Kingston Fossil Plant – Peninsula Site
Hydrogeologic Investigation and Suitability Assessment
Scope of Work

I. Introduction

The Kingston Fossil Plant (KIF) is located at the base of a peninsula formed by the Clinch and Emory River embayments of Watts Bar Lake. Construction of KIF began in 1951 and commercial operation began in 1955. Land acquisition for KIF included approximately 550 acres east of the current plant operational area, commonly referred to as the KIF Peninsula site. TVA is considering development of a Coal-Combustion Byproduct (CCB) disposal facility within this Greenfield site (Figure 1). The area was originally devoted to agricultural and residential use. Proposed development of the CCB disposal facility might encompass 90 acres within the area shown in Figure 1. These cultivated fields are currently used by TWRA to support an onsite wildlife management program.

II. Previous Investigations

The plant site resides within the Valley and Ridge physiographic province, a region characterized by narrow, subparallel ridges and valleys trending northeast-southwest. The controlling structural feature of the region is a series of northeast-striking thrust faults which have forced older rocks from the southeast over younger units. Bedrock units of the Rome Formation (lower Cambrian age), Conasauga Group (middle to upper Cambrian), and the Knox Group (Cambro-Ordovician) subcrop beneath the KIF Reservation in narrow, northeast-trending bands (Figure 2). These units generally dip to the southeast at angles averaging 45 to 50 degrees. The KIF Peninsula site is primarily underlain by the Maynardville formation, Knox Group, and Lower Conasauga Group; however, only the Knox Group immediately underlies the proposed disposal area.

Preliminary site investigations for KIF were conducted by Benziger and Kellberg (1951). However, exploratory borings were in the vicinity of the current plant site. Five of these borings (V - 8+00,V - 6+00,V - 4+00, T - 6+00, R - 6+00; Figure 3) are located on the western margin of the KIF Peninsula site. Overburden thickness in the area of the main plant site is highly variable, ranging from about 5 ft along a portion of the northern perimeter of the site to a maximum of 65 ft on the western boundary. Overburden in the main plant area consists primarily of unconsolidated alluvial deposits that typically grade coarser with depth. Ground elevations at the KIF Peninsula site are 20 to 60 higher than those of the main plant site (Figure 4). Hence, overburden materials at the KIF Peninsula might be expected to be primarily of residual origin. Modern day floods near the mouth of Clinch River (CRM 0.7) suggest that the highest modern (1903) flood measurement was near 746 ft-msl. However, the spatial extent of fluvial deposition has not been mapped at the KIF Peninsula site.

Carpenter and Bohac (1988) performed a subsurface investigation at the KIF Peninsula site in 1988. As part of this investigation, fifteen exploratory borings were drilled to top of bedrock (SPT-1 to SPT-16; Figure 3) by Singleton Material Engineering Laboratory (Singleton, 1988) and seismic refraction surveys were completed along four transects (Figure 3) to define variation in top of bedrock. Overburden thickness ranged from 10.3 to 52 feet and averaged 30 feet based on SPT borings. Carpenter and Bohac (1988) suggested that medium to fat clays are the predominant soil type at the Peninsula site, but ranged from fat to silty with colors from dark brown to light yellow. Basal gravel zones and layers of sandy clay to clean, fine sand were also encountered in the borings. Boring logs from Singleton (1988) describe soils below residual soils and immediately above bedrock as alluvial in nature, but this might be the result of poor field classification since existence of alluvial deposits below a residual soil and immediately above bedrock is geologically unlikely at this location. Also, the description of the color of these so-called alluvial soils in the logs of these borings indicate that the field classification is likely to be erroneous. Lab permeameter testing of two silty-sandy-clay soil samples provided vertical hydraulic conductivity estimates of 3.5E-08 and 8.6E-08 cm/s, and porosity values of 0.41 and 0.44. These values are typical of residuum.

Subsequent boring work by TVA and MACTEC Engineering (MACTEC, 2003) included the installation of 31 Geoprobe™ borings to refusal (GP-1 to GP-40), six auger borings to refusal (B-11, B12, B-13, B-18, B22, and B-23), and two bedrock corings into the upper 30 feet of bedrock (B-22 and B-23; Figure 3). MACTEC (2003) describes the subsoil encountered in all test borings for the full depth as "residuum". However, the log for boring B-11 indicates the presence of fine subrounded gravel. These observations, coupled with those of Singleton (1988), suggest a possibility that lower elevations of the site may have been subjected to fluvial deposition. However, these data may simply represent weathering products (e.g. residual gravel and sandy facies) associated with the Knox. A 1924 pre-impoundment map of the Clinch and Emory Rivers (Figure 5) indicates that erosion of the KIF Peninsula site has primarily occurred along eastern margins of the site along the Emory and along south-eastern parts of the site just downstream of the confluence of the rivers.

