Geotechnical Engineering Report

Sub-District H Water Main Extension Project – Phase 3

Wesley Chapel Road and Schababerle Hill Road
California, Campbell County, Kentucky
Project No. N1095342
May 21, 2010 (Revised)
January 12, 2010 (Original)

Prepared for:

Northern Kentucky Water District
Erlanger, Kentucky

Prepared by:

HCN
A Terracon COMPANY
Cincinnati, Ohio

May 21, 2010 (revised)
January 12, 2010 (original)

Northern Kentucky Water District
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Attn: Mr. John Scheben
TEL: 859-426-2717
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Re: **Geotechnical Engineering Report**
Proposed Sub-District H Water Main Extension Project – Phase 3
Wesley Chapel Road and Schababerle Hill Road
California, Campbell County, Kentucky
HCN/Terracon Project Number: N1095342

Dear Mr. Scheben:

H.C. Nutting, a Terracon Company (HCN/Terracon) has completed the geotechnical engineering services for the above referenced project. This study was performed in general accordance with our proposal number PN1090210, dated March 10, 2009. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork during the installation of water main along with slope stability considerations. This report has been prepared as requested by NKWD and Viox & Viox to more specifically address the geotechnical aspects along the waterline alignment for incorporation onto the project plans.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,
H.C. Nutting, a Terracon Company

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Senior Staff Engineer

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Senior Principal – Office Manager

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EXECUTIVE SUMMARY

This summary should be used in conjunction with the entire report for design purposes. It should be recognized that details were not included or fully developed in this section, and the report must be read in its entirety for a comprehensive understanding of the items contained herein. The section titled **GENERAL COMMENTS** should be read for an understanding of the report limitations.

A geotechnical study was performed for the phase 3 portion of the proposed sub-district H water main extension project in Campbell County, Kentucky. The project involves installation of an 8-inch water main along Wesley Chapel Road and Schababerle Hill Road in California, Kentucky. Based on a review of provided plan and profile drawings the proposed water main invert elevations are generally about 3 to 6 feet below existing site grades.

A total of fourteen (14) test borings, including three (3) borings along Schababerle Hill and eleven (11) borings along Wesley Chapel Road were performed as part of the exploration program. The typical subsurface profile at the test borings consisted of natural cohesive soils underlain by shale and limestone bedrock.

Based on the results of the test borings and the anticipated water main subgrade elevations, we anticipate that trench excavations in the area of the test boring locations will typically consist of medium stiff to hard natural cohesive residual soils and weathered shale bedrock with limestone. We anticipate excavations could likely be completed using conventional trench box support or conventional trench box support incorporated with laid-back slopes (open-cut and cover). All temporary cut slopes required for water main installation should be made in accordance with OSHA Safety Regulations.

In general, the placement of the water main, hydrants, and valves within the soil profile will not add significant load on the underlying bearing material. However, it is important to have uniform and proper support, and to maintain proper line and grade of the pipe to prevent the pipe from becoming over-stressed in hoop compression or bending. Any soft to medium stiff soils encountered at pipe subgrade elevation may need undercutting to expose suitable stiff to very stiff bearing materials. Based on review of the project plans, the use of pipe restraints and thrust blocks along portions of the alignment is proposed.

It is our understanding that open-cut techniques are preferred; however, directional drilling construction techniques may be implemented for installation of water main across the creek between Sta. 0+50 and Sta. 1+00 along Wesley Chapel Road. Based on test boring WR-1 drilled in the vicinity of creek, we anticipate that the encountered materials will generally consist of completely weathered shale bedrock with limestone.

Close monitoring of the construction operations discussed herein will be critical in achieving the design subgrade support. We recommend that HCN/Terracon be retained to perform construction testing and inspection for this project.

GEOTECHNICAL ENGINEERING REPORT
SUB-DISTRICT H WATER MAIN EXTENSION PROJECT
WESLEY CHAPEL ROAD AND SCHABABERLE HILL ROAD
CALIFORNIA, CAMPBELL COUNTY, KENTUCKY
HCN/TERRACON PROJECT NO. N1095342
MAY 21, 2010 (REVISED)
JANUARY 12, 2010 (ORIGINAL)

1.0 INTRODUCTION

A geotechnical engineering report has been completed for the Phase 3 portion of the proposed Sub-District H Water Main Extension project in Campbell County, Kentucky (Figure 1). A total of fourteen borings, including eleven borings along Wesley Chapel Road (designated as WR-1 to WR-11) and three borings along Schababerle Hill (designated as SR-1 to SR-3) were drilled to depths of 9 to 15.3 feet below existing grades. Logs of the borings along with a site vicinity map, a boring location plan, and subsurface profile are included in Appendix A of this report.

The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- subsurface soil conditions
- groundwater conditions
- earthwork recommendations
- slope stability considerations
- pipe subgrade recommendations

2.0 PROJECT INFORMATION

The Northern Kentucky Water District (NKWD) is planning to extend the public water system into various unserved areas of Campbell County. The project is divided into four different phases (Phase 1 to Phase 4) and will involve installation of approximately 66,985 lineal feet of new 6, 8, and 12-inch water mains. This project involves an 8-inch water main installation along Wesley Chapel Road and Schababerle Hill located in California, Campbell County, Kentucky (see Figure 1). The project length along Wesley Chapel Road and Schababerle Hill will be 15,000 and 3,510 feet, respectively. Based on a review of provided plan and profile sheets, the proposed 8-inch water main invert is generally 3 to 6 feet below existing grade. The water main alignment is generally along the edge of the pavement within its right-of-way and crosses two existing creeks/ditches along Wesley Chapel Road (between Sta. 0+50 and Sta. 1+00) and Schababerle Hill Road (between Sta. 20+50 and Sta. 21+00). It is anticipated that horizontal directional drilling techniques will be used for water main installation across the creek.

The existing grades along Wesley Chapel Road generally increase from north to south (Sta. 0+00 to Sta. 150+00) and vary approximately between El. 620 feet and El. 900 feet. Schababerle Hill

Road has a rolling terrain with the existing grades varying approximately between El. 870 and El. 690 feet.

3.0 SUBSURFACE CONDITIONS

3.1 Typical Profile

The test boring locations are illustrated on Figure 2A through 2H in Appendix. Underlying the surficial asphalt pavement or topsoil the subsurface conditions at the site consisted of natural cohesive soils of residual origin and shale bedrock. Existing fill soils were encountered immediately below the pavement at two test borings (SR-3 and WR-5). The asphalt pavement thickness varied between 6 and 11 inches and topsoil thickness varied between 4 and 6 inches. Asphalt pavement was underlain by 6 inches of granular base at one test boring location (WR-4).

Description	Approximate Depth to Bottom of Stratum (feet)	Material Encountered	Consistency/Density
Existing Fill[1]	2.5	Fat Clay, Lean Clay	Stiff
Natural Cohesive Soils	2.5 to 9	Silty Clay, Lean Clay, Fat Clay	Soft to Hard
Bedrock[2]	Bottom of Boring	Weathered Brown and Unweathered Gray Shale with Limestone	Soft (rock hardness)

1. Existing fill extended to a depth of 2.5 feet below existing grades. It appears that the existing fill was placed with some compactive effort. However, we have not reviewed any records showing its placement as structural fill.
2. Based on the elevations at which bedrock was encountered, published geological literature suggests that the majority of the bedrock within Phase 3 belongs to members of Fairview and McMillan formation under Maysville group with occasional members of Latonia formation under Kope group. Bedrock belonging to Maysville group generally contains more limestone than shale and that belonging to Kope group is generally rich in shale.

Conditions encountered at each boring location are indicated on the individual boring logs. Stratification boundaries on the boring logs represent the approximate location of changes in soil types; in-situ, the transition between materials may be gradual. Details for each of the borings can be found on the boring logs in Appendix A of this report.

3.2 Groundwater

Groundwater conditions were noted during and after drilling operations at each of the test boring locations. No groundwater or "dry" conditions were reported during and after drilling operations at each of the test boring locations except WR-6. A "dry" condition is reported when no water is

observed in the borehole or on the sampling tools. At test boring WR-6, water was encountered during drilling at a depth of 5 feet below existing grades. Boreholes were backfilled immediately upon completion and patched at the roadway surface for safety reasons. Therefore, long-term groundwater conditions at the site were not obtained.

We estimate that the long-term groundwater level at the site is at/near the overburden/bedrock interface or deeper within the profile. Perched water may be encountered at shallower depths within the existing fill or at the fill/natural soil interface.

Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings were performed. Therefore, groundwater levels during construction or at other times in the life of the structure may be higher or lower than the levels indicated on the boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

4.1 Geotechnical Considerations

Based on the provided water main alignment plans prepared by Viox & Viox (October 28 and November 13, 2009), the proposed water main inverts are generally about 3 to 6 feet below existing site grades. The proposed water main alignment has two creek crossings within phase 3 - between Sta. 0+50 and Sta. 1+00 along Wesley Chapel Road and Sta. 20+50 and Sta. 21+00 along Schababerle Road. It is our understanding that open-cut methods are preferred; however, directional drilling construction techniques may be implemented for installation of water main near the creek crossing.

Based on the results of the test borings and the anticipated water main subgrade elevations, we anticipate that trench excavations in the area of the test boring locations will typically consist of medium stiff to hard natural cohesive residual soils and weathered shale bedrock and limestone. Based on the project plans, the use of pipe restraints and thrust blocks along portions of the alignment is proposed. The use of thrust blocks/restraints are typically shown where horizontal and/or vertical grade changes cannot be accommodated by the inherent flex of the waterline. Recommendations for the use of thrust blocks/restraints or lowering the waterline into bedrock where stability is a concern has been provided for evaluation by the waterline designer and NKWD. Additional details regarding general water main construction are provided in the following sections, followed by a station-by-station overview of our recommendations.

4.2 Construction Assessment

We anticipate excavations could likely be completed using conventional trench box support or conventional trench box support incorporated with laid-back slopes (open-cut and cover). Open-cut and cover techniques (with/without trench box support) can be considered, provided that precautions are taken to protect any existing utilities, structures, roadways, or creeks within the construction area. The following table shows the proposed invert elevations and anticipated bearing materials at the soil test boring locations.

Test Boring	Approx. Location	Water Main Alignment	Approx. Invert Elevation (feet)	Approx. Depth Below Existing Grade (feet)*	Anticipated Bearing Soil Type**
WR-1	Sta. 1+50	Right	629	5	Very Stiff Lean Clay/ Soft Weathered Shale
WR-2	Sta. 15+00	Right	768	3	Soft Weathered Shale
WR-3	Sta. 31+00	Right	838	4	Very Stiff Fat Clay
WR-4	Sta. 45+00	Left	832	3	Stiff Fat Clay
WR-5	Sta. 60+50	Left	870	4	Medium Stiff Lean Clay
WR-6+	Sta. 75+00	Left	815	4	Soft to Medium Stiff Fat Clay
WR-7+	Sta. 90+00	Left	859	4	Stiff Lean Clay
WR-8	Sta. 106+00	Left	840	4	Very stiff Fat Clay
WR-9	Sta. 120+00	Right	887	3	Very Stiff Fat Clay
WR-10	Sta. 135+00	Right	874	4	Stiff Silty Clay/Lean Clay
WR-11	Sta. 150+00	Right	897	3	Stiff Lean Clay
SR-1	Sta. 2+00	Left	852	6	Very Stiff Fat Clay
SR-2	Sta. 17+00	Left	705	4	Very Stiff Fat Clay
SR-3+	Sta. 31+50	Right	795	6	Soft Weathered Shale

*Based on existing grade along proposed alignment.
**Some variation in soil type and consistency should be expected.
+The boring was relocated to the opposite side of the road/water main alignment due to drill rig setup issues.

In general, the placement of the water main, hydrants, and valves within the soil profile will not add significant load on the underlying bearing material. However, it is important to have uniform and proper support, and to maintain proper line and grade of the pipe to prevent the pipe from

becoming over-stressed in hoop compression or bending. Based on the proposed invert elevations and subsurface conditions encountered at the test borings, we anticipate the bearing material at invert elevations should generally consist of stiff to very stiff cohesive soils. In the vicinity of test borings WR-5 and WR-6, we anticipate that the subgrade soils will consist of soft to medium stiff cohesive soils. Any soft to medium stiff soils encountered at pipe subgrade elevation may need undercutting to expose suitable stiff to very stiff bearing materials. The undercut area may be brought up to design bearing levels with engineered fill as discussed in the Bedding and Backfill section of this report. For uniform support, the water main should be bedded on a minimum of 3 inches of appropriate granular (sand) material. The contractor should adhere to all installation specifications provided by the water main manufacturer. Thrust blocks and pipe restraints should also be provided along the water main alignment in accordance with manufacturer's specifications.

