Section 2
Corrective Action Objectives

2.1 Corrective Action Objectives

Corrective action objectives have been developed for this site based on the requirements provided under the North Carolina Solid Waste Management Rule .1636; Selection of Remedy. This section, which pertains to remedy selection, states that at a minimum, potential remedies must:

1. Be protective of human health and the environment;

2. Attain the approved groundwater protection standards;

3. Control the source of release so as to reduce or eliminate, to the maximum extent practical, further releases of Appendix II constituents into the environment that may pose a threat to human health or the environment; and

4. Comply with standards for management wastes as specified in Rule .1637(d).

These corrective action objectives serve as the primary basis upon which the corrective action alternatives are developed and evaluated. Using the presumptive remedy approach, a limited number of media-specific remedial technologies are identified. These are then screened for site specific feasibility, technical implementability, and practicality (cost) based on readily available information from similar sites.

2.2 General Response Actions

General Response Actions are categories of activities which are applied toward remediation of contaminated sites. The corrective action objectives developed for a site dictate which general response actions should be undertaken. Within each general response action (other than No Action) there are several technology types and process options.

The general response actions identified for the North Wake Unlined Landfill that will meet the remedial action objectives or will provide a baseline against which actions may be compared consist of the following:

- No Further Action - A No Action response is always identified for the purpose of establishing a baseline with which to compare other general response actions. There are no preventative or corrective actions taken as a result of this general response action; however, monitoring of the contamination may be prescribed.

- Institutional Controls - These controls utilize actions that control contact with the contamination rather than remediating the contamination itself. These actions may be physical, such as fences or barriers, or legal such as property acquisition, deed restrictions, zoning changes, restrictions on water use, or security restricted access.

- Containment - As a general response action, containment prevents risk to human health and the environment by restricting contact to or migration of the contaminants via the soil, water or air pathways. A number of technologies and different materials are available for use in establishing migration barriers.

- Removal/Excavation - This response action physically removes or collects the existing contaminated media from the site. Other response actions are usually necessary in order to achieve remedial action goals and objectives for the removed and collected media. Collection and removal of solids/soils media is often associated with source control activities and eventually reduces contaminant concentrations in the surrounding surface water, groundwater, biota, and air media. Collection or removal actions in water and air media may not prevent continued migration of contaminants in those media, but typically intercept the most contaminated portions of those media. Removal or excavation is generally not an effective response action for low level contamination.

- Treatment - These actions involve removal of the contaminant from contaminated media, or alteration of the contaminant. The result is a reduction in mobility, volume, or toxicity of the contaminant.

- Disposal/Discharge - This general response action involves the transfer of contaminated media, concentrated contaminants, or treated materials to a site reserved for long term storage of such materials. Disposal sites are strictly regulated in operation and the types of materials that they may accept.

The general response actions presented above form the basis for identifying technology types and process options specific for the site, which are subsequently screened for effectiveness, implementability and practicality (cost).

2.3 Potential Exposure Pathways

Potential exposure pathways for the site include the following:

- direct human contact with waste,

- human exposure to contaminated surficial groundwater,

- human/ecological exposure to contaminated groundwater discharging to surface water, and

- human exposure to contaminated groundwater in deeper aquifers.

Site access controls (fences) and the landfill cap prevent direct human contact with buried waste, therefore exposure through this pathway is not likely.

Depth to surficial groundwater at the site is generally about 25 to 35 feet below land surface. There are no ditches or ponds that intersect the groundwater table on the site. Exposure of the public to potentially contaminated groundwater is not possible.

The surficial aquifer discharges locally to the small streams to the north and south of the site, and ultimately to the Neuse River to the east. The land immediately east of the landfill is owned by Tyco (formerly Mallinckrodt Chemical). "No Trespassing" signs and fencing have been placed along both the landfill property and Tyco property. All historic surface water sampling indicates that contamination is not present. While potential exposure to possibly contaminated discharging groundwater exists, because of the factors mentioned, potential exposure to discharging groundwater is unlikely.

All potable water in the adjacent Falls River subdivision is supplied by the City of Raleigh. Based on a review of Wake County's well permit database, no public or private supply or irrigation wells are known to exist in Falls River Subdivision. Therefore, direct contact with extracted groundwater from either the surficial or deeper aquifer is not possible in the adjacent residential area.

Section 3
Identification and Screening of Corrective Measure Alternatives

This section identifies the potentially applicable remedial technologies and presents the criteria used to screen them. The measures that pass the initial screening are grouped into corrective measure alternatives for further evaluation in Sections 4 and 5.

3.1 Identification of Potential Corrective Measures

Varieties of measures have been used to control, contain, collect, treat and generally remediate groundwater contamination. Based on historical patterns of remedy selection and EPA/state scientific and engineering evaluation of performance data on technology application, preferred technologies for remediation of groundwater contamination have been identified. By considering these technologies, or presumptive remedies, the assessment of corrective measures can be focused at an early stage on those technologies or actions that have been proven effective at other sites. The following sections discuss the technologies or actions that may apply to this site.

3.1.1 Institutional Controls

Institutional controls for landfills include access restrictions (perimeter fencing, locked access gates) to regulate site use, deed restrictions or land acquisition to regulate future development and groundwater use restrictions. Institutional controls are typically implemented to supplement engineering controls.

3.1.2 Monitored Natural Attenuation (MNA)

MNA is a risk management strategy used to control exposure to hazards associated with subsurface contamination. MNA is ideal for instances where naturally occurring destructive and nondestructive mechanisms will reduce dissolved-phase contaminant concentrations to below groundwater protection standards before the contaminant plume reaches potential receptors. Destructive processes include biodegradation, abiotic oxidation and hydrolysis. Nondestructive attenuation mechanisms include sorption, dilution and volatilization. Typically, a detailed natural attenuation demonstration is required followed by routine groundwater monitoring to document the effectiveness of natural attenuation. Existing water quality data can often be used to provide a preliminary evaluation of the effectiveness of natural attenuation.

3.1.3 Hydraulic Control/Remediation of Groundwater

Several methods are routinely used at landfills to provide hydraulic control of groundwater and leachate at unlined landfills. These include perimeter ditches, groundwater barrier walls and extraction wells. Technologies potentially applicable to this site are identified below.