The most recent site investigation has involved groundwater level monitoring at piezometers B, C, E, F, and I (Figure 3). These 1-inch diameter piezometers were installed in 1993 using Geoprobe™ methods and extend to top of bedrock. Continuous water level measurements were collected at piezometers B and F from September 2003 to present using pressure transducer dataloggers (Figure 6). Two additional dataloggers were recently installed at piezometers C and E to supplement the water level database.

III. Karst Features

The Knox Group is a thick sequence of silica-rich carbonate rocks that weather to form silty clay soils rich in chert and resistant to erosion. Depth to bedrock is highly variable, but in many locations there is an extremely thick mantle of silty clay residual soil over solid rock. The Knox Group, together with the Maynardville formation in the Conasauga Group, are the principal groundwater-bearing rock units on the site. The width of valleys and ridges is determined by geologic factors such as the dip angle and formation thickening due to thrust faulting of underlying geologic formations. Weathering and erosion processes, coupled with the general dipping attitude of bedrock underlying the area, result in a relatively steep northwest-facing slopes, while southeast-facing slopes are commonly more gentle.

Figure 7 shows topography of the KIF Peninsula site based upon pre-disturbed mapping by TVA in 1950. Seven dolines are highlighted for easy viewing. The largest doline (near the centroid of the proposed footprint) was subsequently drained to the Clinch River via a large canal. This doline also impounds water.

A visual inspection of all dolines on the site indicates no direct drainage to bedrock. Rather, the dolines are all closed. This is supported by existing boring data that indicates a minimum of 10 ft of overburden material between the base of dolines and the top of the Knox Group. As shown in Figure 8, boring and seismic refraction data suggest that bedrock depressions are generally correlated with the dolines illustrated in Figure 6.

Borings in the vicinity of the larger two dolines (e.g. GP-2, GP-5, GP-6, B-12, B-13, GP-14, etc) suggest appreciable overburden thickness (Figure 9). Parts of the upgradient sinkhole (now the pond area) may have been infilled. Smaller dolines to the northeast (near GP-25 and GP-27) also indicate appreciable overburden thickness. However, these depressions in the bedrock surface are oriented along structural strike and solutioned fractures in the Knox are likely interconnected with the larger downgradient dolines. The area near GP-34 and GP-40 does not indicate a depression in bedrock surface although the 1950 topography map (Figure 7) indicates a doline. Likewise, existing boring data doe does not suggest decreasing overburden thickness. It appears that this doline was infilled. It would not be surprising that solutioned fractures extending from the end of the cove near this area accounted for stoping of overburden to reservoir.

Knox bedrock outcops along the bank of the Clinch River, but is over-floated over east of seismic line L-J (coincident with topographic break). Karst geomorphologic development has progressed primarily along a fracture zone(s) paralleling geologic strike (NE-SW) - typical of the Knox in East Tennessee. This produces the larger bedrock depressions/dolines that are elongated in strike-parallel fashion. Site topography and antecedent surface drainage has also influenced karst morphology at the site. Fractures orthogonal to strike probably produce secondary solutional development and pirating of residual overburden toward the reservoir. This is exacerbated by surface drainage (e.g. end of cove feature).

IV. Investigations to Support Permit

Task 1. Exploratory Drilling and Soils Testing

Additional exploratory boring and Geoprobing™ at the site shall be conducted to achieve an equivalent triangular grid pattern having a spacing of approximately 200 ft between holes (Figure 10). Existing boreholes and probings have been considered in the selection of locations for the additional boreholes and probings (Attachment 1). Supplementary borings and Geoprobe™ locations are located in the immediate vicinity of larger site dolines. During exploratory drilling, additional boreholes and probings will also be located in areas exhibiting anomalies such as severe bedrock weathering.

Approximately 22 exploratory boreholes will be sampled continuously or at 5-ft intervals to top of bedrock using the standard penetration test (SPT) spoon. Approximately 40 undisturbed representative samples of overburden soil will be collected using the Shelby tube method and a minimum of ten samples will be selected for various lab tests - e. g. permeability tests (ASTM D-5084),. Bedrock coring will be conducted in eight boreholes to characterize the upper 30 ft of bedrock and in three boreholes to characterize the upper 10 ft of bedrock. In one borehole, the coring will be completed to a depth of 60 ft below top of bedrock (boring NB 44).

