reading has stabilized. A stable reading is considered to be +/- 0.5% by volume on the instrument's scale. Once the reading has stabilized for 5 seconds, the reading will be recorded and the tubing will be disconnected from the valve. These steps will be repeated for each landfill gas monitoring well.

Gas monitoring in on-site structures will attempt to identify the "worst case" concentrations. The monitoring locations will be in corners along floors and ceilings, at cracks in the floor, and at other areas likely to accumulate gas. Gas monitoring will also be conducted in any confined space requiring the entry of personnel for maintenance or inspection. The monitoring will take place prior to entry by personnel in accordance with OSHA regulations.

4.0 RECORD KEEPING AND REPORTING

The landfill gas data will be recorded in accordance to the SWS's Landfill Gas Monitoring Guidance document included as Appendix A. The records will be maintained in the landfill operating record.

4.1 Landfill Gas Monitoring Data Form

A landfill gas monitoring form is included as Appendix B.

4.2 Sampling Reports

The landfill gas monitoring reports will be prepared in accordance with the (NC DENR) Division of Waste Management Solid Waste Section Landfill Gas Monitoring Guidance document. The report will describe the method of sampling, the date, time, location, sampling personnel, atmospheric temperature, reported barometric pressure, equipment calibration information, exceptions noted during sampling, and general weather conditions at the time of sampling, in addition to the concentration of combustible gases.

4.3 Permanent Record Keeping

A copy of the landfill gas monitoring results and any remediation plans will be maintained in the landfill operating record. The reports will be maintained at the facility or an alternative location near the facility approved by the Division.

5.0 CONTINGENCY PLAN

If methane gas levels that exceed the regulatory limits are detected, the results shall be reported to Burke County immediately. The County will notify the NCDENR, SWS in writing and will take immediate steps to ensure safety and protection of human health.

If methane levels exceed the LEL in existing gas wells, the need for additional gas wells will be evaluated, as well as the need for monitoring within any nearby structures in the direction of the gas migration. If the exceedance is in a gas well not located at or near a property boundary, additional investigation including use of bar-hole probes or temporary gas wells may be implemented to determine whether or not the exceedance extends to the property boundary. If necessary, additional permanent gas wells may be installed between the exceeding well(s) and the property boundary to demonstrate that the site is in compliance.

If the compliance level is exceeded in an on-site structure, options will be evaluated to reduce the current methane levels and to prevent further migration of methane into the structure. At a minimum, the following actions will be taken if the methane concentration exceeds 25% of the LEL in any structure:

- Put out all smoking materials and turn off all ignition sources;
- Evacuate all personnel;

- Vent the structure;
- Do not allow personnel to reenter the building except to perform gas monitoring until the results of additional monitoring indicate that methane concentrations are sustained or stabilized below 25% of the LEL;
- Begin continuous monitoring within the structure; and
- Undertake an assessment to determine the origin and pathways of the gas migration.

Within seven days of detection, the monitoring results will be placed in the Operating Record and the County will indicate actions taken and actions proposed to resolve the problem. Within 60 days of detection, the County will develop and implement a landfill gas remediation plan for the combustible gas releases and notify the Division that the plan has been implemented. The plan will describe the nature and extent of the problem and the proposed remedy.

6.0 CERTIFICATION OF PROFESSIONAL GEOLOGIST OR ENGINEER

The landfill gas monitoring plan for this facility has been prepared by a qualified geologist or engineer who is licensed to practice in the State of North Carolina. The Certification of Professional Geologist or Engineer form is included as Appendix D.

7.0 CERTIFICATION OF REGISTERED LAND SURVEYOR

All future landfill gas monitoring wells will be surveyed for location and elevation by a North Carolina Registered Land Surveyor.

8.0 REFERENCES

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Johnson, A.I., 1967, *Specific Yield - Compilation of Specific Yields For Various Materials:* U.S. Geological Survey Water Supply Paper 1662-D.

Joyce Engineering, Inc., June 2012. *First Semiannual Groundwater Monitoring Report of 2012* John's River Landfill, Burke County, North Carolina.

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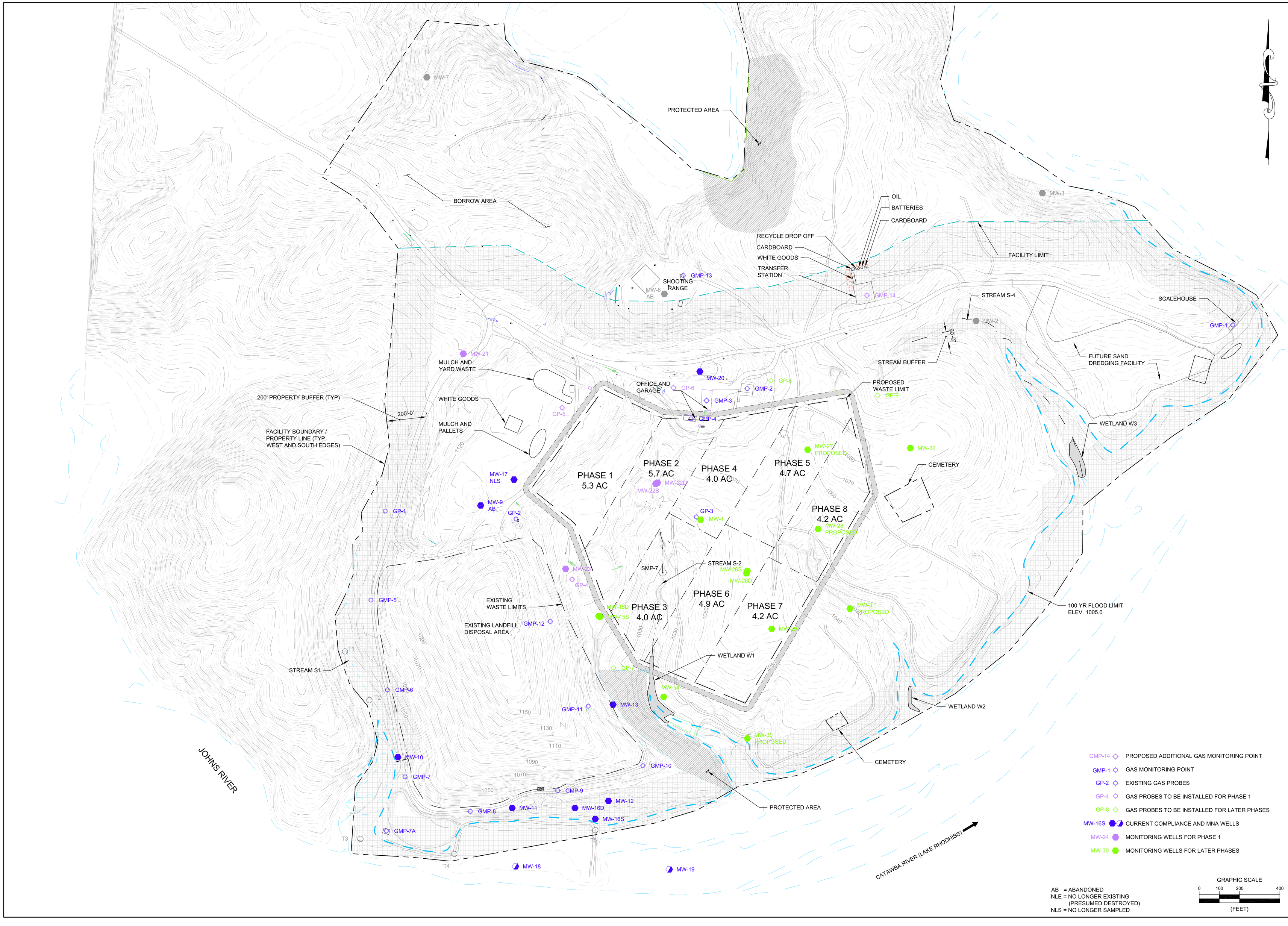
DRAWING