3.1.3.1 Groundwater Barrier Wall

Groundwater barrier walls prevent the migration of contaminated groundwater in the subsurface. Common types of barrier walls include slurry walls constructed of low-permeable materials, sheet piling, geomembrane, or in situ reactive barriers which channel flow through a reactive barrier which, depending on the contaminant present, may use a combination of physical, chemical or biological processes to treat the plume. This method may be limited based on the contaminants present, and is more expensive than traditional barriers.

3.1.3.2 Groundwater Extraction

Groundwater extraction, commonly called pump-and-treat, is one of the most widely used ground-water remediation technologies. Extraction wells are located at the leading edge and/or within the plume to collect groundwater and pump it to a treatment facility. Pump-and-treat may be applicable to this site to prevent further migration of leachate-contaminated groundwater. Collected groundwater would be diverted to a sanitary sewer line at the Subtitle D landfill and treated at the Neuse River Wastewater Treatment Plant (WWTP).

Based on existing groundwater quality data, no special handling or pretreatment of effluent would be necessary to make it acceptable to the WWTP. A more rigorous analysis would be required to determine flow rates of a groundwater extraction system, and to confirm that these rates would be acceptable to the WWTP.

3.1.4 In situ Groundwater Treatment

In situ groundwater treatments involve enhancing the natural remediation capability of the subsurface environment by biological, chemical, or mechanical methods. Biological methods include using products such as Hydrogen Releasing Compound (HRC), or enhanced remediation through products such as Emulsified Oil Substrate (EOS) or introduction of methane, oxygen, nitrogen, hydrogen, or phosphorus to promote natural bacterial activity. Chemical methods include introduction of an oxidizing agent such as persulfate, Fenton's Reagent or Oxygen Releasing Compound (ORC). Mechanical treatment would include methods such as air sparging, hot water/steam flushing, surfactants, or vacuum extraction.

3.1.5 Capping

Capping is performed to reduce infiltration of precipitation, thereby reducing leachate generation which may impact groundwater. A low permeability cap was installed as part of the landfill closure in 1997.

3.1.6 Gas Recovery

The generation of landfill gas within a capped, unvented landfill may speed up groundwater migration by increasing the pressure inside the landfill. Gas venting, either active (removed by a vacuum) or passive (vented to the air) reduces pressure by allowing gas to escape. Venting would also remove VOC contaminant mass from the source material. The existing landfill currently utilizes both an active landfill vacuum system and a perimeter vacuum system. The perimeter vacuum system consists of both landfill gas extraction wells along the west and north perimeter and a horizontal collector trench along the east perimeter. The horizontal collector trench is installed to the top of bedrock and includes an HDPE liner along the outer wall. The vacuum systems reduce the pressure induced migration of contaminants in groundwater and serve to remove VOC contaminant mass from both the source material and the impacted groundwater.

3.2 Screening Criteria

This section describes the methodology employed for initial screening of potential corrective measures. The screening criteria are based on the evaluation criteria given in .1636. Technologies that pass the initial screening are grouped into corrective measure alternatives and further evaluated in Sections 4 and 5.

The screening criteria are as follows:

- Effectiveness – The evaluation focuses on the potential effectiveness of technologies in meeting the corrective measure objectives and how proven and reliable the process is with respect to the contaminants and conditions at the site.

- Implementability – The evaluation encompasses both the technical and administrative feasibility of the technology. It includes an evaluation of the treatment requirements, waste management, and the relative ease or difficulty in achieving the operation and maintenance requirements. Technologies that are clearly unworkable at the site are eliminated.

- Relative Cost – both capital and operation and maintenance costs are considered. The preliminary cost analysis is based upon engineering judgment, and each evaluation is evaluated as to whether costs are high, moderate, or low relative to the other options.

The screening focuses more on the effectiveness criterion, with less emphasis on the implementability and relative cost criteria. Technologies surviving the screening process are those that are expected to achieve the correction measure objectives for the site, either alone or in combination with others.

3.3 Screening of Potential Corrective Measures

The remedial technologies that are evaluated as part of the screening process are summarized as follows:

- Institutional Controls

- Monitored Natural Attenuation

- Groundwater Barrier Wall
- Groundwater Extraction and Treatment
- In situ Treatment
- Capping
- Gas Recovery

The potential site application of each is presented below, followed by a screening level evaluation of each technology.

3.3.1 Institutional Controls

Site Application

Existing institutional controls at the site include fencing to restrict site access and locking entrance gates to access the buffer areas to the east, west, and north. Existing institutional controls are being strengthened by placement of "No Trespassing" signs. Deed restrictions may be placed on County owned land and groundwater use restrictions could be implemented to ensure human contact with groundwater is prevented. In addition, the County may evaluate purchasing the buffer area between the current landfill boundary and the City of Raleigh greenway to the north. Property acquisition would increase the buffer between the source and the compliance boundary and thereby increase the amount of time for monitored natural attenuation.

Conclusion

The County already practices this method. Fencing encompasses the entire landfill. This alternative aimed at reducing or eliminating the pathways for exposure, is considered effective and already implemented in some instances. Costs associated with this technology are low, but would increase with property acquisition. It should be retained for further evaluation, and included in each of the corrective measure alternatives.

3.3.2 Monitored Natural Attenuation (MNA)

Site Application

This technology would be used to address the low-level groundwater contamination. Natural destructive and non-destructive process would reduce contaminant levels, at a downgradient point-of-compliance, to levels acceptable to state regulators. At a minimum, continued semi-annual groundwater sampling for Appendix I and detected Appendix II constituents would be conducted to track contaminant levels in the wells. Additional, select wells would be sampled annually to monitor contaminant migration. These include wells MW-28, MW-28d, MW-33, MW-34, MW-34d, MW-35, installed as part of the Groundwater Quality Assessment, and the recently installed MW-36, and MW-36d. Additionally, because of the historic detections of VOCs in samples from MW-5, MW-6, MW-8, MW-9, MW-10, MW-24, and TB-1a, these wells would continue to be sampled semi-annually for the Appendix I list plus detected Appendix II parameters and some or all of the MNA indicator parameters including: Alkalinity, carbon dioxide, chloride, dissolved hydrogen, ferrous iron, nitrate, sulfate, sulfide, total organic carbon, BOD, COD, methane/ethane/ethene, low-level fatty acids, ORP, and dissolved oxygen.