4.3 Trench Excavations

All temporary cut slopes required for water main installation should be made in accordance with OSHA Safety Regulations. It is anticipated that the depths of excavation will range from about 4 and 6 feet below existing grades. In areas of soft to medium stiff subgrade soils, excavations can be as deep as 7.5 ft. below existing grades. We anticipate that trench boxes or other types of temporary shoring will be utilized within the existing roadway and in close proximity to existing physical features.

Where sufficient space is available, the excavation slope can be laid back, in accordance with OSHA criteria. According to OSHA, stiff to very stiff cohesive soils, such as those typically encountered at the test boring locations classify as Type B soil, which requires a 1H:1V slope or flatter (for excavations less than 20 feet deep). Where medium stiff to soft cohesive soils are encountered, or where seepage is encountered, all soils should classify as OSHA Type C soils, requiring a 1.5H:1V slope or flatter. Excavations within weathered shale bedrock could be performed at 0.75H:1V side slopes or flatter. It is recommended that temporary excavation slopes be examined periodically to evaluate any potential destabilizing effects. The required safe temporary cut slope will have to be field evaluated.

Trench excavations are not anticipated to be deeper than about 8 feet below existing grade. It is our opinion that the overburden soils/weathered shale bedrock encountered in the test borings can typically be excavated using conventional rubber tired backhoes and trackhoes. The weathered bedrock typically breaks along the natural horizontal bedding planes. Excavation of narrow trenches in the shale and limestone can be difficult. A rock trencher or line drilling may be used to define the edge of the trench, with the rock being excavated with a large hydraulic hoe. Breaking with percussion tools will likely be advantageous to excavate some zones of limestone. The Contractor's "responsible person" should also establish a minimum lateral distance from the crest of the slope or excavation for all spoil piles and vehicles. Likewise, the contractor's "responsible person" should establish protective measures for exposed slope faces.

We recommend that the engineering specifications state that the contractor will be responsible for the temporary shoring, bracing, and sheeting design, if required, and the protection of roadways, utilities, and any other structures. We recommend that a pre-condition survey of all-adjacent structures and roadways be performed prior to the start of construction.

If utility trenches are backfilled with relatively clean granular material, they should be capped with at least 18 inches of cohesive fill in non-pavement areas to reduce the infiltration and conveyance of surface water through the trench backfill.

Unless visually apparent, the location of private underground utilities and other manmade physical features were not easily identified during our site reconnaissance. Oftentimes, the subsurface soils adjacent to these underground features, whether in-use or abandoned, may not represent the subsurface conditions encountered in the soil test borings. Unless notified in advance, identifying and/or locating the presence of underground manmade features such as leach fields, septic systems, irrigation piping, drainage tile, vaults, privies, cisterns, wells, shelters, private utilities, etc. is beyond our scope of services. Interviewing individual home and property owners for the purposes of identifying/locating known underground physical features is also outside the range of our site reconnaissance activities.

These manmade features are often used to collect, store, and/or provide an avenue for transporting water/ liquid waste. Similarly, underground utilities bedded in granular soils and utility trenches that may be inadequately backfilled tend to "hold" water. As a result, the soils in the area of the underground features tend to be saturated or near saturation, resulting in "weakening" of the soil structure and increased susceptibility to failure if exposed and/or disturbed. Due to the proposed construction being within a developed area where manmade disturbances are likely, we recommend that the contractor carefully evaluate their excavation methods so that properly laid back slopes or sheeting/shoring/trench boxes can be readily utilized during construction. Additionally, if any suspicious surficial features (i.e., depressions, mounds, etc.) and/or seepage within the excavation are observed, further excavation should stop and the owner and geotechnical engineer should be notified.

4.3 Undercut and Replacement

The bottom of the excavations for the water main pipes and valves/hydrants must be stable so that no excessive settlement will occur. In some of the proposed pipe subgrade areas where soft to medium stiff soils may be encountered (test borings WR-5 and WR-6) or if excessive water seepage is encountered during excavation, the on-site cohesive fill or natural soil is highly susceptible to strength loss when wet and disturbed, and therefore, a limited undercut and replacement could be required or other stabilizing measures be used.

It is recommended that continuous close inspection by geotechnical personnel be conducted during the water main excavation to minimize potential undercut quantities. Where unstable conditions are observed, appropriate undercut and replacement or stabilization should be

completed. Actual required subgrade stabilization measures would be a field decision based on the encountered conditions.

4.4 Bedding and Backfill

It is recommended that pipe bedding material be used and consist of a "shaped" surface of well-graded sand and/or gravel (with a maximum size less than 1 inch) with no more than 10 percent passing the No. 200 sieve. This granular material should not be less than 3 inches in thickness below the bottom of the pipe and should extend to a height of at least 12 inches above the top of the pipe. This material should be placed in 4 to 6 inch thick lifts and be uniformly compacted to at least 95 percent (in non-pavement areas) of the Standard Proctor maximum dry density (ASTM D 698) at 2 percent below to 3 percent above of the optimum moisture content. Some pipe manufacturers provide backfill requirements pertaining to their particular brand or type of pipe. If this is the case for this project, the manufacturer's specifications could be adopted. If the manufacturer's specifications vary significantly from those provided herein, HCN/Terracon should be contacted to evaluate the appropriateness of the compaction specifications.

The remaining backfill above the granular zone previously described, can consist of on-site cohesive soils or high quality granular material unless specified otherwise. Excavated overburden soils from the water main alignment areas appear to be suitable for reuse as trench backfill, though likely wet of optimum. We anticipate significant drying of the upper horizon of cohesive soils will be required to achieve workable moisture contents. Material classifying as fat clay, such as the cohesive material encountered in majority of the test borings, should be placed wet of optimum to reduce swell potential. The trench backfill above the bedding fill should be in compliance with Northern Kentucky Water District and KTC 2004 specifications if within the roadway right-of-way (low strength mortar). Any proposed backfill material (on-site or imported) should be properly tested to determine its optimum moisture content and moisture-density characteristics and pre-approved before use. All backfill material should be free of organics, topsoil, debris and other deleterious substances. Maximum solid particle size (rock fragments, etc.) should be less than about 4 inches. The following table provides property requirements for structural fill:

Fill Type [1]	USCS Classification	Acceptable Location for Placement
Lean clay	CL (LL<40)	All locations and elevations
Fat clay [2]	CH (LL >50)	In non-structural fill areas
Well graded granular	GW[3]	All locations and elevations

On-site soils	Varies	The on-site soils, including the existing uncontrolled fill material, typically appear suitable for use as fill; however, if they do not meet the low volume change zone criteria, they should not be utilized within 2 feet of finished grade beneath pavement areas. Appropriate moisture conditioning may be needed.

1. New structural fill should consist of approved materials that are free of organic matter and debris. Frozen material should not be used, and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted to the geotechnical engineer for evaluation.

2. Delineation of fat clays should be performed in the field by a qualified geotechnical engineer or their representative. Generally it is preferred not to use high plasticity clay within the structural fill areas, within 2 ft. of pavement subgrade.

3. Similar to KTC DGA stone or crushed limestone aggregate or granular material such as sand, gravel or crushed stone containing less than 8% low plasticity fines.

4. Low plasticity cohesive soil or granular soil having at least 18% low plasticity fines.

Compaction Requirements

Fill Lift Thickness	8-inches or less in loose thickness 6-inches or less if hand compaction equipment used
Compaction Requirements [1] (Pavement Areas)	Top 12" beneath pavement areas, 100% of the materials maximum standard Proctor dry density (ASTM D 698); structural fill beneath the top 12" should be compacted to at least 98% of the materials maximum standard Proctor dry density (ASTM D 698)
Compaction Requirements (Landscape Areas)	95% of maximum standard Proctor dry density (ASTM D 698) provided long-term plans do not include a structure in these areas
Moisture Content - Cohesive Soil (Low Plasticity)	Within ±3% of optimum moisture content (OMC) as determined by the standard Proctor test at the time of placement and compaction
Moisture Content - Granular Material	Within ±2% of OMC

1. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved.

2. Specifically, moisture levels should be maintained low enough to allow for satisfactory compaction to be achieved without the cohesionless fill material pumping when proofrolled.

3. All materials to be used as structural fill should be tested in the laboratory to determine their suitability and compaction characteristics.

Flowable concrete fill (low strength mortar) is used within roadway easements to reduce construction time and minimize the risk of future trench settlement. This material would also be suitable as backfill. It is our experience that reduced labor costs associated with flowable concrete backfill make the use of this material an attractive alternative. Flowable concrete is a semi-rigid backfill, typically stronger than the soil that was removed. The flowable concrete fill should not be placed in more than 36-inch lifts. A minimum 50 psi strength mix would be suitable.

4.5 Drainage and Groundwater Considerations

Water should not be allowed to collect in the bottom of excavations or on prepared subgrades of the construction area either during or after construction. Undercut or excavated areas should be sloped toward one corner to facilitate removal of any collected rainwater, groundwater, or surface runoff.

Based on the predominately cohesive soil types and observed groundwater conditions during drilling, we do not anticipate significant seepage within the excavations. Any encountered water can most likely be removed with typical sump and pump methods. The presence and handling of groundwater should be further evaluated at the time of construction.

4.6 Slope Stability Considerations

Based on the relatively very stiff to hard cohesive overburden soils and relatively shallow brown shale bedrock (about 7.5 to 12.5 feet below existing grade), deep-seated (global) slope failure does not appear to be a concern (although detailed slope stability analyses were not performed). Areas with any obvious existing slope instability were not identified along Wesley Chapel Road and Schababerle Hill road. However, test borings WR-6, WR-7, and SR-3 were relocated to the opposite side of the water main alignment along the roadway due to drill rig setup issues. At test boring WR-6, soft to medium stiff soils were encountered to a depth of 7.5 ft. below existing grades. Stiff lean clay and highly weathered shale were encountered at test borings WR-7 and SR-3 at the

anticipated pipe invert elevations. As discussed earlier, the soft to medium stiff soils anticipated at the pipe invert elevation in the vicinity of WR-6 may need to be undercut and backfilled with new structural fill. In general, vegetation should be maintained on the side slope. Furthermore, the side slope should be observed and monitored on a periodic basis to note any sloughing, movement, or lateral distress in the pavement. Trenches should not remain open for prolonged periods and should be backfilled as soon as practical.

4.7 Creek Crossing

The proposed water main alignment crosses an existing creek near the intersection of California Cross Road and Wesley Chapel Road (between Sta. 0+50 and Sta. 1+00). Along Schababerle Hill Road, the water main crosses an existing ditch between Sta. 20+50 and Sta. 21+00. Due to the open nature of the area, we anticipate that water main installation in the area of the existing creek can be accomplished with open-cut methods. Trench excavations should be performed as discussed previously. Excavation in both overburden soil and bedrock should be anticipated. Due to the multiple pipe bends anticipated in the area of the creek crossing, we further recommend that pipe restraints and/or thrust blocks be utilized in the area of the creek crossing.

Dewatering techniques, such as a cofferdam or sandbags, will likely be required to create a "dry" environment during excavation and subgrade preparation at the creek crossing. Water should be maintained a minimum of 2 feet below the excavation subgrade elevation during pipe installation and fill placement. The contractor should be required to submit their dewatering plan to the NKWD for review prior to implementation.

It is our understanding that while open-cut methods are considered feasible and preferable, directional drilling construction techniques may be implemented for installation of the water main across the creek. The horizontal directional drilling (HDD) method of horizontal earth boring is a process of boring a pilot hole with a drill head suitable for the soil conditions. Once the initial pilot hole is complete, a reamer, slightly larger than the pilot hole is attached to the drill stem and pulled back. The reamer enlarges the borehole to accommodate the pipe that is then pulled into place.