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BURKE COUNTY, NORTH CAROLINA

LANDFILL GAS MONITORING PLAN

PROJECT NO.
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APPENDIX A

Solid Waste Section – Landfill Gas Monitoring Guidance

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

DIVISION OF WASTE MANAGEMENT

SOLID WASTE SECTION

LANDFILL GAS MONITORING GUIDANCE

NOVEMBER 2010

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SECTION 1 - Introduction

North Carolina Solid Waste Management Rules 15A NCAC 13B require quarterly monitoring of methane gas (at MSW landfills) and quarterly monitoring of methane and other explosive landfill gases (LFG) (at C&D and other landfills) to ensure that landfill gas does not exceed the lower explosive limit (LEL) at the facility property boundary or 25 percent of the lower explosive limit in facility structures. If the concentration exceeds the specified limits, steps must be taken to ensure the protection of public health and a remediation plan must be implemented immediately. A landfill gas monitoring plan is necessary to ensure that these performance standards are met and this guidance document was developed to assist in establishing a standardized procedure for the monitoring of landfill gas.

Background

Organic matter in landfills begins to decompose almost immediately after being placed in a disposal site. Putrescible wastes such as food products and sewage sludges begin to break down by biological processes very rapidly whereas paper, cardboard or cellulose based materials are slower to decompose. However, when conditions become favorable, most organic matter will decompose. The decomposition process typically goes through several stages that depend on conditions such as pH, temperature, and moisture content. The final stage results in the production of methane and although the rate of production may vary, most landfills produce methane.

Landfill Gas Generation

Landfill gas is a natural by-product of the anaerobic decomposition of organic waste in a landfill. The composition, quantity and rate of landfill gas generation are dependent on the types of waste that are decomposing and the level of microbial activity within the wastes. The decomposition of biodegradable waste begins with aerobic decomposition which lasts until the oxygen in the landfill is depleted. The anaerobic phase then begins, resulting in landfill gas production.

There are four stages of landfill gas composition: the first stage is characterized by elevated nitrogen levels and occurs when the landfill is new. The second stage is characterized by elevated carbon dioxide levels and occurs for a relatively short period of time after the initial stage is complete. The third and fourth stages are characterized by elevated methane concentrations and represent the active life of a landfill and the post-closure time frame.

Landfill gas is generally composed of 50-55% methane (CH_4); 45-50% carbon dioxide (CO_2); less than 5% nitrogen (N_2); and less than 1% non-methane organic compounds. These individual gases generally remain co-mingled and do not naturally separate. The Solid Waste Section (SWS) Rules typically focus on methane (CH_4) and its explosive properties due to public safety issues. Hydrogen sulfide (H_2S) is also of particular concern in landfills and is typically recognized by its rotten egg odor. H_2S is immediately dangerous to life and health at concentrations of 100 parts per million (ppm).

Landfill Gas Migration

The production of landfill gas creates a positive pressure within the landfill that forces the gas to migrate. Landfill gas migrates from place to place by diffusion and pressure gradient and will follow the path of least resistance. Subsurface gas typically migrates above the groundwater table and is restricted laterally by streams. Porous soils lying above the bedrock can serve as pathways to transmit large volumes of gas. Underground off-site migration is common and can be facilitated by the presence of pipelines, buried utility corridors or trenches located within or adjacent to the landfill boundaries. Movement depends on soil type and moisture, and migration distances of 1,500 feet have been observed. Barometric pressure also influences movement. Falling barometric pressure allows methane to migrate out of the landfill and into surrounding areas.

SECTION 2 - Factors Influencing Landfill Gas Generation and Migration

Factors that affect landfill gas generation and migration through the subsurface include the following:

Waste Composition
The production of landfill gas is directly related to the amount of organic matter present in waste. The bacteria that break down the waste require small amounts of specific minerals such as calcium, potassium, magnesium and other micronutrients. Bacteria are able to thrive and produce landfill gas if the minerals/micronutrients are present. If the minerals/micronutrients are not present or if substances that inhibit bacterial growth exist, landfill gas production will occur at a reduced rate. Some forms of organic matter such as cellulose break down quickly whereas matter such as lignin breaks down more slowly. The rate at which landfill gas is produced depends on the proportions of each type of organic matter present in the waste.

Moisture Content
Landfills with higher moisture content generate higher concentrations of landfill gas in earlier stages of development (such as during leachate recirculation). Moisture accelerates the methanogenic process.