89 new borings or geoprober

8-12 cone penetrometer Tests

Boring logs will include ground surface elevations, date of drilling, method of drilling, method of borehole sealing, textural classification, sample intervals, SPT blow counts, depths to water bearing zones, static water levels during drilling and 24-hrs after completion of drilling, and descriptions of the soils using the unified soil classification system. Selected soil samples from each significant stratum encountered will betested in the laboratory for grain-size distribution, natural moisture content, Atterberg limits, permeability (where necessary), compressibility and triaxial-shear testing. Attachment 1 describes the geotechnical component of the investigation in greater detail.

Prior to grouting each borehole, 24-hr static water level will be measured to the nearest 0.1 ft and referenced to ground elevation. A neat cement/bentonite grout mixture consisting of 94 pounds of Portland cement (ASTM C150-69A), 4 pounds of powdered bentonite, and 6.5 gallons of water shall be used for grouting. The borehole shall be pressure grouted from the bottom of the hole to ground surface using a grout pump and tremie pipe system. The contractor is responsible for documenting the grouting procedure, including boring number, measured total depth and diameter, static water level prior to grouting, grout composition, and volume injected.

Task 2. Literature Review and Carbonate Features Inventory

All relevant literature and available geologic, soil survey, and topographic maps of the site area will be examined. The existing carbonate rock features inventory will be expanded to identify any carbonate landforms (e.g. dolines, sinkholes, and springs) that might exist at the site. As part of the carbonate features inventory, a visual survey of existing bedrock outcrops will be completed by a registered professional geologist to identify formational changes, bedrock joints and orientations, etc. Samples will be collected using a rock hammer and classification of the samples will be used to subdivide bedrock formations. Strike and dip measurements will also be performed during the survey.

Residuum thickness is substantial over the vast majority of the site and > 10-ft thick in dolines. Boring logs and lab permeability measurements indicate of low to moderate hydraulic conductivity values for overburden soils. Due to the absence of open karst features (e.g. sinkholes or sinking streams) and resurgence locations, qualitative dye tracing at this site would be extraordinarily difficult. Likewise, active or passive monitoring for tracer dyes would require a network of monitoring wells that might not intercept interconnected fractures. Therefore, dye tracing is not proposed in this site investigation. However, single-well aquifer testing will be conducted to characterize the hydraulic properties of overburden soils and shallow bedrock.

Task 3. Monitoring Well Installation and Water Level Measurements

Approximately eight selected boreholes will be completed as 2-inch diameter monitoring/test wells in both bedrock and overburden. Water level data from new wells, existing piezometers, and 24-hr water level measurements in borings will be used to prepare a potentiometric surface map at high and low flow conditions.

Overburden/Epikarst Wells

The well casing shall consist of threaded, flush-jointed schedule-40 PVC pipe with an outside diameter (OD) of 2 inches. The well screen shall consist of 10-ft to 20-ft sections of threaded, flush-jointed PVC pipe with 0.01-in. slots. The well screens shall extend through the saturated overburden, epikarst zone, and upper 3 ft of bedrock. No drilling mud or filler material shall be utilized in drilling of overburden/epikarst wells. Each well shall possess a 2-ft section of blank casing and cap at bottom. After the well screen is set to the desired depth, a "filter-pack" consisting of #1 sand pack will be installed around the screen to 2 ft above the top of sand pack. Immediately above the sand pack, a bentonite seal (minimum 1-ft thick) will be placed. After allowing time for hydration, the well annulus above the bentonite layer will be filled with drill-cuttings.

Bedrock Wells

Bedrock wells will be installed using auger drilling in soil and coring in bedrock. These wells shall extend approximately 30 ft into bedrock (except at boring location 44 where coring extends to a depth of 60 ft). The bedrock wells will be completed with materials similar to their counterparts (above) except that #2 filter-pack shall be used around the screen.

Well Development

All new wells will be developed using a combination of over pumping/backwashing techniques accompanied by cyclic surge-blocking. One well development cycle shall follow the sequence of over pumping, then backwashing, then surge-blocking. A minimum of three complete development cycles shall be conducted at each test well. The pump used for over pumping shall be designed for well development and be capable of pumping a minimum of 3 gpm at 20 ft TDH. Backwashing shall consist of rapid introduction of water by gravity until the well overflows. The contractor shall record water turbidity during development based on visual observations.