Control of tunnel alignment and elevation is typically more easily achieved in uniform material. Based on test boring WR-1 drilled in the vicinity of creek, we anticipate that the encountered materials will generally consist of completely weathered shale bedrock with limestone (as the creek is at a lower elevation than the boring drilled in pavement). Based on the elevation at which bedrock was encountered at WR-1, published literature suggests that bedrock belongs to the Latonia Formation under Kope group which is rich in shale. Therefore, we do not anticipate drilling difficulties, regarding varying material types, will be encountered during water main construction; however, the hole should be supported at all times to prevent collapse. The contractor selected to perform the HDD should have equipment and proof of experience appropriate for such construction. The contractor should have experience with similar soil geology and installation type (size and length) for the project.

4.8 Thrust Block and Restrained Joints Recommendations

Thrust block or restrained joints are used to resist thrust forces that occur in waterlines when the pipeline changes directions, changes sizes, or stops. A thrust block may be constructed between the fitting and the undisturbed side or bottom of the trench. The base of the thrust block is designed to support the anticipated thrust loads by providing a bearing area through which the thrust forces can be transferred to the soil without exceeding the bearing capacity of the soil.

An alternative method of providing thrust restraint is the use of restrained joints. A restrained joint is a special type of push-on or mechanical joint that is designed to provide longitudinal restraint. Restrained joint systems function in a manner similar to thrust blocks; as the reaction of the entire restrained unit of piping with the soil balances the thrust forces. The objective in designing a restrained joint thrust restraint system is to determine the length of pipe that must be restrained on each side of the focus of a thrust force. This will be a function of the pipe size, the internal pressure, depth of cover, the characteristics of the soil surrounding the pipe, and whether the pipe is polyethylene encased.

The provided plans depicting the water main alignment shows several bends where thrust blocks are anticipated. Based on the invert elevations of the water main pipeline, natural cohesive soils and/or weathered shale bedrock are anticipated in the vicinity of the thrust blocks.

The following soil parameters can be used in sizing the thrust blocks and restrained joints:

Material	Angle of Internal Friction (ϕ)	Total Unit Weight (γ, pcf)	K_o (At-rest)	K_p (Passive)
Stiff to Very Stiff Natural Cohesive Soil	26 °	125	0.56	2.56
Weathered Shale Bedrock	36 °	135	0.41	3.85

The following allowable bearing capacities can be used in sizing the thrust block for downward directed thrust:

Bearing Material	Allowable Bearing Capacity
New Engineered Granular Fill (placed over stiff to very stiff natural soils)	3,000 psf
Stiff to Very Stiff Natural Cohesive soils	3,000 psf
Weathered Shale Bedrock	8,000 psf

The following table summarizes the recommended coefficient of friction values for the interface of thrust block concrete and in-situ soil. These are ultimate values (no safety factors applied).

Interface Material	Coefficient of Friction
Stiff to Very Stiff Existing Fill	0.30
Stiff to Very Stiff Natural Cohesive soils	0.35
Weathered Shale Bedrock	0.50

It is recommended that the trench backfill in the areas of thrust blocks and restrained joints consist of compacted granular backfill or flowable concrete fill.

4.9 Overview of Geotechnical Recommendations

The following table is being provided for use by the NKWD and the waterline designer to aid in waterline design, and development of the project plans. The table generally outlines our recommendations along the alignment in consideration of the geotechnical aspects outlined above and based on review of the plan and profile information provided to us. The actual design of the waterline and design methodology is the responsibility of the designer. We have not considered flowrates, pressures, valve/hydrant placement, etc., along the waterline, which may require the further use of thrust blocks/restraints, grade change, waterline relocation, in addition to the recommendations provided below. We request the opportunity to review such changes and/or meet with the NKWD/designer to discuss any of our recommendations, as deemed necessary. It should be further acknowledged that our test borings provide limited, widely-spaced information and that "ground truth" is only obtained in the field during construction at the time of excavation. Adjustments in the field at the time of construction based on actual field conditions should be anticipated. Additional exploration and/or long-term monitoring may be required.

Alignment	Approximate Station	Applicable Test Boring(s)	Geotechnical Consideration(s)	Remarks[2]
Wesley Chapel Road	0+00 to 2+50	WR-1	Dewatering required	Creek crossing; Use thrust blocks/restraints
	2+50 to 34+00	WR-1, WR-2, WR-3[1]	None anticipated	Bedrock Excavation near WR-1 and WR-2
	34+00 to 36+00	WR-3	None anticipated	Bend in Alignment (Road Crossing); Use thrust blocks/restraints
	36+00 to 59+00	WR-3, WR-4, WR-5[1]	None anticipated	Within road
	59+00 to 62+00	WR-5	May need undercutting	Bend in Alignment (Road Crossing); Use thrust blocks/restraints.

Alignment	Approximate Station	Applicable Test Boring(s)	Geotechnical Consideration(s)	Remarks[2]
Wesley Chapel Road	62+00 to 82+00	WR-5, WR-6	May need undercutting	Within Road
	82+00 to 83+50	WR-6	May need undercutting	Bend in Alignment (Road Crossing); Use thrust blocks/restraints.
	83+50 to 106+00	WR-7, WR-8	None anticipated	Within road
	106+00 to 110+00	WR-8	None anticipated	Bend in Alignment (off road to avoid culvert)
	110+00 to 118+00	WR-8, WR-9[1]	None anticipated	Within road
	118+00 to 120+00	WR-9	None anticipated	Bend in Alignment (Road Crossing); Use thrust blocks/restraints
	120+00 to 127+00	WR-9	None anticipated	Within road
Schababerle Hill Road	0+00 to 20+00	SR-1, SR-2	None anticipated	Within road
	20+00 to 22+00	SR-2	None anticipated	Bend in Alignment (Road & Creek Crossing); Use thrust blocks/restraints
	22+00 to 32+00	SR-2, SR-3	None anticipated	Bedrock excavation near SR-3

(1) Boring drilled outside of station range.
(2) Thrust block/restraint use based on project plans.

5.0 GENERAL COMMENTS

HCN/Terracon should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. HCN/Terracon also should be retained to provide observation and testing services during grading, excavation, foundation construction and other earth-related construction phases of the project.

The analysis and recommendations presented in this report are based upon the data obtained from the borings performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the modifying effects of weather. The nature and extent of such variations may

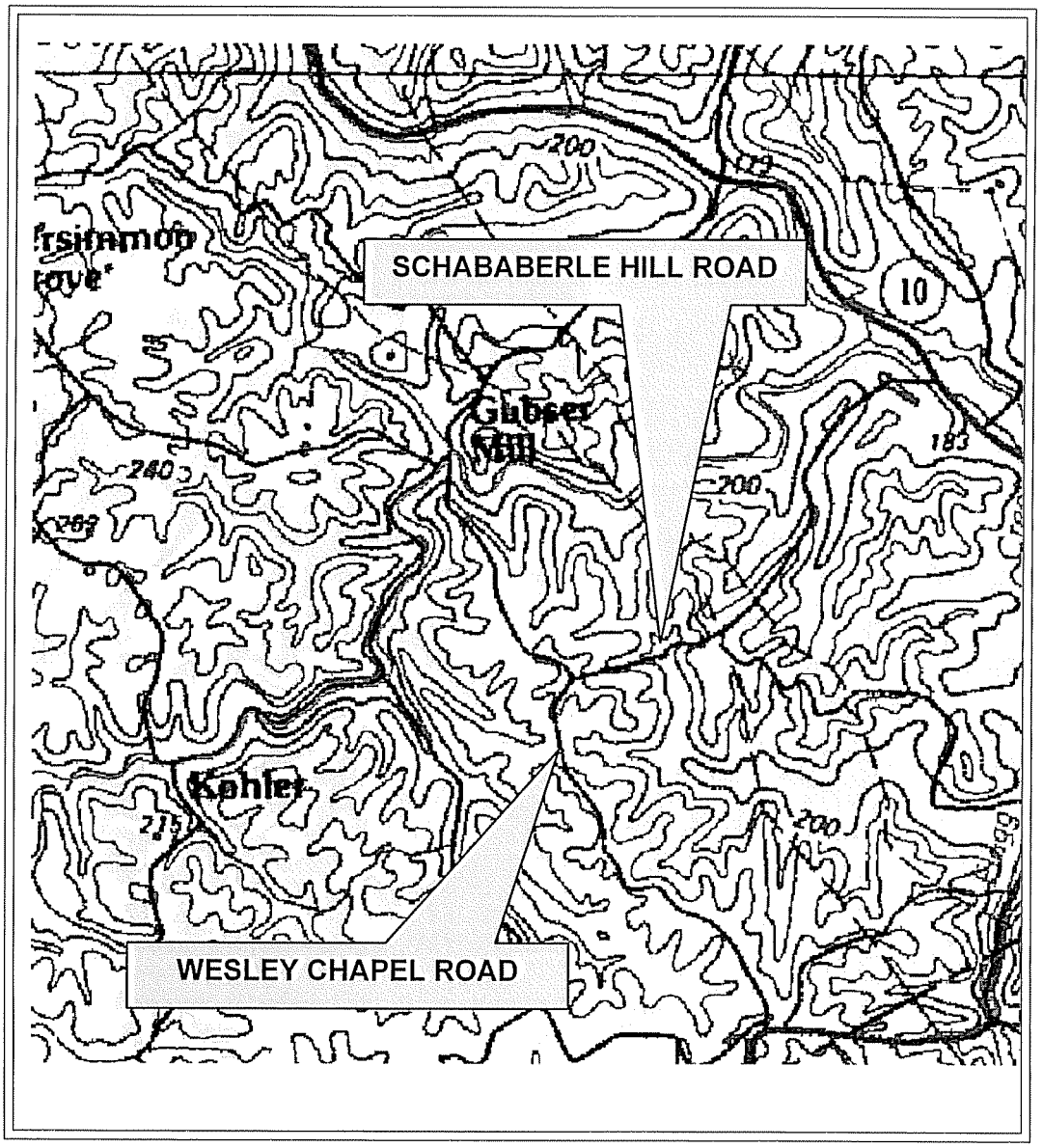
not become evident until during or after construction. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

The scope of services for this project does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless HCN/Terracon reviews the changes and either verifies or modifies the conclusions of this report in writing.

APPENDIX A
FIELD EXPLORATION

UNITED STATES – DEPARTMENT OF THE INTERIOR – GEOLOGICAL SURVEY



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1000 0 METERS 1000 2000

1 .5 0 1

MILES

1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

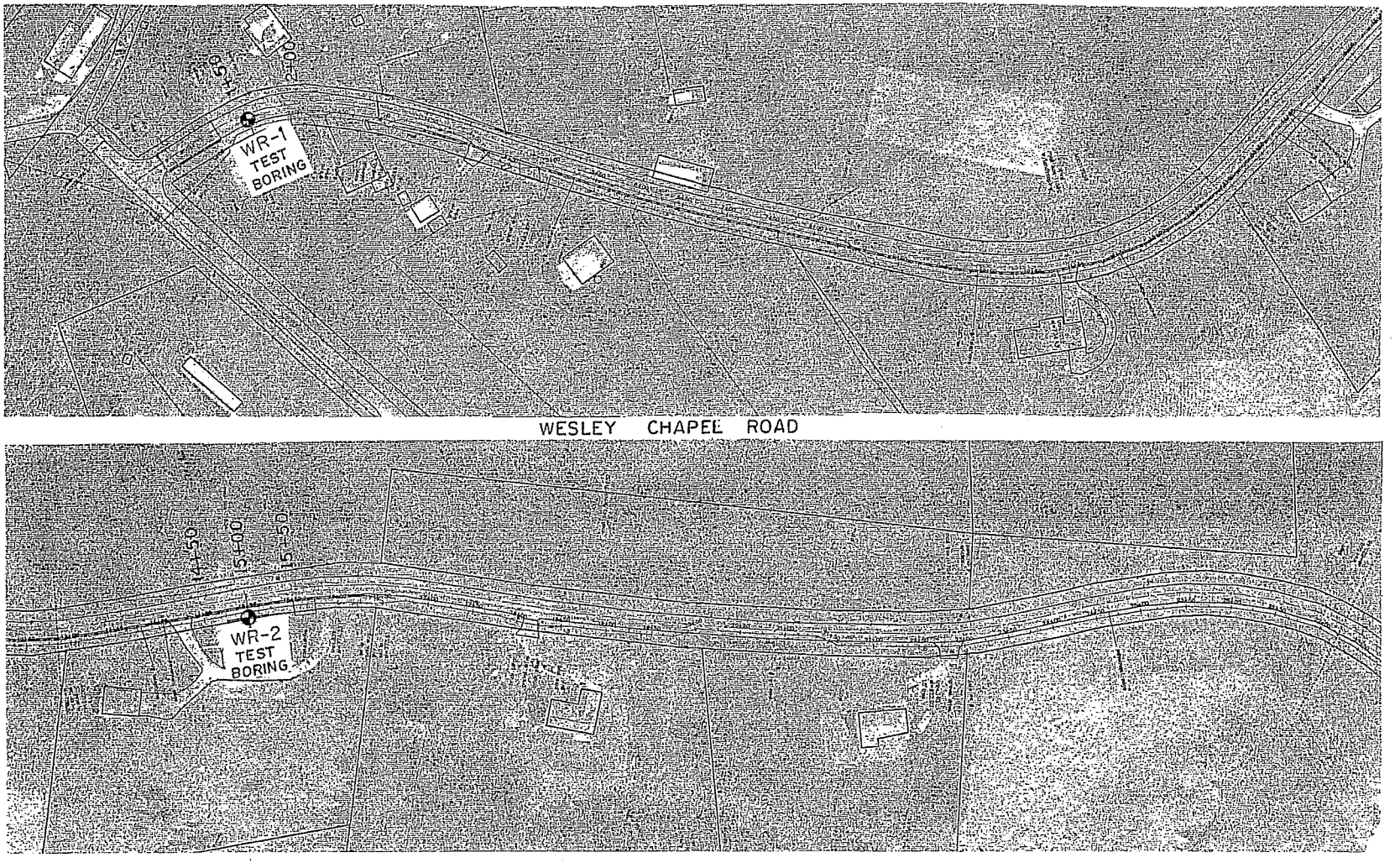
CONTOUR INTERVAL FEET FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP OF CALIFORNIA, KENTUCKY 1983