Temperature
Landfill bacteria are temperature dependant. They are able to survive and function below the freezing point, but they also function well at temperatures up to 65°C. Anaerobic bacteria produce small amounts of heat and may not be able to maintain the temperature of a shallow landfill when external temperatures decrease, so LFG generation may exhibit seasonal variations. Saturated landfills may not achieve ideal temperatures because the bacteria do not generate sufficient heat to raise the temperature of the excess water. Higher temperatures promote volatilization and chemical reactions with the waste so the trace gas component of landfill gas tends to increase with higher landfill temperatures.

Age of Landfill
Typically, landfills have an increasing generation of landfill gas for a number of years until closure at which time landfill gas generation reaches a peak and begins to subside. An evaluation of the age of the landfill and use of a landfill gas generation curve can be helpful in determining the likelihood of significant landfill gas concentrations from the landfill.

Landfill Cap
The type or presence of landfill cover can influence landfill gas generation and migration. Although a low permeability cap will reduce moisture and landfill gas generation over the longer term, initially, the installation of a landfill cap could drive landfill gas migration further from the landfill in the subsurface without proper ventilation (either passive or active). This is especially true in the case of unlined (unvented) landfills.

Water Table
Landfill gas movement in unlined landfills may be influenced by groundwater table variations. A rising water table could cause displacement and force upward movement of landfill gas.

Man-made and Natural Conduits
Structures such as drains, trenches, and buried utility corridors can act as conduits for landfill gas migration. Geologic features including fractured bedrock, porous soil, and permeable strata also provide conduits for landfill gas migration

Landfill Liner Conditions
The presence of a Subtitle-D (or equivalent) landfill liner has the capability to limit the lateral migration of landfill gas in the subsurface. Unlined landfills have no barrier to prevent lateral landfill gas migration in the subsurface.

Weather Conditions
Barometric pressure and precipitation have significant effects on landfill gas migration. Increased barometric pressure yields decreased landfill gas venting from the subsurface, until the pressure within the subsurface is greater than the atmospheric (barometric) pressure. Conversely, as the barometric pressure decreases, the landfill will vent the stored gas until pressure equilibrium is reached. Capping of a landfill can influence the effect of barometric pressure on landfill gas migration. Generally, a more permeable landfill cap will allow greater influence by barometric pressure than a less permeable landfill cap.

SECTION 3 – Current Solid Waste Section Rules Pertaining to Landfill Gas Monitoring

Web link to the 15A NCAC 13B rules - http://portal.ncdenr.org/web/wm/sw/rules

15A NCAC 13B

.0101- DEFINITIONS
.0101 (14) "Explosive gas" means Methane (CH4)
.0101(25) "Lower explosive limit" (LEL) means the lowest percent by volume of a mixture of explosive gases which will propagate a flame in air at 25 degrees Celsius and atmospheric pressure.

.0503 - SITING AND DESIGN REQUIREMENTS FOR DISPOSAL FACILITIES
.0503(2) A site shall meet the following design requirements:

(a) The concentration of explosive gases generated by the site shall not exceed:

(i) twenty-five percent of the limit for the gases in site structures (excluding gas control or recovery system components); and

(ii) the lower explosive limit for the gases at the property boundary;

.0543 - CLOSURE AND POST-CLOSURE REQUIREMENTS FOR C&DLF FACILITIES
.0543(e) Post-closure criteria.

(1) Following closure of each C&DLF unit, the owner and operator must conduct post-closure care. Postclosure care must be conducted for 30 years, except as provided under Subparagraph (2) of this Paragraph, and consist of at least the following:

(C) maintaining and operating the gas monitoring system in accordance with the requirements of Rule .0544 of this Section; and

(2) The length of the post-closure care period may be:

(A) decreased by the Division if the owner or operator demonstrates that the reduced period is sufficient to protect human health and the environment and this demonstration is approved by the Division; or

(B) increased by the Division if the Division determines that the lengthened period is necessary to protect human health and the environment.

.0544 - MONITORING PLANS AND REQUIREMENTS FOR C&DLF FACILITIES
.0544(d) Gas Control Plan

(1) Owners and operators of all C&DLF units must ensure that:

(A) the concentration of methane gas or other explosive gases generated by the facility does not exceed 25 percent of the lower explosive limit in on-site facility structures (excluding gas control or recovery system components);

(B) the concentration of methane gas or other explosive gases does not exceed the lower explosive limit for methane or other explosive gases at the facility property boundary; and

(C) the facility does not release methane gas or other explosive gases in any concentration that can be detected in offsite structures.

(2) Owners and operators of all C&DLF units must implement a routine methane monitoring program to ensure that the standards of this Paragraph are met.

(A) The type of monitoring must be determined based on soil conditions, the Hydrogeologic conditions under and surrounding the facility, hydraulic conditions on and surrounding the facility, the location of facility structures and property boundaries, and the location of all offsite structures adjacent to property boundaries.

(B) The frequency of monitoring shall be quarterly or as approved by the Division.

(3) If methane or explosive gas levels exceeding the limits specified in Subparagraph (d)(1) of this Rule are detected, the owner and operator must:

(A) immediately take all steps necessary to ensure protection of human health and notify the Division;

(B) within seven days of detection, place in the operating record the methane or explosive gas levels detected and a description of the steps taken to protect human health; and

(C) within 60 days of detection, implement a remediation plan for the methane or explosive gas releases, place a copy of the plan in the operating record, and notify the Division that the plan has been implemented. The plan must describe the nature and extent of the problem and the proposed remedy.

(4) Based on the need for an extension demonstrated by the operator, the Division may establish alternative schedules for demonstrating compliance with Parts (3)(B) and (3)(C) of this Paragraph.

(5) For purposes of this Item, "lower explosive limit" means the lowest percent by volume of a mixture of explosive gases in air that will propagate a flame at 25 C and atmospheric pressure.

.0566 - OPERATIONAL REQUIREMENTS FOR LAND CLEARING/INERT DEBRIS (LCID) LANDFILLS

.0566(13) The concentration of explosive gases generated by the facility shall not exceed:

(a) Twenty-five percent of the lower explosive limit for the gases in facility structures.

(b) The lower explosive limit for the gases at the property boundary.

.1626 – OPERATIONAL REQUIREMENTS FOR MSWLF FACILITIES

.1626(4) Explosive gases control.