Task 4. Offsite Water Supply Survey

A field survey will be conducted to identify offsite groundwater supplies and public water supplies located within approximately one mile of the KIF Peninsula site. Boggs and Julian (2004) identified 13 residential wells and one public water supply spring located within one mile of the existing ash disposal area. Although these water supplies are located more than one mile east of the KIF Peninsula site, they will be resurveyed as part of this task. The TDEC groundwater supply database for this area will be obtained to determine if new groundwater supply wells have been installed in the site area. Hydraulic boundaries (Clinch and Emory Rivers) to the KIF Peninsula site reside to the north, west, and south. Hence, groundwater supplies on opposite river banks will not be included in this survey. Surface water supplies within one mile of the KIF Peninsula site will also be identified via TVA databases, interviews with local utility districts, and contacts with the TDEC Division of Water Supply.

Task 5. Aquifer Testing

Single-well pumping tests and borehole flowmeter surveys will be performed at new monitoring/test well locations. These tests involve pumping a well at a constant rate while monitoring the water level response in the pumped well. Conventional aquifer tests produce estimates of the transmissivity and average hydraulic conductivity for the aquifer, but reveal little about the spatial distribution of aquifer properties which invariably exist in geologic media. A sensitive electromagnetic (EM) flowmeter capable of measuring flow rates as low as 20 mL/min will be used to measure vertical flow in each well during constant-rate pumping. Flow measurements will generally performed at intervals of 0.5 to 1.0 ft along the full length of the well screen to obtain discrete estimates of hydraulic conductivity corresponding to the flow measurement intervals and to identify hydraulically active fracture zones. The EM flowmeter is also capable of measuring the natural (ambient) vertical flow often present in wells or boreholes. Knowledge of ambient flow allows one to infer the direction of the vertical component of the hydraulic gradient in the vicinity of the test well.

Task 6. Report Preparation

Data collection, analyses, and interpretation from all hydrogeologic investigations identified above will be delivered in the form of a report describing the suitability of the site for the proposed CCB disposal facility.