Conclusion
MNA has been studied at the site since December 2000. Based on the MNA data obtained over the last several years and the generally low level detections of Appendix I and II constituents, MNA is considered effective in achieving the corrective measure goals and is readily implementable. Costs are limited to sampling and analysis, and therefore are minor. However, Solid Waste Section policy states that sites with fractured bedrock contamination and migration beyond the facility boundary may only MNA when paired with an active system as the remedial option.

This technology should be retained for further evaluation.

3.3.3 Groundwater Barrier Wall

Site Application
A groundwater barrier wall would be constructed downgradient of the northern landfill edge to prevent further migration of leachate-contaminated groundwater. The barrier wall would be approximately 1,000 feet in length and connect to the landfill gas cut-off trench on the eastern portion of the landfill perimeter. A generalized schematic of a conceptual groundwater barrier wall is provided on **Figures 3-1 and 3-2**. To be effective as a barrier to groundwater migration, a barrier wall would need to be tied into a confining unit. There are two types of barriers available; geomembrane barrier walls, which are only implementable to depths of approximately 20 feet, and slurry walls which are significantly more costly than other applicable technologies.

To maintain an inward hydraulic gradient and prevent mounding at the wall, extraction wells or other forms of leachate collection between the landfill and barrier wall would be necessary. Extracted groundwater would be pumped to the sewer at the Subtitle D landfill.

Conclusion
The hydrogeology of the site consists of a surficial aquifer in the partially weathered rock and a fractured bedrock aquifer. Although these two groundwater media act as a single unit, there is no confining unit to act as a barrier to vertical flow into the bedrock. Therefore, a barrier wall will only be effective in preventing horizontal groundwater movement above the fractured bedrock. In addition, the depth to groundwater is deep, in some cases greater than 40 feet, making excavation difficult and costly.

A planning level cost of construction of a moderate depth slurry wall is approximately $40 per square foot. Assuming a length of 1,000 feet, and an average depth of 30 feet, a slurry wall would cost nearly $1,200,000 to construct. In this instance, a barrier wall would not be a cost-effective remedial option relative to other considerable options. The implementability is low due to the extensive excavation requirements to construct. Because of these factors, a barrier wall is not retained for further consideration. However, as part of the landfill gas cut-off trench, an HDPE liner was placed in the trench along the western landfill perimeter. The liner essentially acts as a groundwater barrier to shallow groundwater migration.

3.3.4 Groundwater Extraction

Site Application

A well-point system would be placed along the landfill perimeter to collect the leading edge of leachate-contaminated groundwater, or in the area to the north eliminate further offsite migration. Collected groundwater would be pumped to the sanitary sewer near the Subtitle D landfill and receive treatment at the Neuse River Wastewater Treatment Plant. A generalized schematic of a conceptual groundwater extraction system for this site is shown in **Figures 3-1 and 3-2**.

Conclusion

Pump-and-treat has been used at about three-quarters of the Superfund sites where groundwater is contaminated. Pump-and-treat is most effective in sand and gravel aquifers where hydraulic control and capture is most easily achieved. The effectiveness of groundwater extraction at this site would be reduced due to the hydrogeology of the site, including the fractured bedrock, low soil permeability and slow rate of groundwater movement.

High costs are associated with well installation and construction of a conveyance system to direct collected groundwater to the sanitary sewer. Operation of the system would be required for an indefinite period of time.

Although the effectiveness of pump-and-treat at this site is questionable, it is retained for further consideration because it is the only active form of groundwater remediation considered in this evaluation.

3.3.5 In situ Groundwater Treatment

Site Application

A series of injection points would be installed along the northern property line from the area near MW-6/6d to just west of MW-9 to be used as air sparging wells or to facilitate introduction of either biological or chemical agents to the impacted groundwater in the saprolite/PWR and shallow fractured bedrock. A generalized well-point system is shown on **Figures 3-1 and 3-2**.

Conclusion

Capital costs for in situ groundwater treatment methods are comparable to pump-and-treat well installation; however, long-term costs are lower. Additional site characterization may be required to determine applicable treatment methods and rates.

In situ groundwater treatment technologies will be retained for further consideration.

3.3.6 Capping

Site Application
A low permeability cap would be installed to eliminate infiltration and reduce leachate generation.

Conclusion
These measures are already in place. A low permeability cap was installed as part of the landfill closure in 1997. Because the cap is already in place, it will not be considered as a separate corrective action alternative.

3.3.7 Gas Recovery

Site Application
Landfill gas extraction wells would be placed within the existing landfill to control gas buildup underneath the cap, and prevent possible pressure driven migration of leachate-contaminated groundwater.

Conclusion
The County already has an active landfill gas recovery system in place. The system is operated by DTE Biomass. In addition, the County has installed a perimeter landfill gas recovery system to capture gas migration beyond the limits of waste. The perimeter system consists of recovery wells along the western and northern perimeter of the landfill. The perimeter recovery wells are spaced at approximately 25 to 50 foot intervals and are under a constant vacuum. All of the perimeter gas recovery wells are installed to the top of bedrock, and in all cases intersect the groundwater surface.

A gas migration cut-off trench was installed along the eastern perimeter of the landfill to supplement the gas migration recovery system. The cut off trench was excavated to below the seasonal low groundwater surface and consists of a biopolymer constructed cut-off trench with a gravel filled vertical collection system under vacuum and a HDPE liner on the down-gradient side of the trench to eliminate offsite gas migration to the east.

The existing perimeter gas extraction system is considered to be an effective remediation option. Not only is gas pressure relieved, but because the extraction wells are under a vacuum, the extraction system also serves to remove VOCs from the waste material and the potentially contaminated groundwater. In addition, shallow groundwater contaminant migration offsite is impeded. Because an active system is already in place, gas recovery is retained for further evaluation in conjunction with other options.

3.4 Corrective Measure Alternatives

Based on the above screening, the following technologies or actions are retained for detailed evaluation in Section 4:

- Institutional Controls,
- Monitored Natural Attenuation,
- Groundwater Extraction and Treatment,
- In situ Groundwater Treatment,
- Gas Recovery.