(a) Owners or operators of all MSWLF units must ensure that:

(i) The concentration of methane gas generated by the facility does not exceed 25 percent of the lower explosive limit for methane in facility structures (excluding gas control or recovery system components); and

(ii) The concentration of methane gas does not exceed the lower explosive limit for methane at the facility property boundary.

(b) Owners or operators of all MSWLF units must implement a routine methane monitoring program to ensure that the standards of (4)(a) are met. A permanent monitoring system shall be constructed on or before October 9, 1994. A temporary monitoring system shall be used prior to construction of the permanent system.

(i) The type and frequency of monitoring must be determined based on the following factors:

(A) Soil conditions;

(B) The hydrogeologic conditions surrounding the facility;

(C) The hydraulic conditions surrounding the facility; and

(D) The location of facility structures and property boundaries.

(ii) The minimum frequency of monitoring shall be quarterly.

(c) If methane gas levels exceeding the limits specified in (4)(a) are detected, the owner or operator must:

(i) Immediately take all necessary steps to ensure protection of human health and notify the Division;

(ii) Within seven days of detection, place in the operating record the methane gas levels detected and a description of the steps taken to protect human health; and

(iii) Within 60 days of detection, implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record, and notify the Division that the

plan has been implemented. The plan shall describe the nature and extent of the problem and the proposed remedy.

(iv) Based on the need for an extension demonstrated by the operator, the Division may establish alternative schedules for demonstrating compliance with (4)(c)(ii) and (iii) of this Rule.

(d) For purposes of this Item, "lower explosive limit" means the lowest percent by volume of a mixture of explosive gases in air that will propagate a flame at 25°C and atmospheric pressure.

.1626(10) Recordkeeping requirements.

(a) The owner or operator of a MSWLF unit must record and retain at the facility, or an alternative location near the facility approved by the Division, in an operating record the following information as it becomes available:

(iii) Gas monitoring results and any remediation plans required by Item (4) of this Rule;

.1627 – CLOSURE AND POST CLOSURE REQUIREMENTS FOR MSWLF ACTIVITES

.1627(d) Post-Closure Criteria

(1) Following closure of each MSWLF unit, the owner or operator shall conduct post-closure care. Post-closure care shall be conducted for 30 years, except as provided under Subparagraph (2) of this Paragraph, and consist of at least the following:

(D)-Maintaining and operating the gas monitoring system in accordance with the requirements of Rule .1626 of this Section.

(2) The length of the post-closure care period may be:

(A) Decreased by the Division if the owner or operator demonstrates that the reduced period is sufficient to protect human health and the environment and this demonstration is approved by the Division; or

(B) Increased by the Division if the Division determines that the lengthened period is necessary to protect human health and the environment.

(3) Following completion of the post-closure care period for each MSWLF unit, the owner or operator shall notify the Division that a certification, signed by a registered professional engineer, verifying that post-closure care has been completed in accordance with the post-closure plan, has been placed in the operating record.

NOTES:

Based on the referenced rules above, the following words / phrases are presently in the Solid Waste Section rules pertaining to methane and explosive landfill gas.

Rule .0101(14) states: *"Explosive gas means Methane (CH)"*.
Rule .0503 (2)(a) refers to *"explosive gases"*.
Rule .0544(d) refers to "*Gas Control Plan"*
Rule .0544(d)(1) refers to *"methane or other explosive gases"*.
Rule .0544(d)(2) refers to "*methane monitoring program*"
Rule .0544(d)(3) refers to *"methane or explosive gas levels*"
Rule .0566 (13) refers to *"explosive gases"*.
Rule .1626 (4) refers to *"explosive gases control"*
Rule .1626(4)(a-b) refers to "*methane monitoring"* and "*methane monitoring program"*.

Monitoring Goals

Landfill design and landfill gas monitoring regulations in North Carolina require that there not be an exceedance of 100% of the Lower Explosion Limit (LEL) (equivalent to 5% methane) at the property boundary, or 25% LEL in on-site structures. These regulations were developed over time to protect the health and safety of the citizens of North Carolina and the U.S. from the asphyxiation and explosive hazards of landfill gas.

NC Rule History

A review of NC landfill guidance documents and regulations from 1972 to the present indicates that from 1972 through 1982, there was no mention of design requirements regarding the control of landfill gas, nor were there any landfill monitoring requirements for landfill gas. In 1982, the regulations were changed to require that sanitary landfill design prevent landfill gas concentrations of 100% LEL at the property boundary line and 25% inside on-site structures. Although a design requirement was added, no design requirement was established to determine if the design requirement was being met. In 1993 with the establishment of .1600 rules, requirements for designs to limit landfill gas levels to below 100% at the property boundary line and 25% in on-site structures and monitoring of landfill gas concentrations around the perimeter of the landfill and inside on-site structures were adopted.

SECTION 4 – Landfill Gas Incidents and Explosions

Hazards Involving Landfill Gas

Landfill fires may or may not be directly caused by landfill gas. The primary concern with these fires is air contamination from the resulting smoke; however they also present a variety of additional problems. In addition to concerns with containing and extinguishing landfill fires, potential reactions involving unknown chemicals in the landfill can cause uncertain hazards. Discarded consumer products in a landfill, such as pesticides, paints, solvents, cleaners, and other material can be the source of chemical releases. Heat from the fire can cause chemicals to volatilize, breakdown, and enter the environment. Also to be considered is the presence of other combustible gases in addition to methane. Whenever an environmental investigation of a landfill is prompted by odorous compounds or explosive gases, the presence of toxic substances should also be investigated. One example is hydrogen sulfide (H2S) that can cause asphyxiation and is flammable. An analysis should include alkyl benzenes, sulfur compounds, vinyl chloride, and methane, and other products associated with industrial wastes, construction and debris waste, and normal organic and inorganic waste.

Fires and explosion hazards become a concern when gases collect in confined spaces. Buildings, basements, and pits are typically regarded as confined spaces. However, landfill gases also collect in and migrate to cracks in the landfill cover, leachate "springs", cracks in adjacent structures, paved parking areas, etc. Fires can occur on the surface and underground. Surface fires involve recently buried waste near the surface in an aerobic decomposing layer, typically 1 to 4 feet below ground. These fires can be intensified by subsurface landfill gas and spread throughout the landfill. Subsurface fires occur deeper within the landfill, involve material buried for months or years, and can burn for days and months.