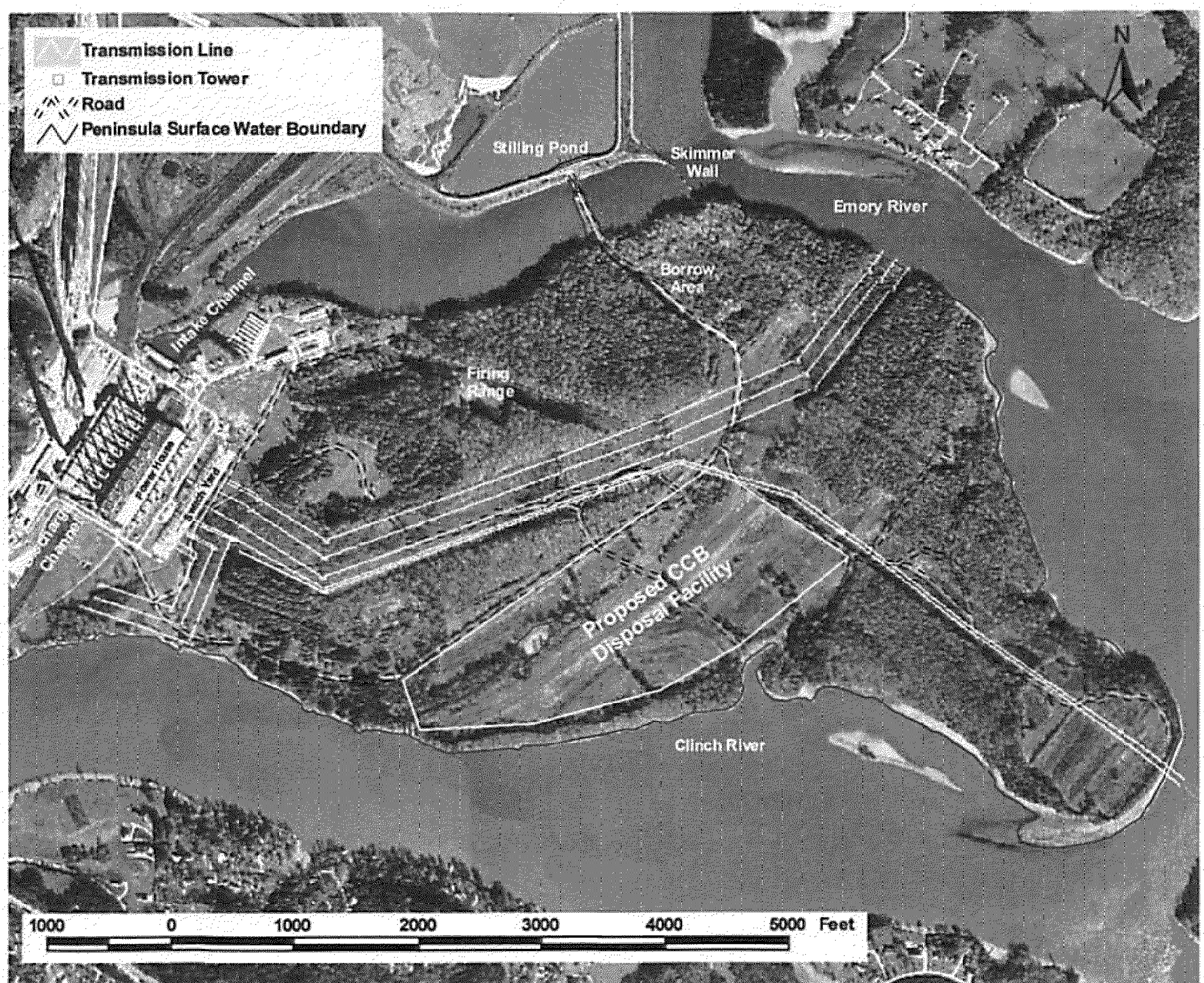


Figure 1. Site Map Showing Proposed CCB Disposal Facility Footprint

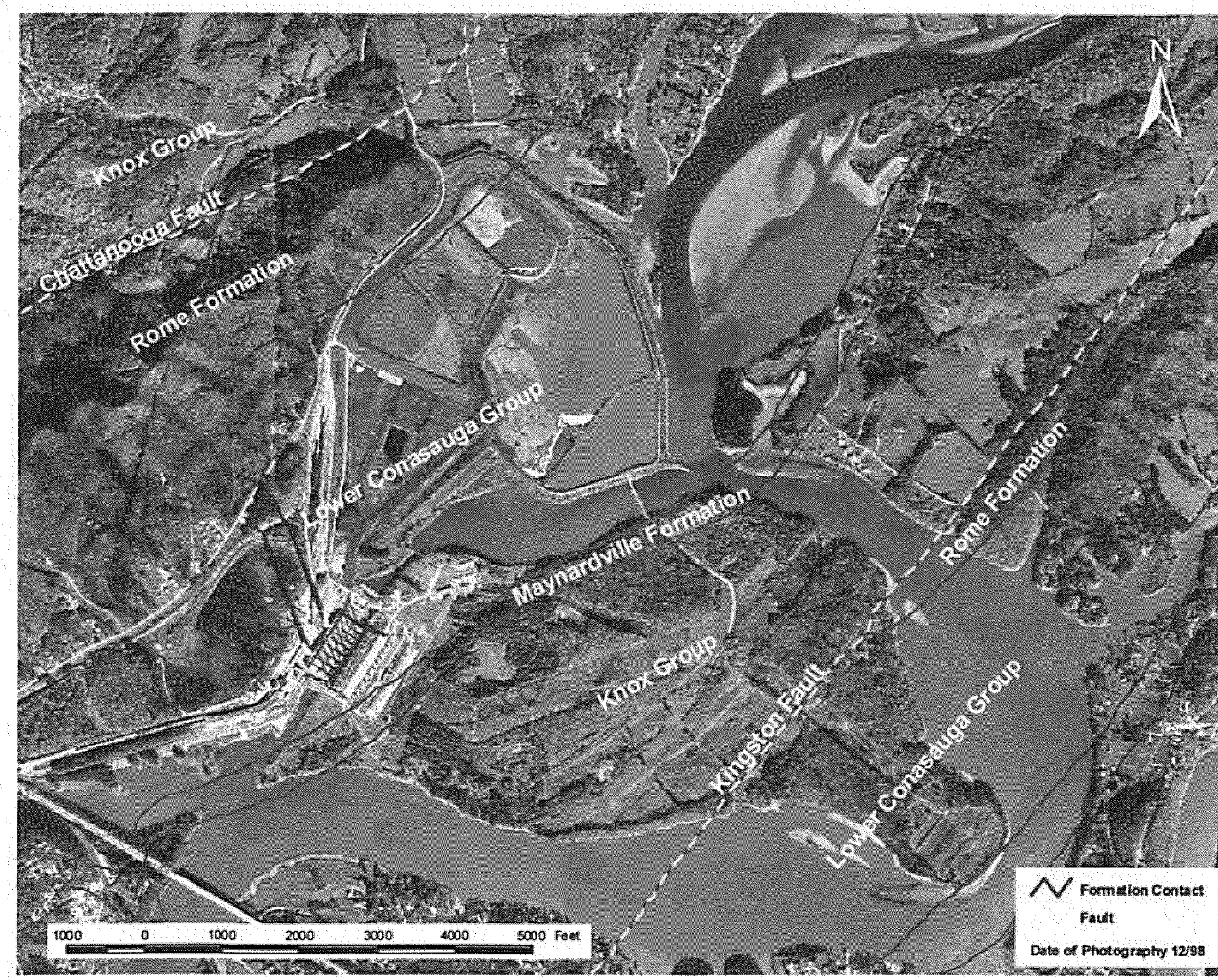


Figure 2. Site Map Showing Geologic Formations and Faults