7.5 MINUTE SERIES (TOPOGRAPHIC)

Project Mngr: AJM	Project No. N1095342	Consulting Engineers and Scientists	SITE VICINITY MAP	FIG. No.
Drawn By: DRK	Scale: AS SHOWN	611 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226	SUBDISTRICT H WATER MAIN EXTENSION – PHASE 3	1
Checked By: AJM	File No. FIGURE 1	PH. (513) 321-5816 FAX. (513) 321-4540	NORTHERN KENTUCKY WATER DISTRICT	
Approved By: JAS	Date: 1/5/2010		WESLEY CHAPEL ROAD AND SCHABABERLE HILL ROAD CALIFORNIA KENTUCKY	



REV.	DATE	BY	DESCRIPTION

A Terracon COMPANY
611 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226
PH. (513) 321-5816 FAX. (513) 321-4540

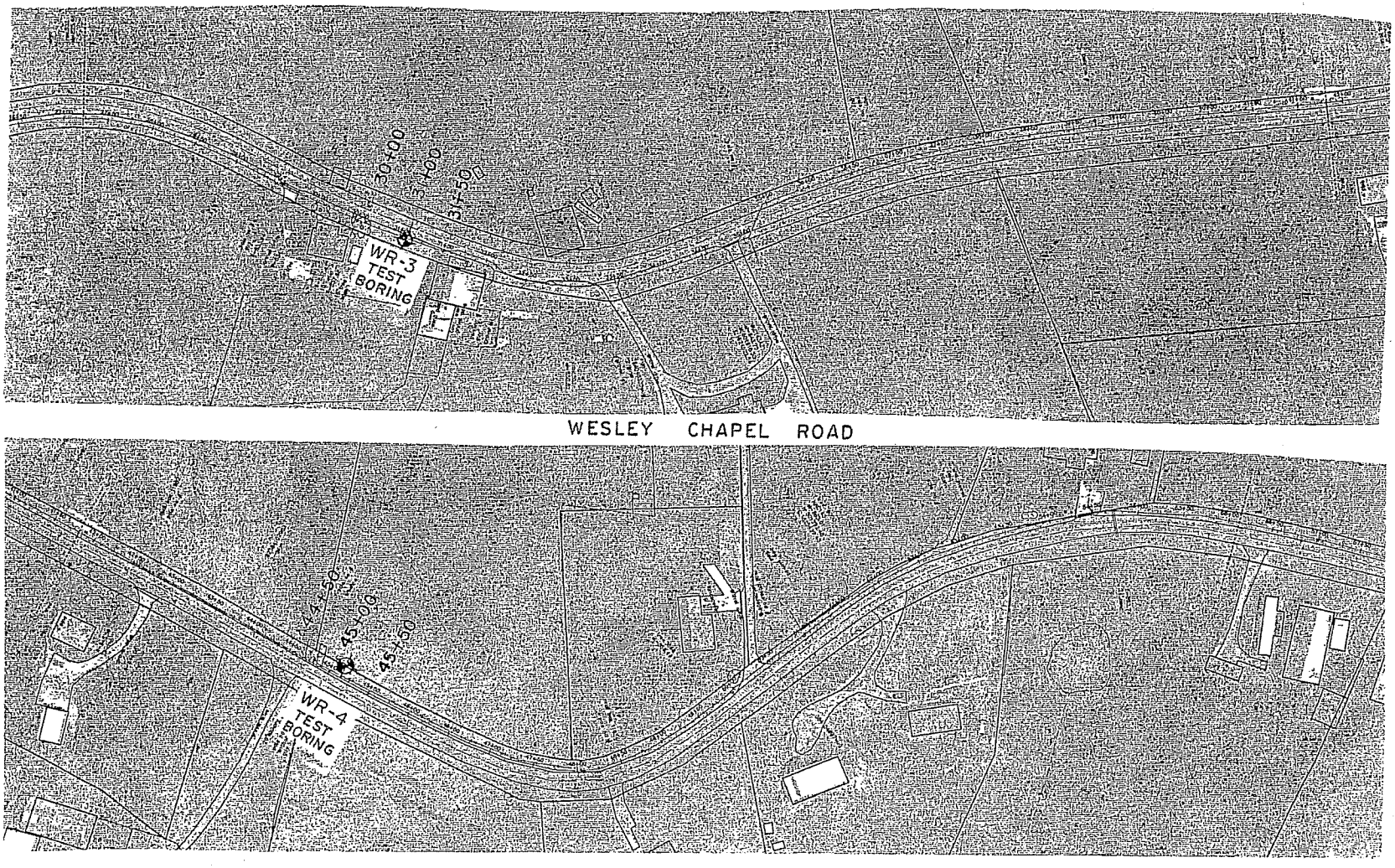
TEST BORING LOCATION PLAN

CLIENT: NORTHERN KENTUCKY WATER DISTRICT
PROJECT: DISTRICT H, PROPOSED 8" WATER MAIN EXTENSION
PHASE 3

CALIFORNIA CAMPBELL COUNTY KENTUCKY

FIGURE 2A

DESIGNED BY:	
DRAWN BY:	
APPVD. BY:	BD
SCALE:	NTS
DATE:	JAN. 2010
JOB NO.	N1095342
ACAD NO.	
SHEET NO:	



REV.	DATE	BY	DESCRIPTION

A Terracon COMPANY
611 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226
PH. (513) 321-5816 FAX. (513) 321-4540

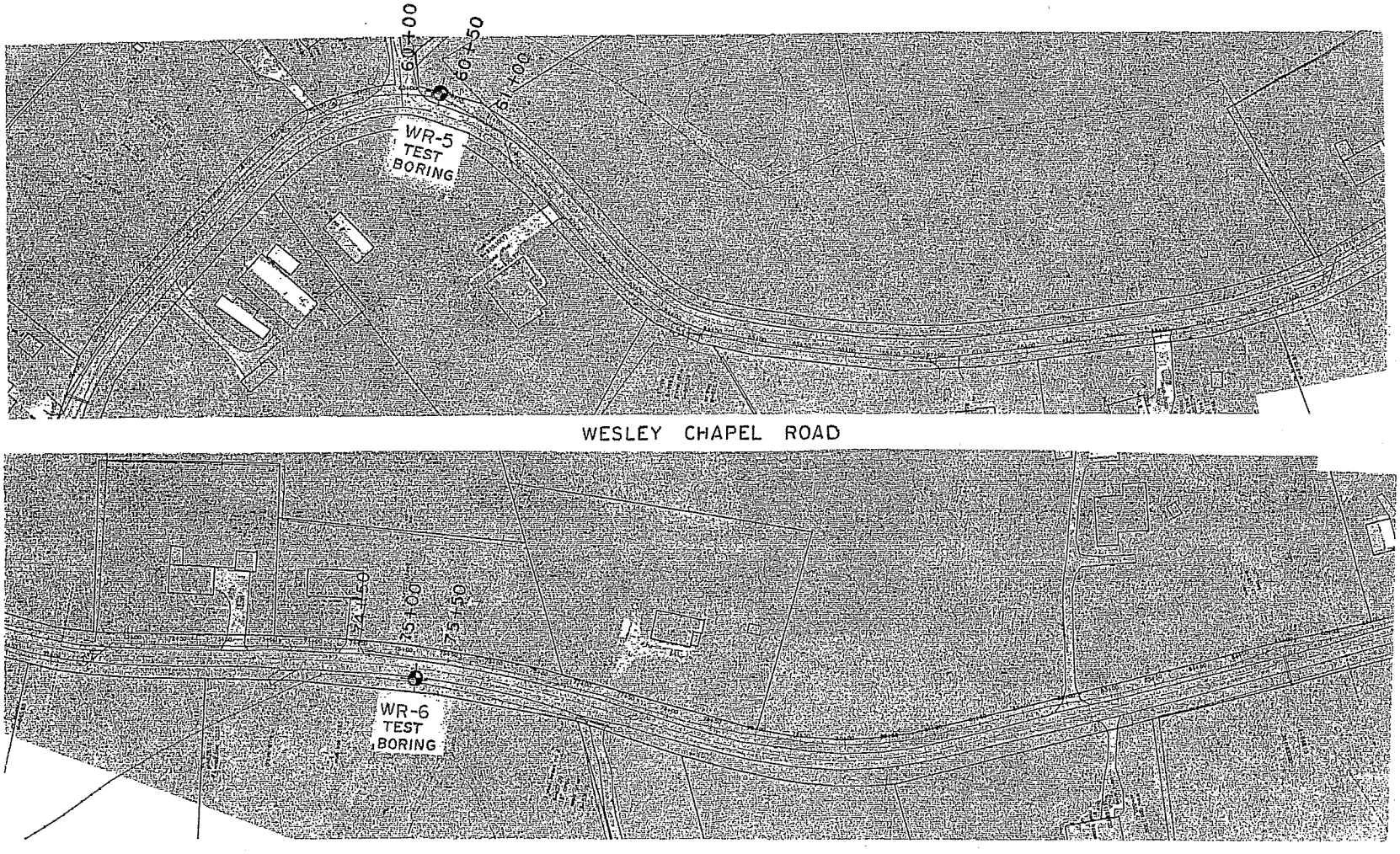
TEST BORING LOCATION PLAN

CLIENT: NORTHERN KENTUCKY WATER DISTRICT
PROJECT: DISTRICT H, PROPOSED 8" WATER MAIN EXTENSION PHASE 3

CALIFORNIA CAMPBELL COUNTY KENTUCKY

FIGURE 2B

DESIGNED BY:	
DRAWN BY:	
APPVD. BY:	B.D.
SCALE:	N.T.S.
DATE:	JAN. 2010
JOB NO.	N1095342
ACAD NO.	
SHEET NO:	



REV.	DATE	BY	DESCRIPTION

A Terracon COMPANY
611 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226
PH. (513) 321-5816 FAX. (513) 321-4540