The following is a brief summary of some incidents involving landfill gas migration from landfills:

2007 Four employees died as a result of exposure to high concentrations of hydrogen sulfide while attempting to repair a leachate pump at a C&D landfill in Superior, Wisconsin (Journal of Environmental Heath 2008).

1999 An 8-year old girl was burned on her arms and legs when playing in an Atlanta, Georgia playground. The area was reportedly used as an illegal dumping ground many years ago (Atlanta Journal-Constitution 1999).

1994 While playing soccer in a park built over an old landfill in Charlotte, North Carolina, a woman was seriously burned by a methane explosion (Charlotte Observer 1994).

1987 Offsite landfill gas migration is suspected to have caused a house to explode in Pittsburgh, Pennsylvania (EPA 1991).

1984 Landfill gas migrated to and destroyed one house near a landfill in Akron, Ohio. Ten houses were temporarily evacuated (EPA 1991).

1983 An explosion destroyed a residence across the street from a landfill in Cincinnati, Ohio. Minor injuries were reported (EPA 1991).

1975 In Sheridan, Colorado, landfill gas accumulated in a storm drain pipe that ran through a landfill. An explosion occurred when several children playing in the pipe lit a candle, resulting in serious injury.

1969 Methane gas migrated from an adjacent landfill into the basement of an armory in Winston-Salem, North Carolina. A lit cigarette caused the gas to explode, killing three men and seriously injuring five others (USACE 1984).

SECTION 5 - Landfill Gas Monitoring Wells

Locations

Landfill gas monitoring well locations will be site specific depending upon site geology, depth to groundwater, surface water features, on-site and off-site structures and sensitive receptors. The landfill gas monitoring wells must be spaced no more than 500 feet apart depending upon site specifics. A readily accessible, unobstructed path must be maintained so that landfill gas monitoring wells are always accessible using four-wheel drive vehicles. Regardless of site specifics, the permittee must obtain approval from the Solid Waste Section for the design and installation of any landfill gas monitoring well system.

Well Construction and Installation

Landfill gas monitoring wells are the same as groundwater monitoring wells with two exceptions. Landfill gas monitoring wells are installed just above the water table within the unsaturated zone and are equipped with a stopcock valve or a quick connect coupling on the cap, which allows for accurate landfill gas measurements. The stopcock valve must be equipped with flexible tubing and a barb connection that will fit the gas meter's inlet tube. The stopcock valve or a quick connect coupling must be closed between monitoring events. The landfill gas monitoring well must also be capped, locked, and labeled with a permanently affixed identification plate stating the well contractor name and certification number, date of well competition, total depth of well, screen length and well ID number. See detailed schematics of a landfill gas monitoring well (Figure 1).

The depth of each landfill gas monitoring well will be site specific depending upon depth to groundwater. Landfill gas monitoring wells must be constructed the same as groundwater monitoring wells as described in 15A NCAC Subchapter 2C. Typically landfill gas monitoring wells must be installed using 2" PVC piping and screen. The screen length, also site specific, must span the majority of the unsaturated zone while still allowing for proper well construction. A North Carolina Professional Geologist or Professional Engineer must be present to supervise the installation of all landfill gas monitoring wells. The exact locations, screened intervals, and nesting of the wells must be approved by the Solid Waste Section Hydrogeologist prior to landfill gas monitoring well installation. Each landfill gas monitoring well must be surveyed for location and elevation by a North Carolina Registered Land Surveyor. Within thirty (30) days of the completed construction of each new landfill gas monitoring well, the boring log and a diagram of each well including, but not limited to total depth, screened interval and distance above seasonal high water table must be submitted to the Solid Waste Section. The submittal must also include a scaled topographic map showing the location and identification of new, existing and abandoned landfill gas monitoring wells.

Nested and Clustered Landfill Gas Monitoring Wells

Nested and/or clustered landfill gas monitoring wells may be required in unsaturated zones of 45 feet or more to measure specific depths of the unsaturated zone. Initially, the installation of one long screen shall be sufficient. If a monitoring event shows an exceedance of the lower explosive limit, then the Solid Waste Section may require the installation of nested and/or clustered landfill gas monitoring wells.

Abandonment of Wells

An abandonment record must be submitted to the Solid Waste Section within 30 (thirty) days of the abandonment of a landfill gas monitoring well. The landfill gas monitoring well(s) must be overdrilled and sealed with grout in accordance with 15A NCAC 2C .0113(d) and certified by a North Carolina Professional Geologist or Professional Engineer.