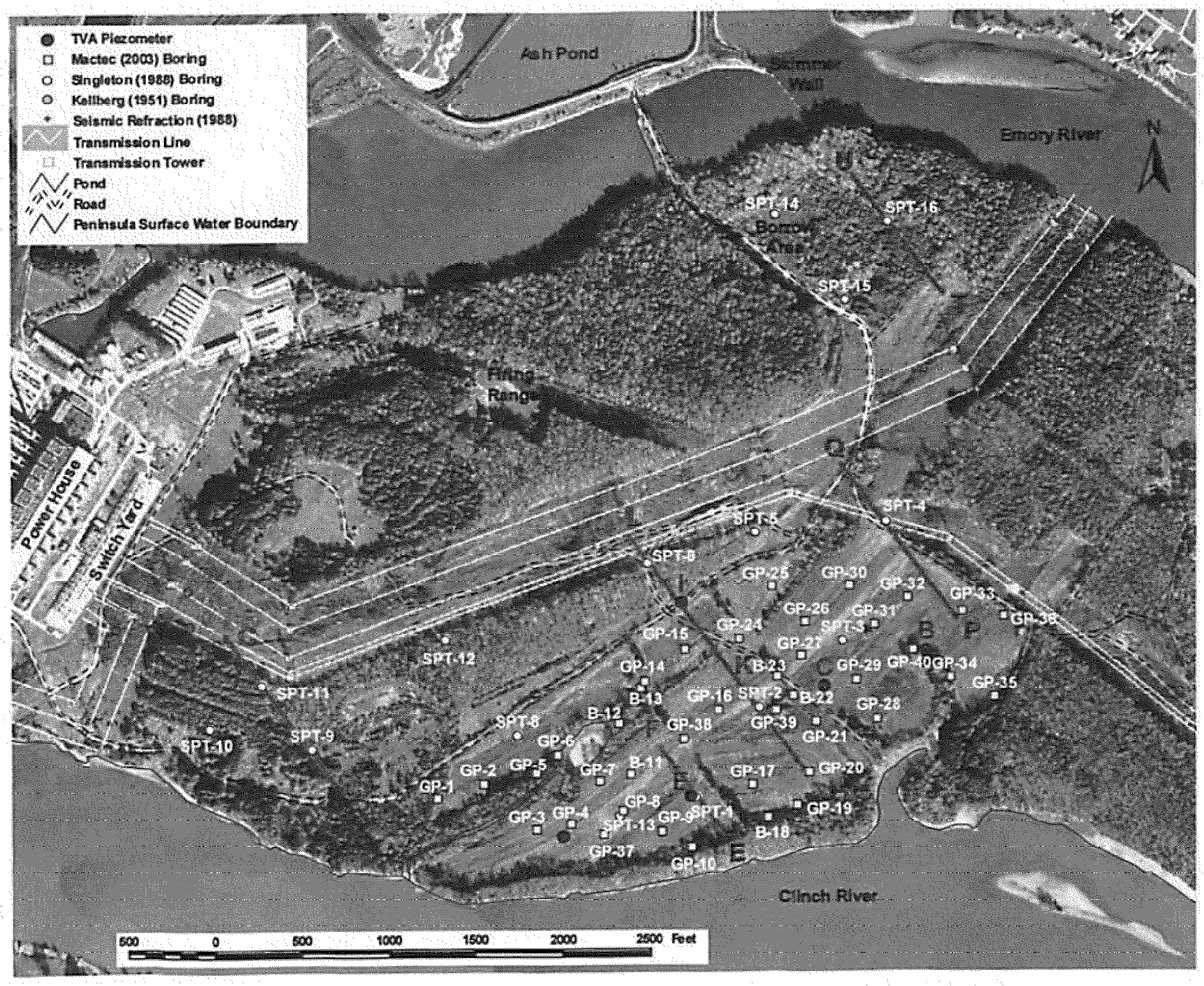


Figure 3. Site Map Showing Locations of Existing Borings and Seismic Refraction Surveys

Figure 4. Site Topography

Figure 5. 1924 Pre-Impoundment Topography (adapted from USACE, 1924)