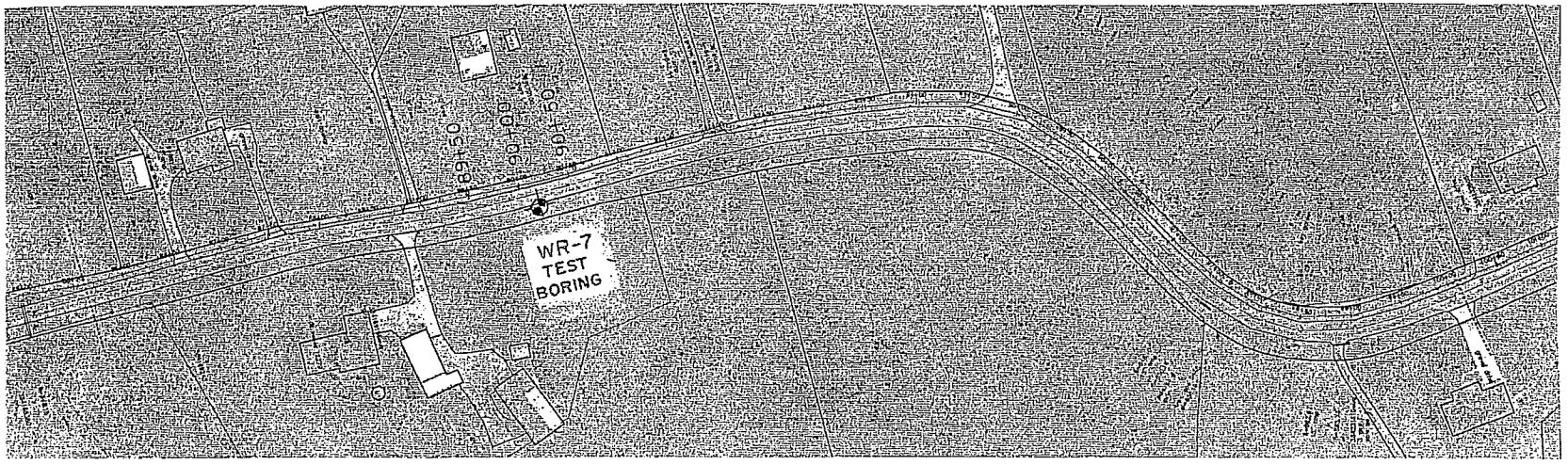
TEST BORING LOCATION PLAN

CLIENT: NORTHERN KENTUCKY WATER DISTRICT
PROJECT: DISTRICT H, PROPOSED 8" WATER MAIN EXTENSION
PHASE 3

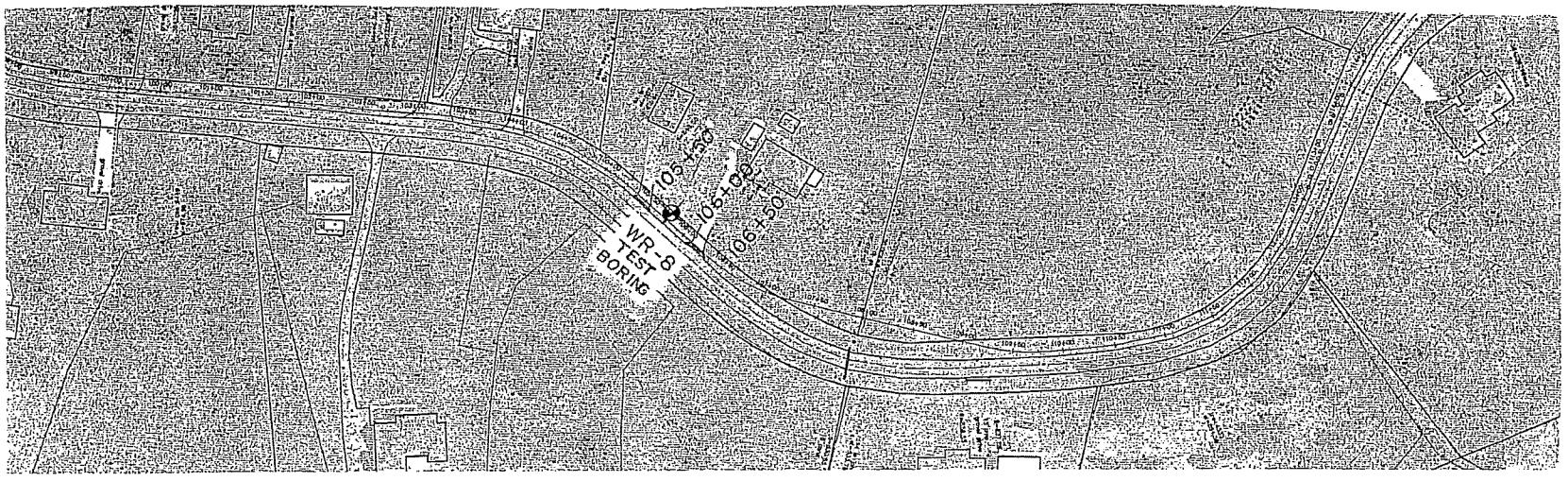
CALIFORNIA CAMPBELL COUNTY KENTUCKY

FIGURE 2C

DESIGNED BY:	
DRAWN BY:	
APPVD. BY:	BD
SCALE:	NTS
DATE:	JAN. 2010
JOB NO.	N1095342
ACAD NO.	
SHEET NO.:	



WESLEY CHAPEL ROAD



REV.	DATE	BY	DESCRIPTION

A Terracon COMPANY
611 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226
PH. (513) 321-5816 FAX. (513) 321-4540

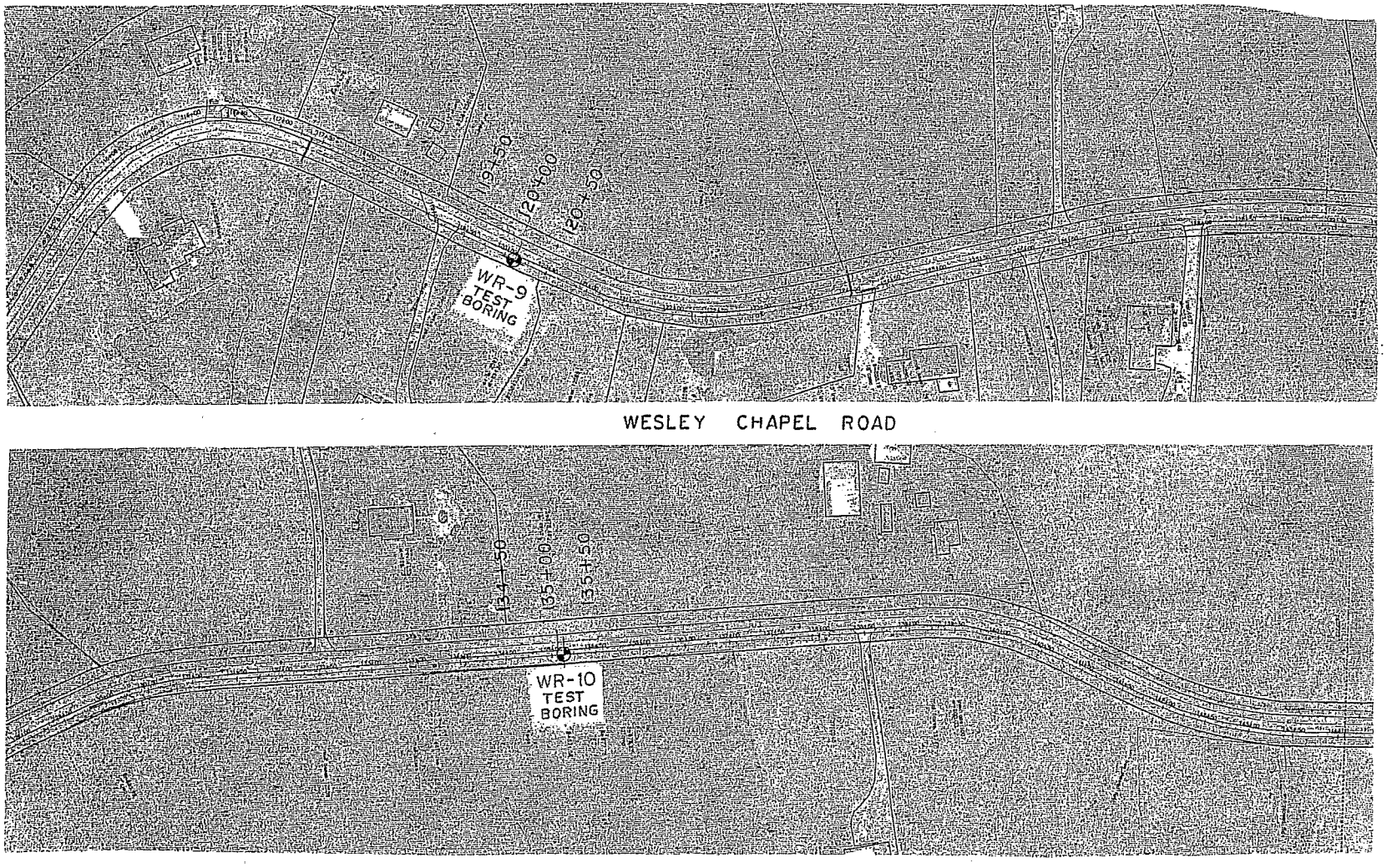
TEST BORING LOCATION PLAN

CLIENT: NORTHERN KENTUCKY WATER DISTRICT
PROJECT: DISTRICT H, PROPOSED 8" WATER MAIN EXTENSION
PHASE 3

CALIFORNIA CAMPBELL COUNTY KENTUCKY

FIGURE 2D

DESIGNED BY:	
DRAWN BY:	
APPVD. BY:	B.D.
SCALE:	N.T.S.
DATE:	JAN. 2010
JOB NO.	N1095342
ACAD NO.	
SHEET NO:	



REV.	DATE	BY	DESCRIPTION

A Terracon COMPANY
611 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226
PH. (513) 321-5816 FAX. (513) 321-4510

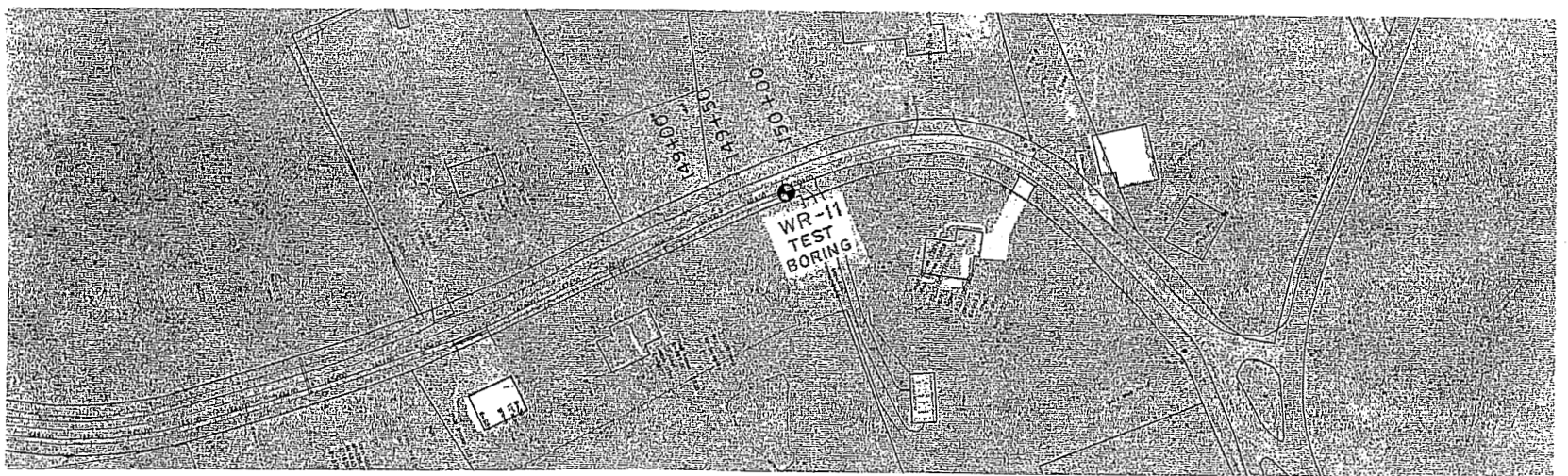
TEST BORING LOCATION PLAN

CLIENT: NORTHERN KENTUCKY WATER DISTRICT
PROJECT: DISTRICT H, PROPOSED 8" WATER MAIN EXTENSION
PHASE 3

CALIFORNIA CAMPBELL COUNTY KENTUCKY

FIGURE 2E

DESIGNED BY:	
DRAWN BY:	
APPVD. BY:	BD
SCALE:	NTS
DATE:	JAN. 2010
JOB NO.	N1095342
ACAD NO.	
SHEET NO.:	



REV.	DATE	BY	DESCRIPTION

A Terracon COMPANY
611 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226
PH. (513) 321-5816 FAX. (513) 321-4540