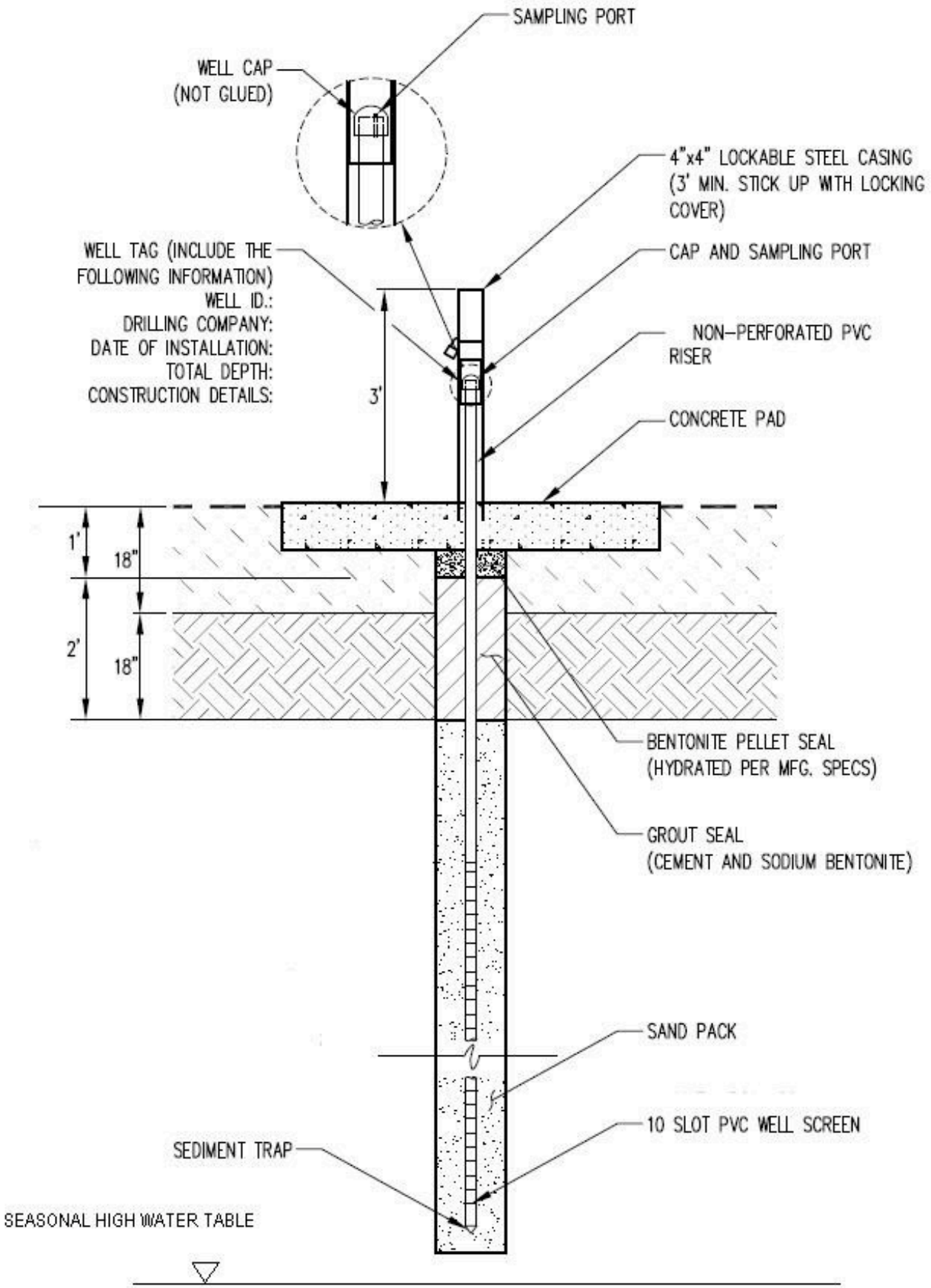
Professional Certification

The certification statement below must be signed and sealed by a North Carolina Professional Geologist or Professional Engineer and submitted with the Landfill Gas Monitoring Plan.

> The landfill gas monitoring plan for this facility has been prepared by a qualified geologist or engineer who is licensed to practice in the State of North Carolina. The plan has been prepared based on first-hand knowledge of site conditions and familiarity with North Carolina solid waste rules and industry standard protocol. This certification is made in accordance with North Carolina Solid Waste Regulations, indicating this Landfill Gas Monitoring Plan should provide early detection of any release of hazardous constituents to the uppermost aquifer, so as to be protective of public health and the environment. No other warranties, expressed or implied, are made.
>
> Signed _____
>
> Printed _____
>
> Date _____
>
> Not valid unless this document bears the seal of the above mentioned licensed professional.

In addition, the boring logs and/or well diagram must be signed and sealed with the stamp of a North Carolina Registered Land Surveyor.

Figure 1 – Landfill Gas Monitoring Well Detail



SECTION 6 – Landfill Gas Monitoring Instrumentation

The person using the landfill gas monitoring instrument must understand the principles of operation and follow the manufacturer's instructions. This includes calibrating the instrument according to the manufacturer's specifications. Include the following on the top portion of the landfill gas monitoring form (See example below) : facility name, permit number, type and serial number of gas monitoring instrument, calibration date of the instrument, date and time of field calibration, type of gas used for field calibration (15/15 or 35/50), expiration date of field calibration gas canister, date of landfill gas monitoring event, name and position of sample collector, pump rate of instrument being used, ambient air temperature, and general weather conditions. Verification that the equipment was calibrated in accordance with the manufacturer's specifications is also required. When determining which field calibration gas to use, take into consideration the expected levels of methane in the landfill gas monitoring wells. If the methane levels are expected to be low, use the 15/15 gas canister (15% CO2/15% CH4). If the methane levels are expected to be high, use the 35/50 gas canister (35% CO2/50% CH4).

For every landfill gas monitoring well, please include the following: verification of sample tube purge prior to each sample taken (should be one minute), the time pumped in seconds (should be at least one minute), barometric pressure, time stabilized reading collected, percent lower explosive limit, percent methane by volume, percent oxygen, percent carbon dioxide, and any observations or comments.

The landfill gas monitoring data form (See example below) and results should be retained in the facility's operating record unless an exceedance has occurred and/or is requested by the Solid Waste Section.

Landfill gas monitoring readings from non-calibrated or inaccurately calibrated instruments are not reliable, and will therefore be rejected by the Solid Waste Section. Landfill gas monitoring readings collected with monitoring equipment that was not designed for landfill gas monitoring will also be rejected by the Solid Waste Section. There are several different landfill gas monitoring instruments on the market which may be used in order to obtain all of the information required by the Solid Waste Section.

Monitoring Times

Monitoring times are also important when conducting landfill gas monitoring. Proper landfill gas monitoring should include sampling during times when landfill gas is most likely to migrate. Landfill gas can migrate and accumulate not only in landfill gas monitoring wells; it can also migrate and accumulate in buildings and other structures. Because subsurface gas pressures are considered to be at a maximum during the afternoon hours, monitoring should be conducted in the afternoon or whenever the barometric pressure is low.

Scientific evidence also indicates that weather and soil conditions influence the migration of landfill gas. Barometric pressure and precipitation have significant effects on landfill gas migration. Increased barometric pressure generates decreased landfill gas venting from the subsurface, until the pressure within the subsurface is greater than the atmospheric (barometric) pressure. On the other hand, when the barometric pressure decreases, the landfill will vent the stored gas until a pressure equilibrium is reached. Capping of a landfill can influence the effect of barometric pressure on landfill gas migration. Generally, a more permeable landfill cap will allow greater influence by barometric pressure than a less permeable landfill cap. As a result, landfill gas monitoring should be conducted when the barometric pressure is low and soils are saturated. During the winter season when snow cover is just beginning to melt or when the ground is frozen or ice covered, landfill gas monitoring should be conducted when the barometric pressure is low.