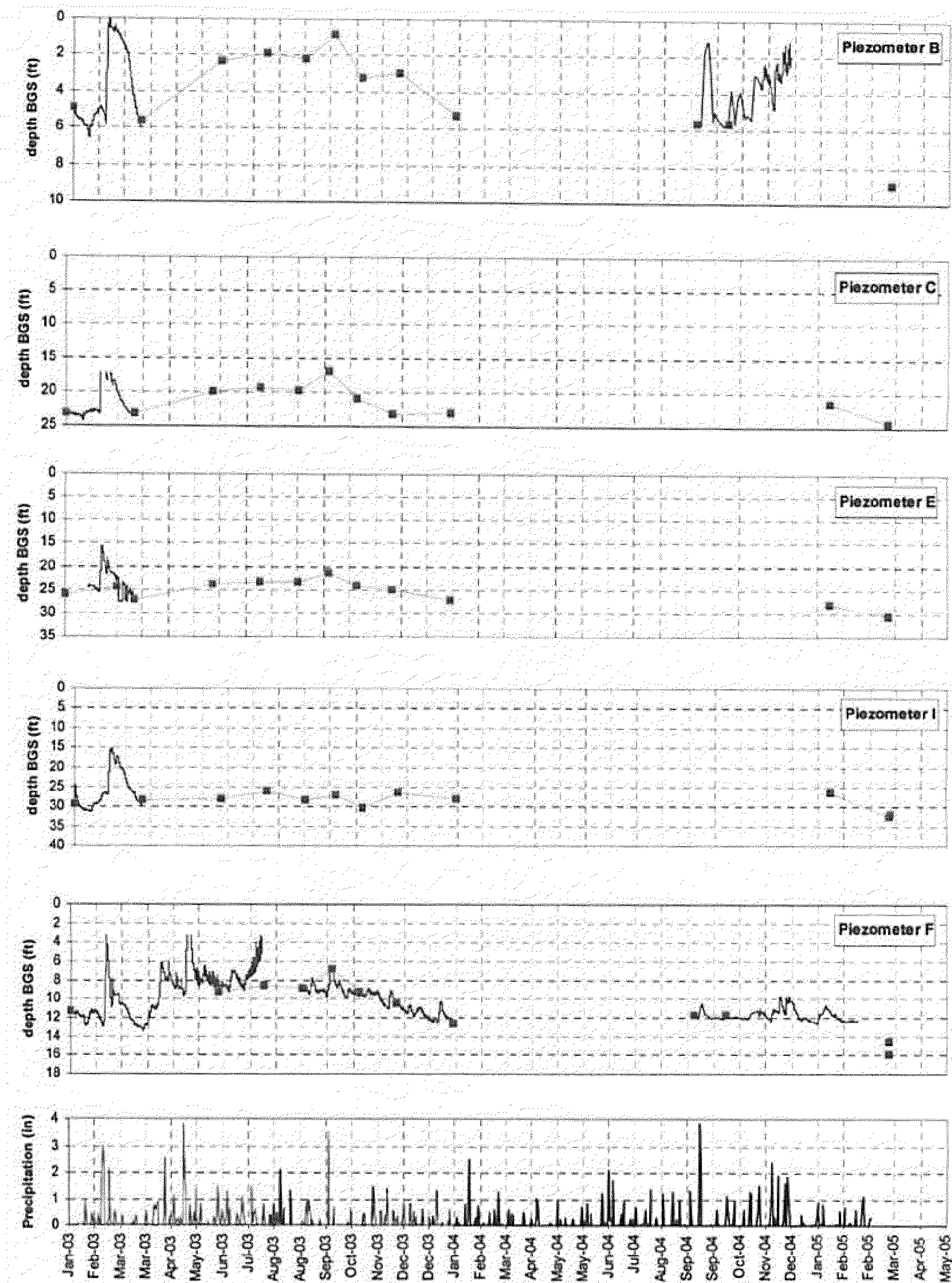


Figure 6. Groundwater Level Data and Precipitation