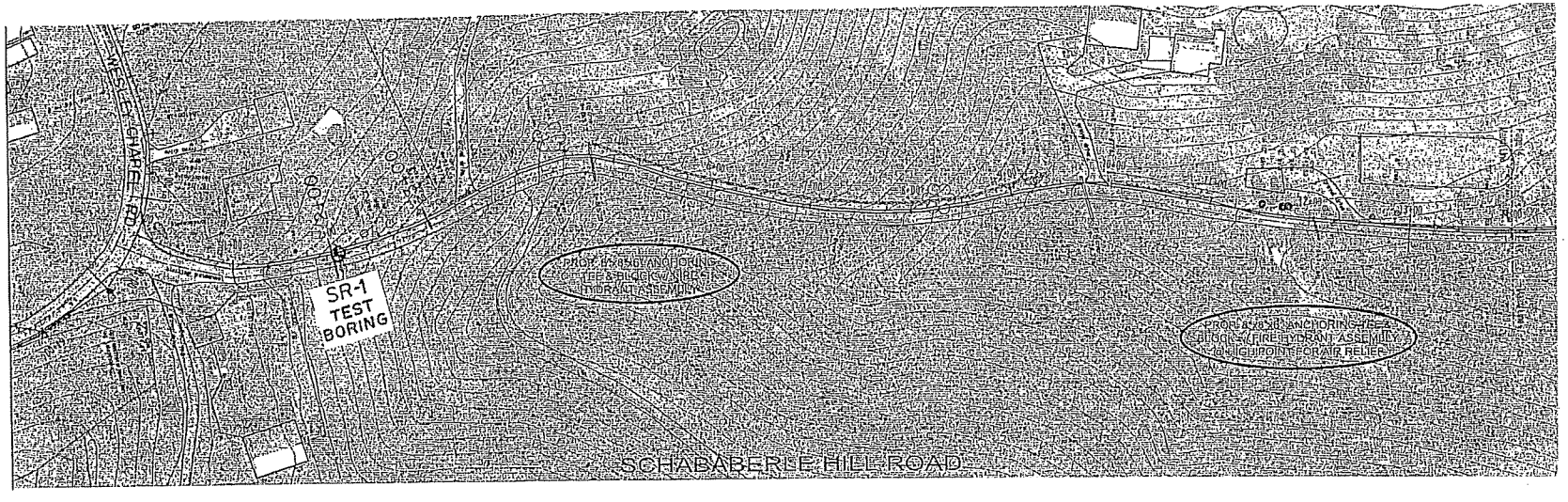
TEST BORING LOCATION PLAN

CLIENT: NORTHERN KENTUCKY WATER DISTRICT
PROJECT: DISTRICT H, PROPOSED 8" WATER MAIN EXTENSION PHASE 3

CALIFORNIA CAMPBELL COUNTY KENTUCKY

FIGURE 2F

DESIGNED BY:	
DRAWN BY:	
APPVD. BY:	B.D.
SCALE:	N.T.S.
DATE:	JAN. 2010
JOB NO.	N1095342
ACAD NO.	
SHEET NO.:	



REV	DATE	BY	DESCRIPTION

A Terracon COMPANY
611 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226
PH. (513) 321-5816 FAX. (513) 321-4540

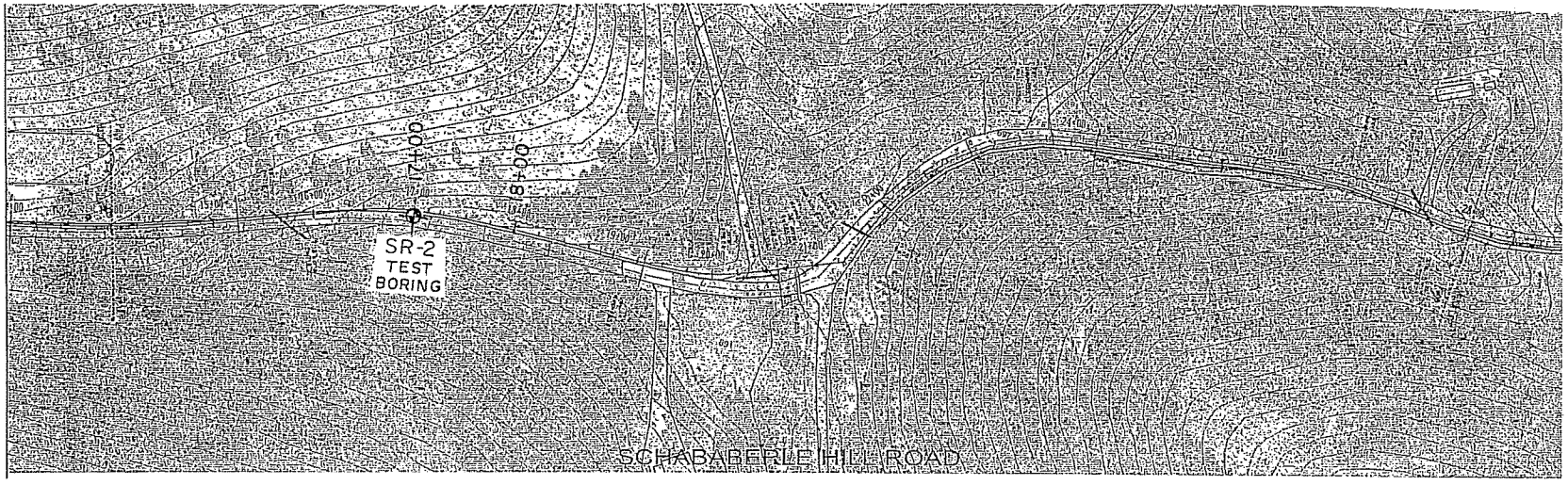
TEST BORING LOCATION PLAN

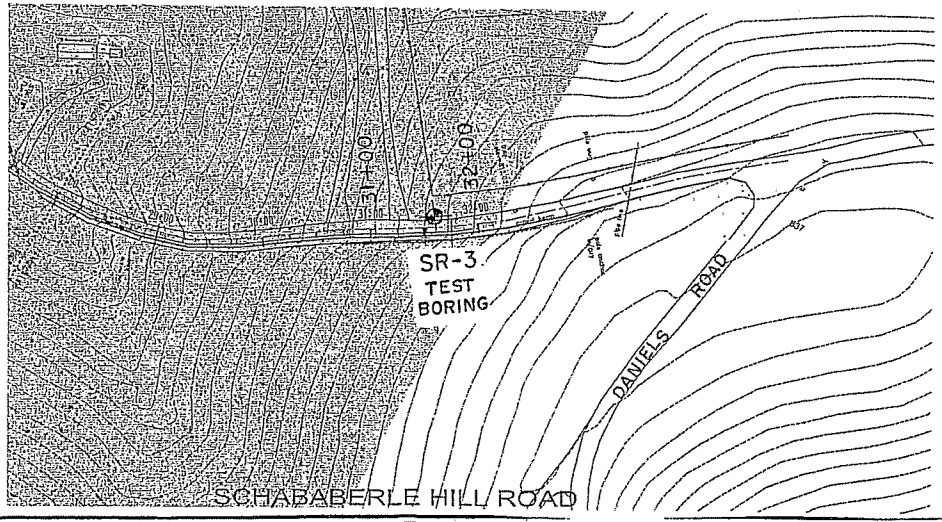
CLIENT: NORTHERN KENTUCKY WATER DISTRICT
PROJECT: DISTRICT H, PROPOSED 8" WATER MAIN EXTENSION
PHASE 3

CALIFORNIA CAMPBELL COUNTY KENTUCKY

FIGURE 2G

DESIGNED BY:	
DRAWN BY:	
APPVD. BY:	BD
SCALE:	NTS
DATE:	JAN. 2010
JOB NO.	N1095342
ACAD NO.	
SHEET NO:	





REV.	DATE	BY	DESCRIPTION

A Terracon COMPANY
811 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226
PH. (513) 321-5816 FAX. (513) 321-4540

TEST BORING LOCATION PLAN

CLIENT: NORTHERN KENTUCKY WATER DISTRICT
PROJECT: DISTRICT H, PROPOSED 8" WATER MAIN EXTENSION
PHASE 3

CALIFORNIA CAMPBELL COUNTY KENTUCKY

FIGURE 2H

DESIGNED BY:	
DRAWN BY:	
APPVD. BY:	B D
SCALE:	N T S
DATE:	JAN. 2010
JOB NO.	N1095342
ACAD NO.	
SHEET NO.:	

LOG OF BORING NO. WR-1

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 634 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf	
	0.3 TOPSOIL 633.7		CH	1	SS	100	2-2-4 (6)	33		4000*	
	FAT CLAY, trace root matter, brown, stiff										
	2.5 631.5										
	LEAN CLAY, little silt (RESIDUUM), brown, trace gray, very stiff		CL	2	SS	100	6-7-10 (17)	22		8000*	LL = 44 PI = 20
	5 629	5									
	COMPLETELY WEATHERED SHALE, little limestone fragments, brown, soft			3	SS	100	3-20-50/0.4'	14			
				4	SS	100	10-11-13 (24)				
		10		5	SS	100	7-16-50/0.4'				
	12.5 621.5										
	SHALE, trace limestone fragments, gray, soft			6	SS	100	40-50/0.3'				
	15.3 618.7	15									
	Boring Completed at 15.3 ft.			7	SS	100	50/0.3'				

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▽
WL	▽ N/E	AB	▽
WL			

A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON_TEST.GDT 1/6/10

LOG OF BORING NO. WR-2

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	Approx. Surface Elev.: 771 ft									
	0.5 TOPSOIL 770.5			1	SS	83	4			9000*
	FAT CLAY, little silt and brown shale fragments, brown, very stiff to hard		CH	1A	SS	83	4-7	14		
	2.5 768.5									
	WEATHERED SHALE, trace limestone fragments, brown, soft			2	SS	100	17-10-14 (24)	14		
		5		3	SS	100	31-24-34 (58)			
	8.1 762.9			4	SS	33	15-50/1"			
	Boring Completed at 8.1 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▽ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-4-09		
BORING COMPLETED	12-4-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

LOG OF BORING NO. WR-3

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 842 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.3 TOPSOIL 841.7									
	FAT CLAY, brown, stiff		CH	1	SS	100	4-3-3 (6)	28		3000*
	2.5 839.5									
	FAT CLAY, trace silt (RESIDUUM), brown, very stiff		CH	2	SS	100	9-10-12 (22)	19		8000*
	5 837	5								
	WEATHERED SHALE, trace to little limestone fragments, brown, medium hard to soft			3	SS	67	4-32-50/2"			
				4	SS	100	15-26-50 (76)			
	9 833									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-4-09		
BORING COMPLETED	12-4-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

LOG OF BORING NO. WR-4

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 835 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.5 ASPHALT PAVEMENT 834.5									
	1 GRANULAR BASE 834									
	FAT CLAY, trace sand, brown, stiff		CH	1	SS	89	2-2-3 (5)	34		3000*
			CH	2	SS	100	3-4-7 (11)	32		4000*
	5 830									
	FAT CLAY, trace weathered shale and limestone fragments, brown, trace gray, very stiff, (RESIDUUM)	5		3	SS	100	20-26-10 (36)	17		
			CH	4	SS	100	27-9-13 (22)			8000*
	9 826									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▽ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-4-09		
BORING COMPLETED	12-4-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

LOG OF BORING NO. WR-5

CLIENT: **Northern Kentucky Water District**

ELEVATION REFERENCE: **Interpolated from Plan & Profile (Approximate)**

SITE: **Alexandria, Kentucky**

PROJECT: **Subdistrict H Water Main Extension Project**

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 874 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf	
	0.4 TOPSOIL 873.6			1	SS	67	3-3-4 (7)	23		3000*	
	FILL, lean clay, some silt, trace sand, root matter, and gravel, dark brown, stiff 2.5 871.5										
	LEAN CLAY, trace sand, brown, medium stiff		CL	2	SS	100	3-2-2 (4)	26		2000*	LL = 39 PI = 19
	5 869	5									
	FAT CLAY, trace shale fragments, brown, trace gray, very stiff		CH	3	SS	100	3-4-7 (11)	33		5000*	
			CH	4	SS	100	8-5-7 (12)			8000*	
	9 865										
	Boring Completed at 9 ft.										