To facilitate the evaluation of corrective measures and the selection of a comprehensive remedy, the technologies are grouped into the corrective measure alternatives listed below:

Alternative A
No Action

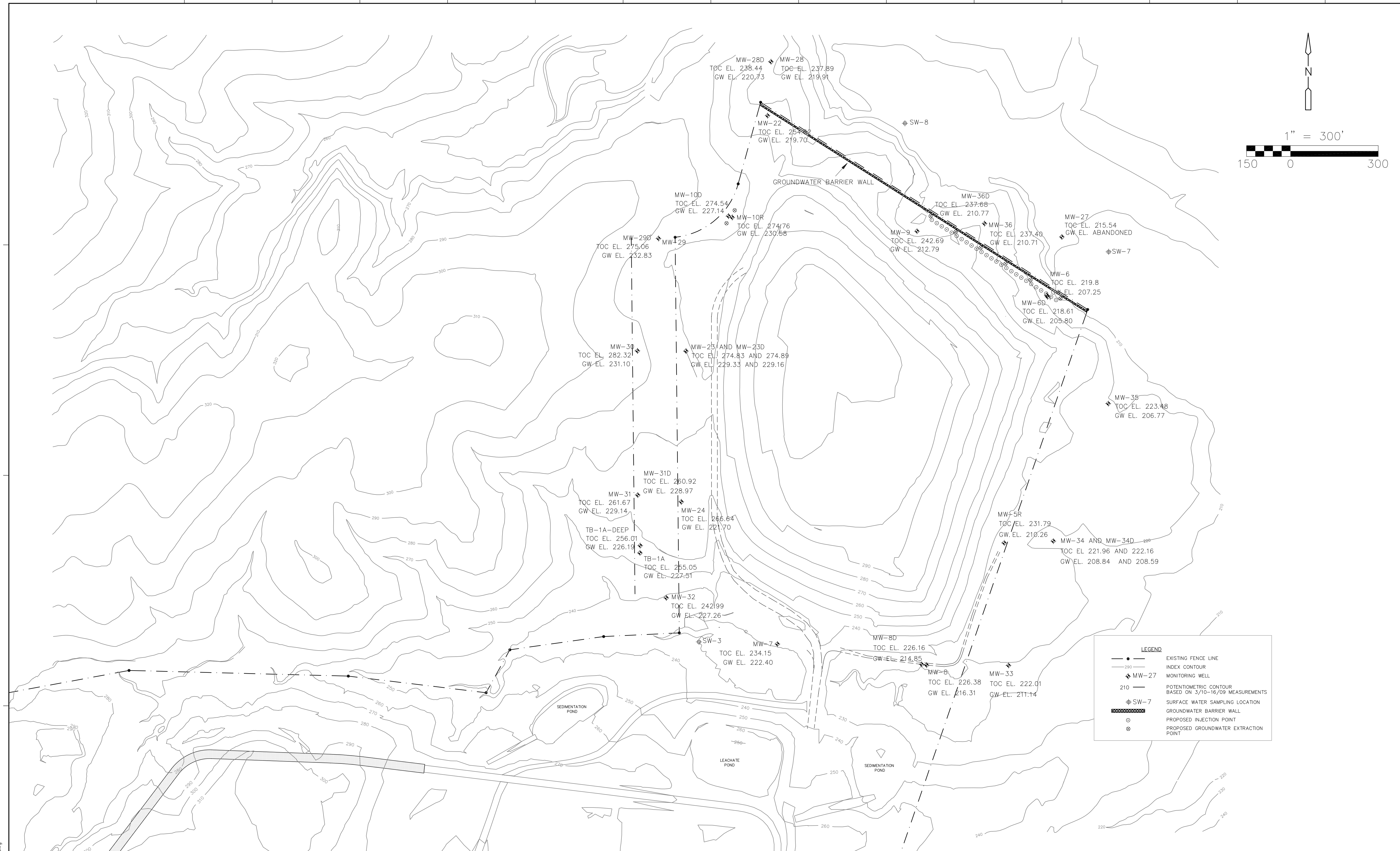
Alternative B
Institutional Controls, Monitored Natural Attenuation, Gas Recovery

Alternative C
Institutional Controls and Groundwater Extraction and Treatment

Alternative D
Institutional Controls and In situ Groundwater Treatment

The No Action alternative (Alternative A) is included as a basis for comparison, and is not intended as a valid corrective measure at this site, or any site undergoing such an assessment.

The alternatives listed above are subject to a detailed evaluation in Section 4.2 and a comparative evaluation in Section 5.1. The evaluation criteria are identified in Section 4.1.



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REV. NO.	DATE	DRWN	CHKD	REMARKS

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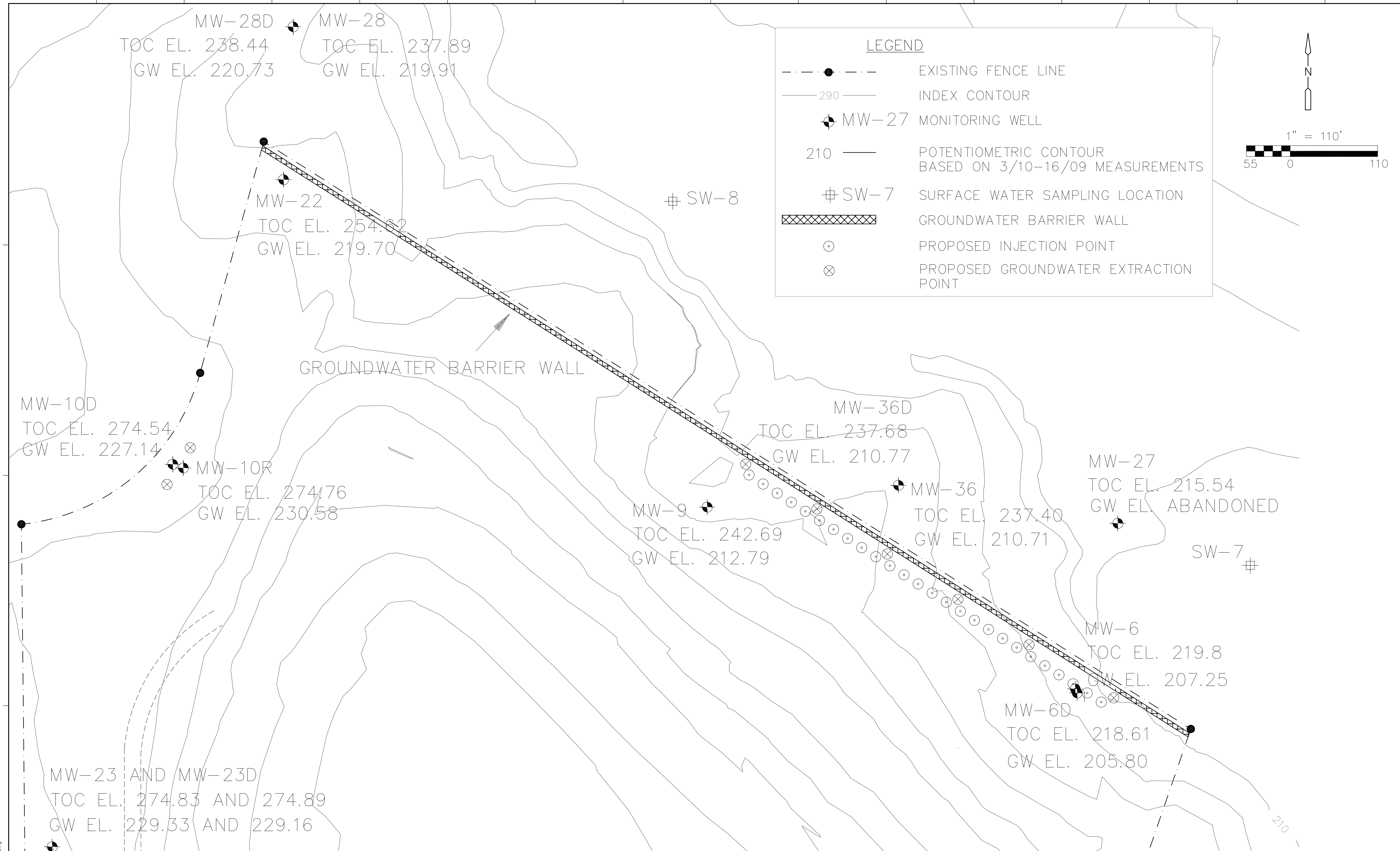
WAKE COUNTY
NORTH CAROLINA