Landfill Gas Sampling Procedures

Any accumulation of landfill gas in the landfill gas monitoring wells is the result of landfill gas migration. The following procedure is a recommended example for conducting landfill gas monitoring well sampling, but always read and follow the manufacturer's instructions because each instrument will be different.

Step 1 – Calibrate the instrument according to the manufacturer's specifications. In addition, prepare the instrument for monitoring by allowing it to properly warm up as directed by the manufacturer. Make sure the static pressure shows a reading of zero on the instrument prior to taking the first sample.
Step 2 – Purge sample tube for at least one minute prior to taking reading. Connect the instrument tubing to the landfill gas monitoring well cap fitted with a stopcock valve or quick connect coupling.
Step 3 – Open the valve and record the initial reading and then the stabilized reading. A stable reading is one that does not vary more than 0.5 percent by volume on the instrument's scale.
Step 4 - Record the stabilized reading including the oxygen concentration and barometric pressure. A proper reading should have two percent oxygen by volume or less. If levels of oxygen are higher, it may indicate that air is being drawn into the system giving a false reading.
Step 5 – Turn the stopcock valve to the off position and disconnect the tubing.
Step 6 – Proceed to the next landfill gas monitoring well and repeat Steps 2 – 5.

Landfill Gas Constituent Sampling and Analysis

Sampling of landfill gas to determine volume percentages/concentrations of each constituent can be accomplished through the use of canisters which are specifically designed for landfill gas analysis. Several analytical methods are available to determine the concentrations of a variety of constituents. Typically, landfill gas analysis of this type is performed to determine the non-methane organic compounds emission rate for Tier 2 testing under the Clean Air Act (Title V Subpart WWW 60.754). Isotropic identification of landfill methane can be accomplished to identify one source of methane from another. In this case, isotopes of carbon and hydrogen in the methane are analyzed to determine the methane source.

NC Division of Waste Management - Solid Waste Section

Landfill Gas Monitoring Data Form

Notice: This form and any information attached to it are "Public Records" as defined in NC General Statute 132-1. As such, these documents are available for inspection and examination by any person upon request (NC General Statute 132-6).

Facility Name: _____ Permit Number: _____

Date of Sampling: _____ NC Landfill Rule (.0500 or .1600): _____

Name and Position of Sample Collector: _____

Type and Serial Number of Gas Meter: _____ Calibration Date of Gas Meter: _____

Date and Time of Field Calibration: _____

Type of Field Calibration Gas (15/15 or 35/50): _____ Expiration Date of Field Calibration Gas Canister: _____

Pump Rate of Gas Meter: _____

Ambient Air Temperature: _____ Barometric Pressure: _____ General Weather Conditions: _____

Instructions: Under "Location or LFG Well" identify the monitoring wells or describe the location for other tests (e.g., inside buildings). A drawing showing the location of test must be attached. Report methane readings in both % LEL and % methane by volume. A reading in percent methane by volume can be converted to % LEL as follows: % methane by volume = % LEL/20

Location or LFG Well ID	Sample Tube Purge	Time	Time Pumped (s)	Initial %LEL	Stabilized %LEL	%CH4 by Volume	%O2	%CO2	Notes

If your facility has more gas monitoring locations than there is room on this form, please attach additional sheets listing the same information as contained on this form.

Certification
To the best of my knowledge, the information reported and statements made on this data submittal and attachments are true and correct. I am aware that there are significant penalties for making any false statement, representation, or certification including the possibility of a fine and imprisonment.

_____ _____
SIGNATURE TITLE

SECTION 7 - References

Agency for Toxic Substances & Disease Registry. "Landfill Gas Primer- An Overview for Environmental Health Professionals. 2001." http://www.atsdr.cdc.gov/HAC/landfill/html/toc.html (accessed February 24. 2010).

California Environmental Protection Agency. "Landfill Gas Monitoring Well Functionality at 20 California Landfills, 2008". http://www.calrecycle.ca.gov/Publications/Organics/2008022.pdf (accessed February 24 2010).

Florida Department of Environmental Protection. Gas Management Systems, under Rule 62-701.530. http://www.dep.state.fl.us/waste/quick_topics/rules/default.htm (accessed February 24, 2010).

Missouri Department of Natural Resources, Flood Grant Team. "An Analysis of Landfill Gas Monitoring Well Design and Construction, 2007". http://www.clu-in.org/conf/itrc/directpush/prez/Missouri_Study.pdf (accessed February 24, 2010).

Missouri Department of Natural Resources. "Design and Construction of Landfill Gas Monitoring Wells". http://www.dnr.missouri.gov/pubs/pub2054.pdf (accessed February 24. 2010).

Wisconsin Department of Natural Resources. Environmental Monitoring for Landfills, under Chapter NR 507.22. http://www.dnr.state.wi.us/org/aw/wm/information/wiacsss.htm (accessed February 24, 2010).

"Landfill Gas-an Overview" Landfill-gas.com. Web, 22, Feb. 2010 http://www.landfill-gas.com/webpage -LFG-overview.doc

SECTION 8 – Suggested Outline for a Landfill Gas Monitoring Plan

1. Introduction
   1.1. Background (project overview, site observations, NCDENR rules referenced)
   1.2. Site Geology with discussion of groundwater depth and flow (potentiometric surface map)
   1.3. Regulatory Limits
2. Landfill Gas Monitoring
   2.1. Landfill Gas Monitoring Well Locations (discussion of reasoning behind proposed locations, discussion of well construction, reference map showing proposed locations, reference table displaying well ID, well depth, screen interval and depth to groundwater)
   2.2. Structure and Ambient Sampling
   2.3. Landfill Gas Monitoring Frequency
3. Landfill Gas Sampling Procedures
   3.1. Detection Equipment Used (discussion of calibration procedures)
   3.2. Landfill Gas Sampling Procedure
4. Record Keeping and Reporting
   4.1. Landfill Gas Monitoring Data Form
   4.2. Sampling Reports
   4.3. Permanent Record Keeping
5. Contingency Plan
6. Certification of Professional Geologist or Professional Engineer
7. Certification of Registered Land Surveyor

Figures

Map displaying proposed landfill gas monitoring well locations

Potentiometric Surface Map

Diagram showing construction of stopcock valve or quick connect coupling on well cap