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-4-09		
BORING COMPLETED	12-4-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON.TEST.GDT 1/6/10

LOG OF BORING NO. WR-6

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 819 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.4 TOPSOIL — 818.6									
	FAT CLAY, little limestone fragments, brown, soft to medium stiff		CH	1	SS	89	6-7-9 (16)	20		1000*
			CH	2	SS	100	4-3-4 (7)	25		2000*
		5	CH	3	SS	100	2-2-1 (3)	23		1000*
	7.5 — 811.5									
	FAT CLAY, trace silt (RESIDUUM), brown, very stiff		CH	4	SS	100	2-4-7 (11)	27		6000*
	9 — 810									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ 5.0	WD	▼
WL	▼ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-4-09		
BORING COMPLETED	12-4-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

LOG OF BORING NO. WR-7

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 863 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.5 TOPSOIL 862.5			~~1~~	~~SS~~	~~100~~	~~2~~			~~5000*~~
	FAT CLAY, trace shale fragments, (RESIDUUM), brown, trace gray, very stiff 2.5 860.5		CH	1A	SS	100	3-3	20		
	LEAN CLAY, little silt, trace limestone fragments, brown, stiff 5 858		CL	2	SS	100	6-7-8 (15)	18		
	HIGHLY WEATHERED SHALE, trace limestone fragments, brown, soft 7.5 855.5	5		3	SS	100	12-8-11 (19)			
	SHALE, gray, soft 9 854			4	SS	100	27-41-39 (80)			
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▽ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-4-09		
BORING COMPLETED	12-4-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

LOG OF BORING NO. WR-8

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 844 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.7 ASPHALT PAVEMENT 843.3									
	2.5 **FAT CLAY**, trace limestone fragments, brown, trace gray, medium stiff 841.5		CH	1	SS	83	5-2-2 (4)	20		2000*
	FAT CLAY, trace shale fragments, brown, trace gray, very stiff		CH	2	SS	61	5-5-8 (13)	25		6000*
		5	CH	3	SS	100	2-3-6 (9)	33		7000*
	7.5 836.5									
	9 **HIGHLY WEATHERED SHALE**, trace limestone fragments, brown, soft 835			4	SS	72	6-25-9 (34)			
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▽ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-4-09		
BORING COMPLETED	12-4-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

LOG OF BORING NO. WR-9

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 890 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.5 TOPSOIL 889.5			1	SS	100	1			1000*
	FAT CLAY, trace root matter, brown, trace gray, soft 887.5		CH	1A	SS	10	2-3	30		
	FAT CLAY, trace shale fragments, brown, trace gray, very stiff		CH	2	SS	100	4-5-6 (11)	33		5000*
		5	CH	3	SS	100	4-8-10 (18)			7000*
	7.5 882.5									
	FAT CLAY, little silt, trace to little shale fragments, brown, stiff 881		CH	4	SS	100	5-7-14 (21)	25		
	9 Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-4-09		
BORING COMPLETED	12-4-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

LOG OF BORING NO. WR-10

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 878 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.8 ASPHALT PAVEMENT 877.2		CL/ML	1	SS	100	8-13-8 (21)	12		
	SILTY CLAY, some limestone fragments, brown, stiff									
	5 873		CL/ML	2	SS	67	8-5-5 (10)			
	LEAN CLAY, little limestone fragments, brown, stiff	5	CL	3	SS	100	10-3-4 (7)	18		4000*
	7.5 870.5									
	9 **FAT CLAY**, little silt, trace shale fragments (RESIDUUM), brown, very stiff 869		CH	4	SS	100	2-4-20 (24)	20		5000*
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▽ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-11-09		
BORING COMPLETED	12-11-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

LOG OF BORING NO. WR-11

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 900 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.6 ASPHALT PAVEMENT 899.4									
	SILTY CLAY, brown, stiff		CL ML	1	SS	22	14-5-4 (9)			
	2.5 897.5									
	LEAN CLAY, brown, stiff		CL	2	SS	100	3-3-4 (7)	25		4000*
	5 895	5								
	FAT CLAY, trace shale fragments, brown, very stiff		CH	3	SS	100	3-4-7 (11)	23		8000*
	7.5 892.5									
	HIGHLY WEATHERED SHALE, trace limestone fragments, brown, soft			4	SS	100	33-30-30 (60)			
	9 891									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▽ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-11-09		
BORING COMPLETED	12-11-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

LOG OF BORING NO. SR-1

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 858 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.9 ASPHALT PAVEMENT 857.1									
	FAT CLAY, trace shale and limestone fragments, brown, very stiff		CH	1	SS	83	2-4-50/2"	18		6000*
			CH	2	SS	50	50/2"	20		
		5	CH	3	SS	100	16-14-16 (30)	33		
	7.5 850.5									
	HIGHLY WEATHERED SHALE, brown, soft			4	SS	100	11-13-50 (63)			8000*
	9 849									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▽ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-11-09		
BORING COMPLETED	12-11-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

LOG OF BORING NO. SR-2

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 709 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.9 ASPHALT PAVEMENT 708.1									
	FAT CLAY, trace limestone fragments, brown, trace gray, stiff		CH	1	SS	100	2-4-3 (7)	29		3000*
			CH	2	SS	100	3-6-16 (22)	31		4000*
	5 704	5								
	FAT CLAY, trace shale and limestone fragments, brown, trace gray, very stiff		CH	3	SS	100	9-6-8 (14)	21		8000*
	7.5 701.5									
	SHALE, gray, soft			4	SS	100	10-28-46 (74)			
	9 700									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▽ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-11-09		
BORING COMPLETED	12-11-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

LOG OF BORING NO. SR-3

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Plan & Profile (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 801 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.9 ASPHALT PAVEMENT 800.1									
	FILL, fat clay, trace shale fragments, gray, stiff 2.5 798.5			1	SS	39	4-6-10 (16)	13		4000*
	HIGHLY WEATHERED SHALE, little limestone fragments, brown, soft			2	SS	67	17-18-29 (47)	16		
		5		3	SS	89	11-45-50/5"			
	7.5 793.5									
	WEATHERED SHALE, brown, soft 9 792			4	SS	100	33-29-49 (78)			
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-11-09		
BORING COMPLETED	12-11-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

BOREHOLE 99 BORINGLOGS-PHASE3.GPJ TERRACON TEST.GDT 1/6/10

Field Exploration Description

The boring locations were laid out on the site by HCN/Terracon personnel using the plan and profile drawings provided by Viox & Viox, Inc. (dated 11/13/09 and 10/28/09). Ground surface elevations at the test boring locations were interpolated from the plan and profile drawings based on the station number information and therefore should be considered approximate. The borings were drilled with a truck-mounted rotary drill rig using continuous flight hollow-stem augers to advance the boreholes. Samples of the soil encountered in the borings were obtained using the split-barrel sampling procedures.

In the split barrel sampling procedure, the number of blows required to advance a standard 2 inch O.D. split barrel sampler the last 12 inches of the typical total 18 inch penetration by means of a rope and cathead manual safety hammer with a free fall of 30 inches, is the standard penetration resistance value (SPT-N). This value is used to estimate the in-situ relative density of cohesionless soils and consistency of cohesive soils.

An automatic SPT hammer was used to advance the split-barrel sampler in the borings performed on this site. A greater efficiency is typically achieved with the automatic hammer compared to the conventional safety hammer operated with a cathead and rope. Published correlations between the SPT values and soil properties are based on the lower efficiency cathead and rope method. This higher efficiency affects the standard penetration resistance blow count (N) value by increasing the penetration per hammer blow over what would be obtained using the cathead and rope method. The effect of the automatic hammer's efficiency has been considered in the interpretation and analysis of the subsurface information for this report.

The samples were tagged for identification, sealed to reduce moisture loss, and taken to our laboratory for further examination, testing, and classification. Information provided on the boring logs attached to this report includes soil descriptions, consistency evaluations, boring depths, sampling intervals, and groundwater conditions. The borings were backfilled with auger cuttings prior to the drill crew leaving the site.

A field log of each boring was prepared by the drill crew. These logs included visual classifications of the materials encountered during drilling as well as the driller's interpretation of the subsurface conditions between samples. Final boring logs included with this report represent the engineer's review of obtained soil samples, driller's field logs and include modifications based on laboratory tests of the samples.

APPENDIX B
SUPPORTING INFORMATION

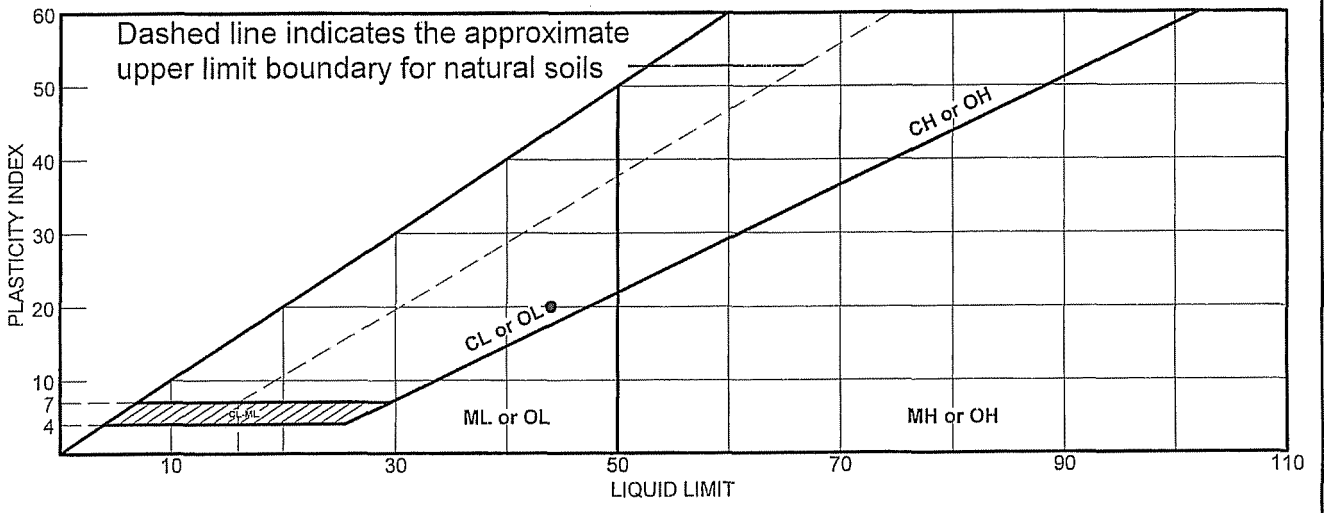
TABLE I: CLASSIFICATION TEST DATA

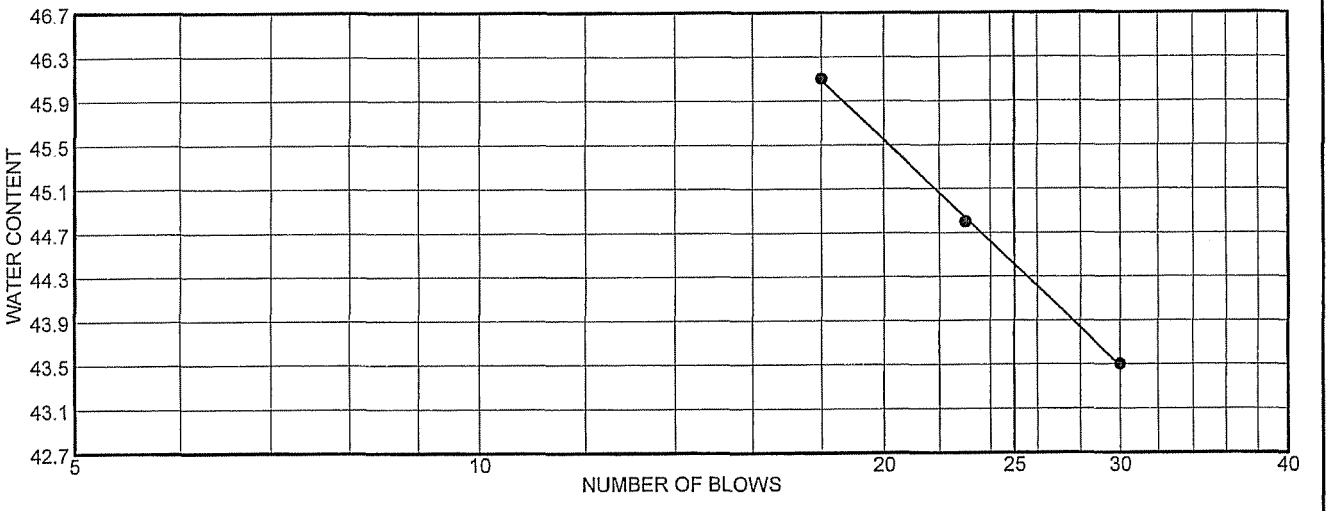
Boring No.	Sample No. (SS)	Depth (Ft.)	U.S.C.S. Classification	Moisture Content (%)	Atterberg Limits		
					Liquid Limit (%)	Plastic Limit (%)	Plasticity Index
SR-1	1	1-2.5		18.1			
	2	2.5-4		19.6			
	3	5-6.5		33.2			
SR-2	1	1-2.5		28.8			
	2	2.5-4		30.7			
	3	5-6.5		21.4			
SR-3	1	1-2.5		13.0			
	2	2.5-4		15.7			
WR-1	1	0-1.5		32.8			
	2	2.5-4	CL	22.1	44	24	20
	3	5-6.5		14.1			
WR-2	1	0-1.5		14.1			
	2	2.5-4		13.6			
WR-3	1	0-1.5		27.7			
	2	2.5-4		18.7			
WR-4	1	1-2.5		34.2			
	2	2.5-4		31.7			
	3	5-6.5		16.7			