NORTH WAKE UNLINED LANDFILL ASSESSMENT OF CORRECTIVE MEASURES

CONCEPTUAL PLAN

PROJECT NO. 6172-71371
FILE NAME: NW-ACM3-1.dwg
FIGURE
3-1



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REV. NO.	DATE	DRWN	CHKD	REMARKS

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WAKE COUNTY
NORTH CAROLINA
NORTH WAKE UNLINED LANDFILL
ASSESSMENT OF CORRECTIVE MEASURES

CONCEPTUAL PLAN

PROJECT NO. 6172-71371
FILE NAME: NW-ACM3-2.dwg
FIGURE
3-2

Section 4
Detailed Evaluation of Corrective Measure Alternatives

Pursuant of the NCDENR Solid Waste rule .1636, the corrective measure alternatives identified in Section 3 are evaluated by considering their ability to meet a number of criteria and the objectives identified in Section 2. The evaluation criteria are provided in Section 4.1, followed by the detailed evaluation of the alternatives in Section 4.2.

4.1 Evaluation Criteria

As identified under .1636 (c), potential remedies should be evaluated based on their ability to meet the corrective measure objectives (identified in Section 2), addressing at least the following:

- *Performance* - Long-term and short-term effectiveness and protectiveness of the potential remedy(s), along with the degree of certainty that the remedy will prove successful;

- *Reliability* - The effectiveness of the remedy in controlling the source to reduce further releases;

- *Implementation* - Ease or difficulty of implementing a potential remedy;

- *Time/Costs* - Practical capability of the owner or operator, including a consideration of the technical and economic capability;

- *Safety, Cross-Media Impacts, Control of Exposure to Residual Contamination, and Community Factors* - The degree to which community concerns are addressed.

A preliminary evaluation of implementability, effectiveness (performance), and cost was presented in Section 3; however, these criteria will be further discussed in this section with regard to each alternative. The following discussion presents an evaluation of each alternative, based on the above criteria. A summary of each alternative's ability to meet the corrective measure objectives is provided at the end of each section.

4.2 Alternative A

Alternative A is the "No Action" alternative. No action would be taken to address the NC2L exceedances in groundwater.

Performance

The performance of this alternative is considered low, since no remediation or additional monitoring is specified.

Reliability
The reliability of this alternative is considered high since there are no components that would potentially fail.

Ease of Implementation
This alternative is considered easy to implement since no action is specified.

Time
No time would be required for implementation of this alternative. An indefinite amount of time would be required for groundwater to meet protection standards.

Costs
No costs are associated with this alternative.

Safety, Cross-Media Impacts, Control of Exposure to Residual Contamination, and Community Factors
No safety, cross media impacts or exposure control concerns are expected for this alternative since no remedial action is specified.

Ability to Meet the Corrective Measure Objectives
The no action alternative would be protective of human health and the environment in the near term, due to the depth of the groundwater. Potentially, leachate contaminated groundwater could discharge to the small streams to the north and south, however, historical data has shown no indication of impact to surface water. Attenuation mechanisms would likely result in discharge of groundwater below protection standards, given the low-level groundwater exceedances observed to date.

This alternative would not attain the groundwater protection standard as specified in .1636(b)(2), nor would it control the source release or prevent further releases of Appendix I or II constituents. This alternative would comply with relevant standards for management of waste since no waste would be generated.

4.3 Alternative B

Alternative B is already in place and includes the use of institutional controls, monitored natural attenuation, gas recovery, and capping. Institutional controls would consist of periodic (as-needed) fence maintenance, addition of warning signs to restrict site access along the Mallinckrodt property, and possible property acquisition. Groundwater would continue to be monitored for its ability to naturally attenuate below groundwater protection levels (NC2L) and the cap and landfill and perimeter gas recovery systems would continue to be utilized.

Performance
The performance of this alternative is considered high since existing data has shown that contaminant levels are effectively attenuating, the groundwater geochemical environment is favorable for natural attenuation, and the perimeter gas recovery system is already operational. Performance of this alternative will be regularly

monitored through the required semi-annual and current MNA sampling of the wells currently in place. The performance of this alternative has already been verified by the sampling for a variety of natural attenuation indicators since December 2000 and the decrease in detected Appendix I constituents since the perimeter gas recovery system installation. Property acquisition would increase the time for MNA between the source and the compliance boundary.