Diagram showing well construction of each landfill gas monitoring well

Table

Table displaying well ID, well depth, screen interval, depth to groundwater

Example of landfill gas monitoring data form

SECTION 9 – Checklist of Items to be Included in a Landfill Gas Monitoring Plan

1. Depth to groundwater discussion
2. Well locations
    a. Number of wells
    b. Well spacing
3. Instrumentation being used
    a. Calibration procedures
4. Sampling procedures as per the manufacture's instructions
5. Map of well locations
6. Table describing each well location
    a. Well ID
    b. Well depth
    c. Screen interval
    d. Depth to groundwater
    e. Subsurface lithology
7. Diagram of cap construction w/ stopcock valve or quick connect coupling
8. Diagram of well construction
9. Potentiometric surface map
10. Professional Geologist or Professional Engineer certification
11. Registered Land Surveyor certification

APPENDIX B

Landfill Gas Monitoring Data Form

Landfill Gas Monitoring Data Form

Facility Name: _____ Permit Number: _____

Date of Sampling: _____ Personnel: _____

Gas Monitor Type & Serial No: _____ Calibration Date: _____

Field Calibration Date & Time: _____ Calibration Gas Type: _____

General Weather Conditions: _____ Barometer : _____

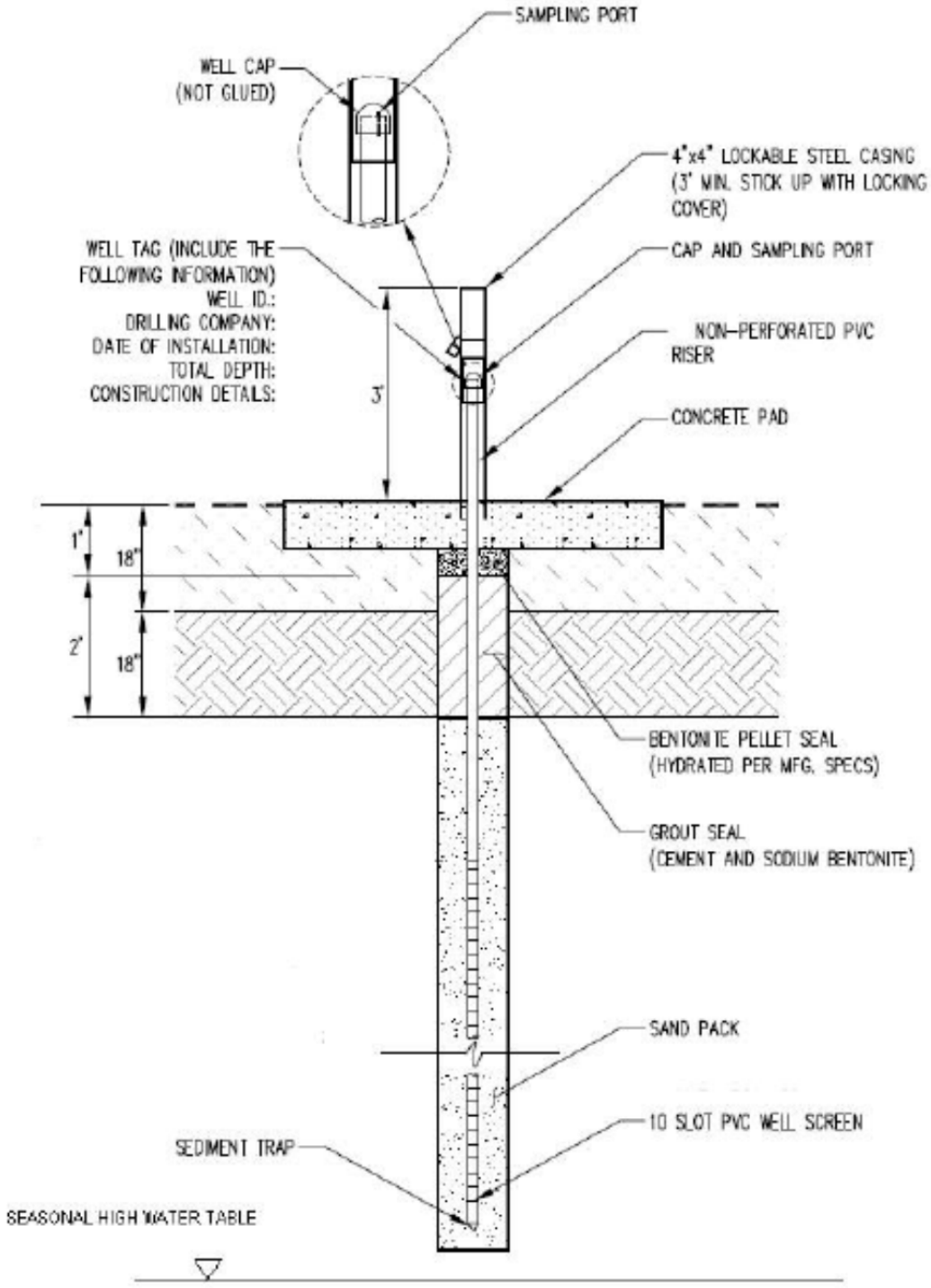
Location or LFG GW ID	Instr. purged	Time	Well Pressure (InWg)	Time Pumped (sec.)	CH_4 (%LEL)	CH_4 (%Vol)	Notes

Abbreviations: GW = Gas Well

LEL = Lower Explosive Limit

APPENDIX C

Landfill Gas Monitoring Well Detail



Landfill Gas Monitoring Well Detail

APPENDIX D

Certification of Professional Geologist or Engineer

LANDFILL GAS MONITORING PLAN
John's River Waste Management Facility
Burke County, NC
Permit No. 12-03

Certification of Professional Geologist or Engineer

The landfill gas monitoring plan for this facility has been prepared by a qualified geologist or engineer who is licensed to practice in the State of North Carolina. The plan has been prepared based on first-hand knowledge of site conditions and familiarity with North Carolina solid waste rules and industry standard protocol. This certification is made in accordance with North Carolina Solid Waste Regulations, indicating this Landfill Gas Monitoring Plan should provide early detection of landfill gas migration, so as to be protective of public health and the environment. No other warranties, expressed or implied, are made.

Signed: _____

Printed: G. Van Ness Burbach, Ph.D., P.G.

Date: 8/31/12