TABLE I: CLASSIFICATION TEST DATA

Boring No.	Sample No. (SS)	Depth (Ft.)	U.S.C.S. Classification	Moisture Content (%)	Atterberg Limits		
					Liquid Limit (%)	Plastic Limit (%)	Plasticity Index
WR-5	1	0-1.5		22.8			
	2	2.5-4	CL	25.8	39	20	19
	3	5-6.5		32.8			
WR-6	1	0-1.5		19.5			
	2	2.5-4		24.5			
	3	5-6.5		23.4			
	4	7.5-9		27.2			
WR-7	1	0-1.5		19.9			
	2	2.5-4		17.9			
WR-8	1	1-2.5		19.7			
	2	2.5-4		24.8			
	3	5-6.5		32.6			
WR-9	1	0-1.5		29.5			
	2	2.5-4		33.2			
	4	7.5-9		25.1			
WR-10	1	0-1.5		12.0			
	3	5-6.5		18.4			
	4	7.5-9		19.9			
WR-11	2	2.5-4		25.0			
	3	5-6.5		23.2			

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	LT BROWN LEAN CLAY	44	24	20			CL

Project No. N1095342 **Client:** NORTHERN KENTUCKY WATER DISTRICT

Project: SUBDISTRICT H WATER MAIN EXTENSION PROJECT

ALEXANDRIA, KY

● **Source:** WR-1 **Sample No.:** 2 **Elev./Depth:** 2.5-4'

Remarks:

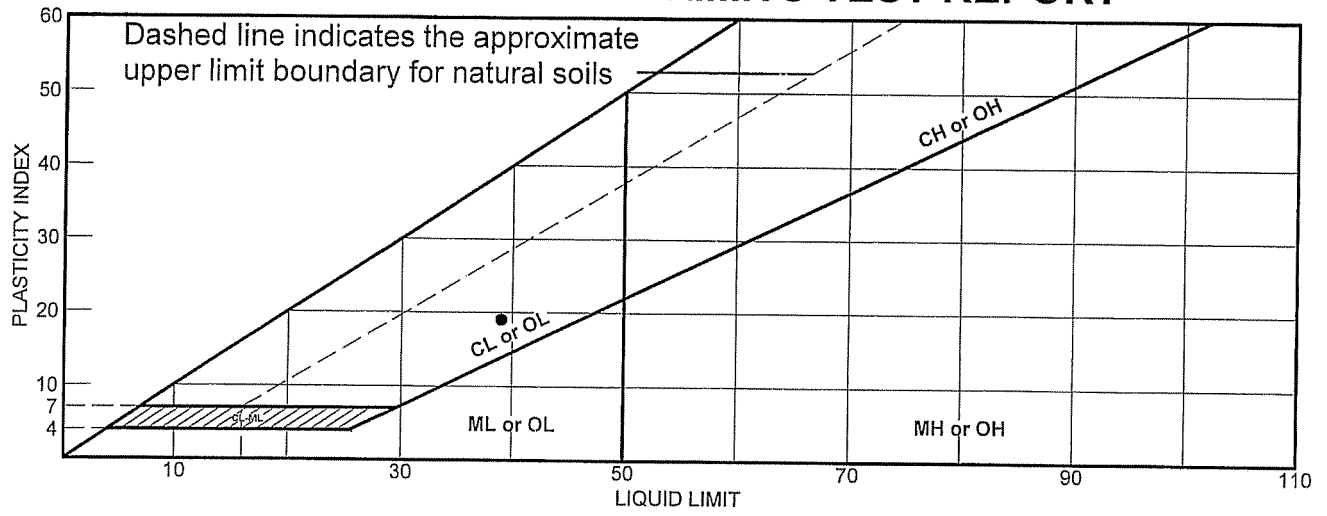
● WC=22.1%

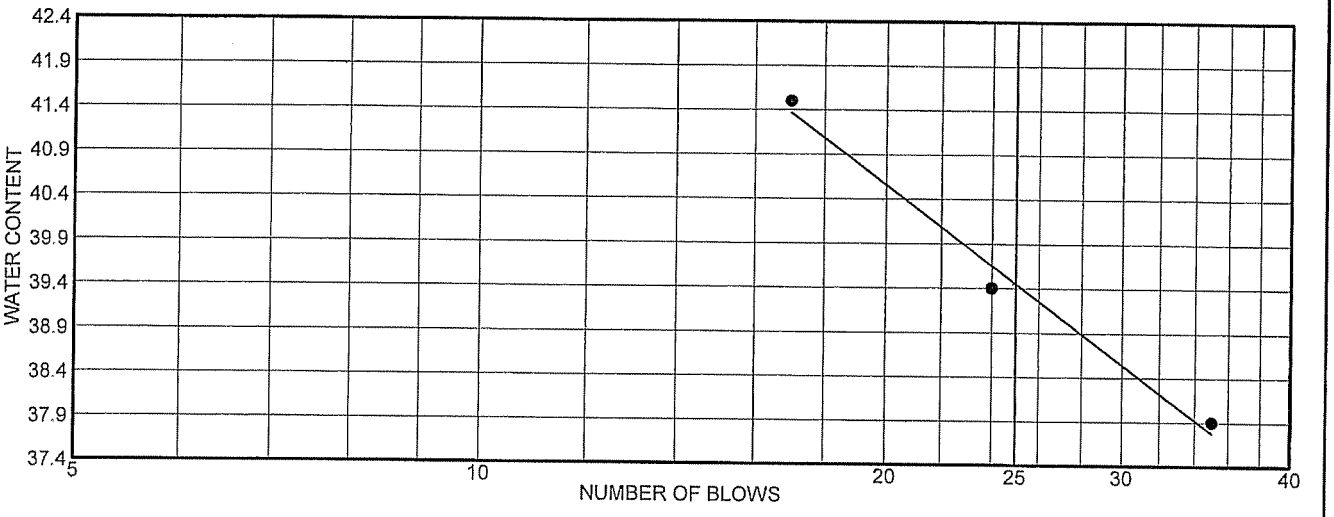
LIQUID AND PLASTIC LIMITS TEST REPORT

H. C. NUTTING COMPANY

Figure 10028

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BROWN LEAN CLAY	39	20	19			CL

Project No. N1095342 **Client:** NORTHERN KENTUCKY WATER DISTRICT

Project: SUBDISTRICT H WATER MAIN EXTENSION PROJECT

ALEXANDRIA, KY

● **Source:** WR-5 **Sample No.:** 2 **Elev./Depth:** 2.5-4'

Remarks:

● WC=25.8%

LIQUID AND PLASTIC LIMITS TEST REPORT

H. C. NUTTING COMPANY

Figure 9947

Laboratory Testing

Selected soil samples were tested in the laboratory to measure natural water content and Atterberg Limits. A calibrated hand penetrometer was used to estimate the approximate unconfined compressive strength of some samples. The calibrated hand penetrometer has been correlated with unconfined compression tests and provides a better estimate of soil consistency than visual examination alone. The test results are provided on the boring logs included in Appendix A.

Descriptive classifications of the soils indicated on the boring logs are in accordance with the enclosed General Notes and the Unified Soil Classification System. Also shown are estimated Unified Soil Classification Symbols. A brief description of this classification system is attached to this report. All classification was by visual manual procedures. Selected samples were further classified using the results of Atterberg limit testing. The Atterberg limit test results are also provided on the boring logs.

APPENDIX C

SUPPORTING DOCUMENTS

GENERAL NOTES

DRILLING & SAMPLING SYMBOLS:

SS:	Split Spoon – 1-3/8" I.D., 2" O.D., unless otherwise noted	HS:	Hollow Stem Auger
ST:	Thin-Walled Tube - 2" O.D., unless otherwise noted	PA:	Power Auger
RS:	Ring Sampler - 2.42" I.D., 3" O.D., unless otherwise noted	HA:	Hand Auger
DB:	Diamond Bit Coring - 4", N, B	RB:	Rock Bit
BS:	Bulk Sample or Auger Sample	WB:	Wash Boring or Mud Rotary

The number of blows required to advance a standard 2-inch O.D. split-spoon sampler (SS) the last 12 inches of the total 18-inch penetration with a 140-pound hammer falling 30 inches is considered the "Standard Penetration" or "N-value".

WATER LEVEL MEASUREMENT SYMBOLS:

WL:	Water Level	WS:	While Sampling	N/E:	Not Encountered
WCI:	Wet Cave in	WD:	While Drilling		
DCI:	Dry Cave in	BCR:	Before Casing Removal		
AB:	After Boring	ACR:	After Casing Removal		

Water levels indicated on the boring logs are the levels measured in the borings at the times indicated. Groundwater levels at other times and other locations across the site could vary. In pervious soils, the indicated levels may reflect the location of groundwater. In low permeability soils, the accurate determination of groundwater levels may not be possible with only short-term observations.

DESCRIPTIVE SOIL CLASSIFICATION: Soil classification is based on the Unified Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

CONSISTENCY OF FINE-GRAINED SOILS

Unconfined Compressive Strength, Qu, psf	Standard Penetration or N-value (SS) Blows/Ft.	Consistency
< 500	<2	Very Soft
500 – 1,000	2-3	Soft
1,001 – 2,000	4-6	Medium Stiff
2,001 – 4,000	7-12	Stiff
4,001 – 8,000	13-26	Very Stiff
8,000+	26+	Hard

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Standard Penetration or N-value (SS) Blows/Ft.	Ring Sampler (RS) Blows/Ft.	Relative Density
0 – 3	0-6	Very Loose
4 – 9	7-18	Loose
10 – 29	19-58	Medium Dense
30 – 49	59-98	Dense
50+	99+	Very Dense

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other Constituents	Percent of Dry Weight
Trace	< 15
With	15 – 29
Modifier	> 30

GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300mm)
Cobbles	12 in. to 3 in. (300mm to 75 mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm)
Silt or Clay	Passing #200 Sieve (0.075mm)

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other Constituents	Percent of Dry Weight
Trace	< 5
With	5 – 12
Modifiers	> 12

PLASTICITY DESCRIPTION

Term	Plasticity Index
Non-plastic	0
Low	1-10
Medium	11-30
High	30+

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]					Soil Classification	
					Group Symbol	Group Name [B]
Coarse Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$ [E]		GW	Well-graded gravel [F]
			$Cu < 4$ and/or $1 > Cc > 3$ [E]		GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH		GM	Silty gravel [F,G,H]
			Fines classify as CL or CH		GC	Clayey gravel [F,G,H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	$Cu \geq 6$ and $1 \leq Cc \leq 3$ [E]		SW	Well-graded sand [I]
			$Cu < 6$ and/or $1 > Cc > 3$ [E]		SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH		SM	Silty sand [G,H,I]
			Fines Classify as CL or CH		SC	Clayey sand [G,H,I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	PI > 7 and plots on or above "A" line [J]		CL	Lean clay [K,L,M]
			PI < 4 or plots below "A" line [J]		ML	Silt [K,L,M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried	< 0.75	OL	Organic clay [K,L,M,N] / Organic silt [K,L,M,O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line		CH	Fat clay [K,L,M]
			PI plots below "A" line		MH	Elastic Silt [K,L,M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried	< 0.75	OH	Organic clay [K,L,M,P] / Organic silt [K,L,M,Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor				PT	Peat

[A] Based on the material passing the 3-in. (75-mm) sieve

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.