Reliability
The reliability of this alternative is considered high since there are no active components that would potentially fail; with the exception of the gas recovery system. The life span of the gas recovery system is not infinite, as gas production will decrease over time and the recovery system will no longer be needed. However, controls are already in place regarding operation and maintenance procedures for both the landfill and the perimeter gas recovery systems.

Ease of Implementation
This alternative is considered easy to implement, and has essentially been in place since December 2000.

Safety, Cross-Media Impacts, Control of Exposure to Residual Contamination, and Community Factors
No safety, cross media impacts or exposure control concerns are expected for this alternative since no intrusive work is specified.

Time
Because this alternative is already in place, no time would be required for implementation of this alternative. Semi-annual sampling, throughout the post-closure period would be required to monitor the ability of contaminants to naturally attenuate, and regular maintenance of the gas recovery system may be required.

Costs
Costs associated with this alternative include as-needed fence and sign maintenance, additional semi-annual sampling and analysis for MNA parameters for the facility back ground well MW-11 and MW-5, -6, -8, -9, -10, and TB-1a, any required maintenance to the gas recovery system, and property acquisition costs. Table 4-1, located at the end of this section, includes a summary of all costs for this alternative. Costs are broken into capital and operations and maintenance (O&M), and considered over a 30-year post-closure period. O&M costs provided in **Table 4-1** assume continued sampling and analysis of MNA parameters for the above wells and does not included required sampling for Appendix I or detected Appendix II constituents as part of the post-closure requirements.

No operation costs are involved with this alternative. The active perimeter gas recovery system is tied into the blower flare for the Subtitle D landfill.

Ability to Meet the Corrective Measure Objectives
This alternative would be protective of human health and the environment due to the depth of groundwater and the fact that all existing monitoring wells will be monitored at least annually. This alternative would not immediately attain the groundwater protection standard as specified in .1636(b)(2). However, based on current data, conditions are present which favor natural attenuation and eventually will result in attainment of the groundwater protection standards across the site.

This alternative would not control the source release, preventing migration of leachate beyond the landfill perimeter; however, with the exception of the MW-36/36d area, existing data indicate that any offsite VOC migration is below the 2L standards.

This alternative would comply with relevant standards for management of waste since no waste would be generated.

4.3 Alternative C

Alternative C includes the use of institutional controls and groundwater extraction. Institutional controls would consist of periodic (as-needed) fence maintenance, addition of warning signs to restrict site access along the Mallinckrodt property and possible property acquisition. Groundwater would be extracted from the surficial and fractured bedrock aquifer through well-points located in the vicinity of MW-6, -9, and -10. These locations were chosen due to their historical Appendix I detections exceeding the NC2L standard. It is expected that a minimum of eight wells would be necessary to provide effective hydraulic control and capture of the leading edges of the plume. Further analysis would be required to evaluate system design and layout.

Collected groundwater would be conveyed to the sanitary sewer line at the Subtitle D landfill, and treated at the Neuse River WWTP.

Performance
The performance of this alternative is expected to be moderate, due to the hydrogeology of the site and the low-levels of contamination present.

Reliability
The reliability of this alternative is considered moderate since there are active components that could potentially fail. Pumps could break or fail and well screens may become blocked or fouled.

Ease of Implementation
This alternative is considered relatively easy to implement however, engineering requirements and construction of the groundwater recovery wells and associated piping would lower implementability.

Safety, Cross-Media Impacts, Control of Exposure to Residual Contamination, and Community Factors

No safety, cross media impacts or exposure control concerns are expected for this alternative, assuming the system is properly operated and maintained.

Time

Approximately six months would be required for implementation of this alternative. Normal required sampling of the existing monitoring wells would be required to monitor the effectiveness of the extraction system.

Costs

Capital costs associated with this alternative are for construction of the groundwater extraction system. O&M costs associated with this alternative include as-needed sign replacement and quarterly analysis of groundwater water discharging to the sewer. A permit for discharge to the sewer would likely be required for this alternative. **Table 4-1** includes a summary of all costs for this alternative. Costs are broken into capital and O&M, and considered over a 30-year period.

Ability to Meet the Corrective Measure Objectives

This alternative would be protective of human health and the environment since contaminated groundwater would be removed from the surficial and shallow fractured bedrock aquifer and no exposure points are expected. Over time, this alternative would likely attain the groundwater protection standard as required in .1636(b)(2). Considerations regarding pump noise and housing would need to be made so as not to disrupt the surrounding community, which has already voiced concern regarding aesthetics.

This alternative would control, but not eliminate, the source release preventing migration of leachate beyond the landfill perimeter. This alternative would comply with relevant standards for management of waste.

4.4 Alternative D

Alternative D includes the use of institutional controls and in-situ groundwater treatment. As in Alternative C, institutional controls would consist of periodic (as-needed) fence maintenance and addition of warning signs to restrict site access and possible property acquisition. Groundwater would be treated with in-situ methods, either mechanical (air sparging), biological (Emulsified Oil Substrate), or chemical (Fenton's Reagent or Oxygen Releasing Compound), injected through a series of well-points in the surficial and shallow fractured bedrock aquifer in the vicinity of MW-6 and –9. This area was chosen due to the recent detection of Appendix I VOC above the NC2L standard in offsite wells MW-36 and MW-36d. Further analysis would be required to evaluate system design and layout and potential effectiveness.

Performance
The performance of this alternative is expected to be moderate to high, due to the hydrogeology of the site and the low-levels of contamination present.

Reliability
The reliability of this alternative is considered moderate to high. However, extensive characterization may be required prior to implementation and because of the uncertainty of injection into bedrock zones, bedrock may need to be contained by installing extraction wells as described in Section 3.3.4.

Ease of Implementation
This alternative is considered moderate to implement due to site characterization, data analysis and modeling requirements.

Safety, Cross-Media Impacts, Control of Exposure to Residual Contamination, and Community Factors
No safety, cross media impacts or exposure control concerns are expected for this alternative.

Time
Approximately six months would be required for implementation of this alternative; however, if biological or chemical treatment is used, multiple treatments may be required. Normal required sampling of the existing monitoring wells and new effectiveness wells would be required to monitor the effectiveness of the treatments.

Costs
Capital costs associated with this alternative are moderate to high depending on methods and include design and installation of the injection well points, possible additional characterization and modeling, and any applicable permit fees. O&M costs associated with this alternative include as-needed fence repair, sign replacement, additional chemical injections or sparging system repair. **Table 4-1** includes a summary of all costs for this alternative. Costs are broken into capital and O&M, and considered over a 30-year period. These costs assume that the in-situ method chosen will effectively treat or contain the groundwater plume in shallow fractured bedrock.

Ability to Meet the Corrective Measure Objectives
This alternative would be protective of human health and the environment since contaminated groundwater would be treated in-situ and no exposure points are expected. Over time, this alternative would likely attain the groundwater protection standard as required in .1636(b)(2).

This alternative would control, but not eliminate, the source release preventing migration of leachate beyond the landfill perimeter and therefore may require long-term use. This alternative would comply with relevant standards for management of waste.

Table 4-1
Estimated Corrective Measures Costs

Capital Costs - Alternative B
Insitutional Controls, Monitored Natural Attenuation, Gas Recovery

Item	unit cost	quantity	cost
None - System Already Operational	$0	lump sum	$0
Property Acquisition	$60,000	5 acres	$300,000
Total Direct Capital Costs (+50%, -30%)			**$300,000**

Operations and Maintanence Costs - Alternative B

Item	unit cost	quantity	cost
Lab Analysis for MNA Constituents[1]	$800	14 samples[2]	$11,200
Annual Sampling Report	$2,000	lump sum	$2,000
Periodic Monitoring and Adjustment of Gas Recovery System	$2,500	quarterly	$10,000
Signs	$50	5 per year	$250
Annual Total (+50%, -30%)			**$23,500**
Present Worth (year 2009 Dollars)[3]			**$291,612**

[1] Semi-annual analysis to include: chloride, nitrate, sulfate, sulfide, TOC, CO2, ferrous iron, methane

[2] Based on 7 wells per event (MW-5, -6, -8, -9, -10, -11, TB-1a), 2 events per year

[3] 30 years at 7.00%

Capital Costs - Alternative C
Insitutional Controls and Groundwater Extraction

Item	unit cost	quantity	cost
Property Acquisition	$60,000	5 acres	$300,000
Install 6, 4-inch, HDPE extraction wells to 60 ft with Submersible Pumps	$100,000	lump sum	$100,000
HDPE Conveyance Pipe	$35	5,000 feet	$175,000
Miscellaneous Valves and Fittings	$6,000	lump sum	$6,000
Power Supply	$10,000	lump sum	$10,000
Subtotal			*$591,000*
Engineering Costs (15%)		lump sum	$43,650
Total Direct Capital Costs (+50%, -30%)			**$634,700**

Operations and Maintanence Costs - Alternative C

Item	unit cost	quantity	cost
Quarterly sampling of effluent	$75	2 hours/event	$600
Lab analysis for Appendix II Constituents[1]	$500	4 samples[2]	$2,000
Annual Sampling Report[3]	$2,000	lump sum	$2,000
Monthly GW Extraction System O&M	$95	8 hours/event	$9,120
Pump/Piping Replacement	$10,000	lump sum	$20,000
Replacement of Access Restricting Signs	$50	5 per year	$250
Annual Electrical Costs	$15,000	lump sum	$15,000
Annual Total (+50%, -30%)			**$49,000**
Present Worth (year 2009 Dollars)[3]			**$608,041**

[1] Analysis to include: Appendix I VOCs

[2] Based on 1 sample per event, 4 event per year

[3] 30 years at 7.00%

Table 4-1
Estimated Corrective Measures Costs

Capital Costs - Alternative D
Insitutional Controls/ In-Situ Groundwater Treatment
(Air Sparging)

Item	unit cost	quantity	cost
Property Acquisition	$60,000	5 acres	$300,000
Install Air Sparging Injection Wells (assume 25 ft ROI)	$2,000	27 wells	$54,000
Piping	$35	700 feet	$24,500
140 cfm compressor and housing	$30,000	lump sum	$30,000
Power supply	$10,000	lump sum	$10,000
Subtotal			*$418,500*
Engineering Costs (15%)		lump sum	$17,775
Total Direct Capital Costs (2008 Estimate)			**$436,300**

Operations and Maintanence Costs - Alternative D

Item	unit cost	quantity	cost
Monthly Air Sparging System O&M	$95	8 hours/event	$9,120
Electrical costs	$15,000	lump sum	$15,000
Air sparging system parts	$10,000	lump sum	$10,000
Replacement of Access Restricting Signs	$50	5 per year	$250
Annual Total (2008 Estimate)			**$34,400**
Present Worth (year 2009 Dollars)[3]			**$426,870**

[3] 30 years at 7.00%

The calculation of present worth costs for alternatives comparison does not account for inflation.

Section 5
Comparative Evaluation of Corrective Measure Alternatives

This section presents a comparative evaluation of the three corrective measure alternatives identified in Section 3. Each alternative is assessed, using the criteria introduced in Section 4.1, with respect to the other two alternatives. Their ability to meet the corrective measure objectives is also compared.

5.1 Comparative Evaluation of Alternatives

Performance

With respect to performance, Alternatives B and C are considered equally effective. Existing data has shown that contaminant levels are, in most cases, effectively attenuated below NC2Ls within 150 feet of the landfill boundary. Although some performance uncertainties exist with respect to the effectiveness of groundwater extraction system, it is still considered equally effective to natural attenuation. Both are expected to perform better than Alternative A, from an effectiveness standpoint. Alternative D is the most effective remedy; however there are inherent uncertainties to in-situ treatment effectiveness in the fractured bedrock.

Reliability

The reliability of Alternatives A and B is considered greater than Alternatives C and D. Alternatives C and D are considered to be most subject to failures and operational problems.

Ease of Implementation

Implementability is highest for Alternative A and lowest for Alternative C. Alternative B would fall in between the two, with regards to this criterion, however Alternative B is already in place. Alternative D would be similar to Alternative C, but would not require as much piping and there is no effluent to handle.

Safety, Cross-Media Impacts and Control of Exposure to Residual Contamination

Alternative A ranks the highest of the three with regards to this criterion, since no residual contamination would be generated and no systems would be installed. Alternative C would offer the greatest opportunity for exposure to residual contamination since leachate-contaminated groundwater would be extracted and piped to the sewer. Alternatives C and D may pose aesthetic and noise issues for the adjoining community.

Time

Implementation of Alternatives A and B require the least time, followed by Alternatives D and C. The time for groundwater in the contaminated areas to meet NC2L standards is expected to be the shortest for Alternative D, followed by Alternatives C, B, and A.

Costs

The cost of implementing and operating Alternatives C and D are both similar, and both are greater than Alternatives A and B. Alternative B is inherently more costly than Alternative A, the "No Action" alternative.

Ability to Meet the Corrective Measure Objectives

Each of the alternatives would be roughly equal with respect to protection of human health and the environment in the near term, due to the depth to groundwater and the lack of exposure points. Alternatives B, C and D are more protective of human health and the environment in the long term due to the required groundwater monitoring associated with each. Monitoring could help identify if the likelihood of exposure has increased (e.g. detected contaminants in surface water).

Each of the alternatives is likely to attain groundwater protection standards, however the extent and volume of groundwater above NC2Ls is expected to differ somewhat. Alternative D would likely provide the quickest and greatest reduction in the volume and extent of groundwater exceeding NC2Ls, followed by Alternatives C, B and A, however, because existing contaminant levels are already low, pump and treat effectiveness will be lowered.

Better control of the source release would be provided by Alternatives C and D, compared to Alternative A and B, since Alternative C includes collection of contaminated groundwater.

All alternatives would comply with relevant standards for management of waste since no waste would be generated.

5.2 Summary of Comparative Evaluation

Table 5-1 summarizes the comparative evaluation of alternatives. Alternatives are ranked with respect to each other and are assigned a "1", "2" or "3". A "1" designates that the alternative ranked the highest (e.g. best meets the particular criterion). When two or more alternatives ranked the same, a "t" was given to indicate that the alternatives are approximately equal for the particular criterion.

A quantitative ranking of the alternatives based on the qualitative information presented above suggests that Alternative B most meets the evaluation criteria. Alternative B had the lowest (best) total ranking (16) followed by Alternative D (20) and Alternatives A and C (21).

Table 5-1

Comparative Evaluation of Corrective Measure Alternatives

Criteria	***A*** No Action	***B*** Institutional Controls, Natural Attenuation, Capping, Gas Recovery, and Property Acquisition	***C*** Institutional Controls and Groundwater Extraction	***D*** Institutional Controls and In-Situ Groundwater Treatment (Air Sparging)
Performance	3	2(t)	2(t)	1
Reliability	1(t)	1(t)	3(t)	3(t)
Ease of Implementation	1	2	3(t)	3(t)
Safety, Cross Media Impacts, Control of Exposure to Residual Contamination, and Community Factors	1(t)	1(t)	3(t)	3(t)
Time …to Implement …to Meet Objectives	1(t) 3	1(t) 2(t)	3(t) 2(t)	3(t) 1(t)
Costs	1(t)	1(t)	3(t)	3(t)
Ability to Meet the Objective of Protecting Human Health and the Environment	3	1(t)	1(t)	1(t)
Ability to Meet the Objective of Attaining Groundwater Protection Standards	3	2	1(t)	1(t)
Ability to Meet the Objective of Source Control	3	3	1(t)	1(t)
Ability to Meet the Objective of Complying with Standards for the Management of Waste	1(t)	1(t)	1(t)	1(t)
Total	**21**	**16**	**21**	**20**

Section 6
Recommended Alternative

6.1 Recommended Alternative

Based on the results of the detailed and comparative analysis and current Solid Waste Section rules, a combination of Alternative B and D is the recommended corrective measure for addressing groundwater contamination at the North Wake Unlined landfill. Alternative B is somewhat already in place and operational and includes the following components:

Institutional Controls – Wake County has already implemented a variety of controls designed to prevent exposure to contaminants. Site access is controlled using chain-link fencing around the landfill boundary to block entrance. As a component of the corrective measure, "No Trespassing" signs would be placed along the fence line and replaced on an as needed basis.

Future institutional controls could include property acquisition. In addition, deed restrictions on County owned property and groundwater use restrictions may also be instituted, although these measures are not recommended at this time.

Monitored Natural Attenuation - Groundwater at the site would be monitored for its ability to naturally attenuate. Current MNA parameter monitoring frequency and analysis will be continued at MW-5, -6, -8, -9, -10, -11, and TB-1a, in addition to the required annual and semi-annual monitoring of the monitoring wells for Appendix I and detected Appendix II constituents.

Landfill Gas Recovery – The low permeability cap and landfill gas recovery system were installed as part of the landfill closure in 1996 and are regularly maintained. The perimeter landfill gas recovery system surrounding the western, northern, and eastern portions of the landfill is regularly monitored and maintained. Because the active perimeter gas recovery system intersects the groundwater table, it contributes to the removal of VOCs from the potentially contaminated groundwater and the cut-off trench to the east provides a shallow groundwater barrier.

6.2 Conclusion

With the exception of the proposed in-situ remediation system, all of the above controls are already in place. The contaminated groundwater is not currently or expected to be a source of drinking water and is not hydraulically connected with waters which the hazardous constituents are migrating or are likely to migrate in concentrations that would exceed surface water contamination levels. The MNA parameters collected to date indicate that factors are present which favor natural attenuation and natural attenuation is occurring across the site, as shown in the Figures in Appendix B. An air sparging program will be used to remediate localized shallow fractured bedrock aquifer contamination and minimize offsite migration of concentrations exceeding the NC2L standards.

6.3 Schedule for Remedy Implementation

Part of the remedy is already in place and operational. The results of the corrective measure assessment will be presented in a public meeting with interested and affected parties, following NCDENR review of this report. Following the public meeting, the selected remedy will be formally submitted to the NCDENR in a brief letter, along with the North Carolina Solid Waste Groundwater Corrective Action Permit Modification Application and related documents. Assuming timely NCDENR review and approval, the MNA with Institutional Controls remedy could be implemented immediately, as it has essentially been in use since 2000. Construction of the air sparging system will begin immediately following approval of the Corrective Action Plan. The next semi-annual sampling of the wells is scheduled for Fall 2009, at which time, the additional MNA parameters will be collected from MW-5, -6, -8, -9, -10, -11, and TB-1a.

6.4 References

Camp Dresser and McKee, January 2000. North Wake Unlined Landfill. Groundwater Assessment Report.

Camp Dresser and McKee, April 2009. North Wake Unlined Landfill. Semi-Annual Monitoring Sampling Report (March 2009 Sampling Event).