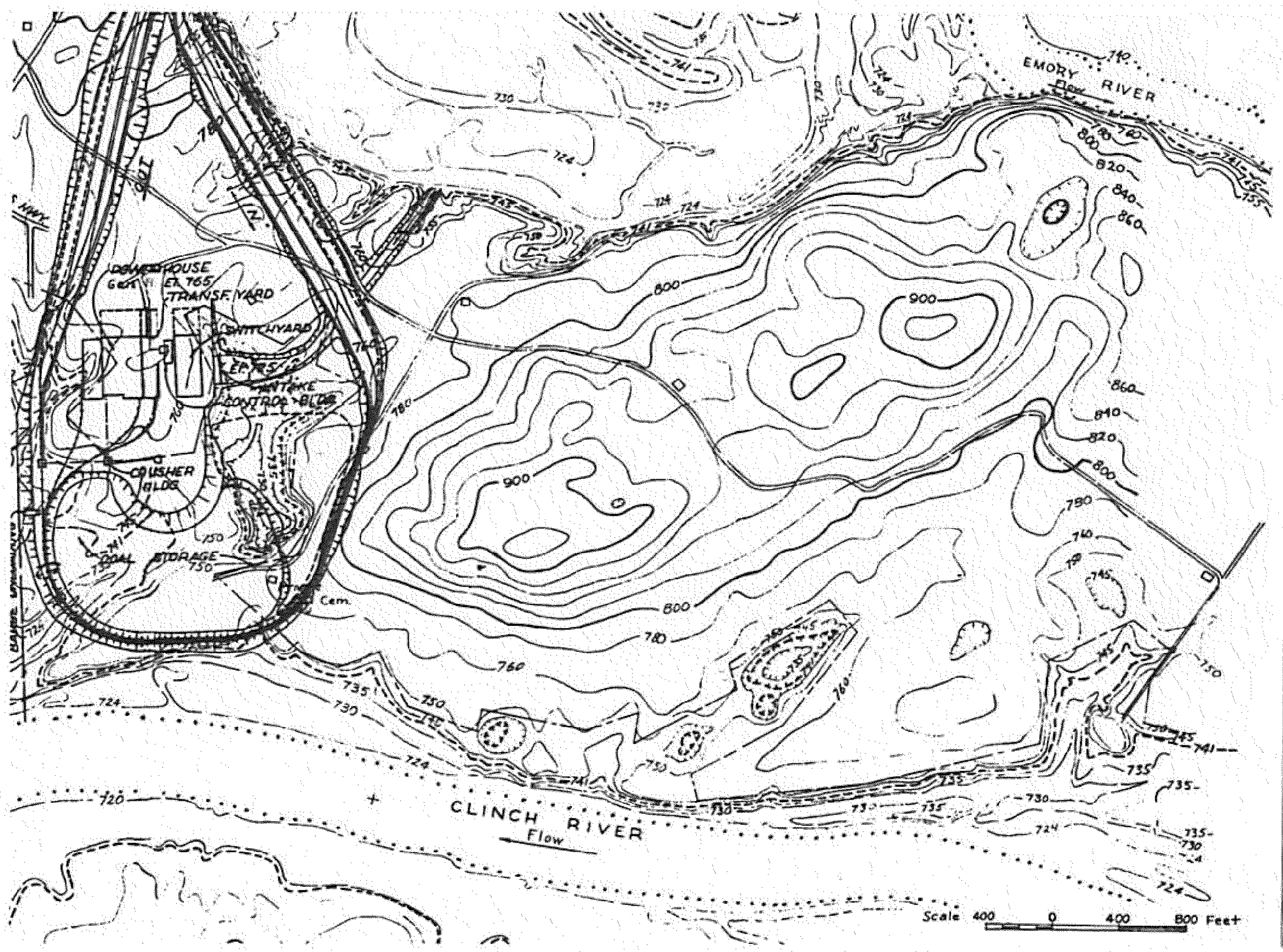


Figure 7. 1950 Pre-Disturbed Topography (adapted from TVA, 1950)

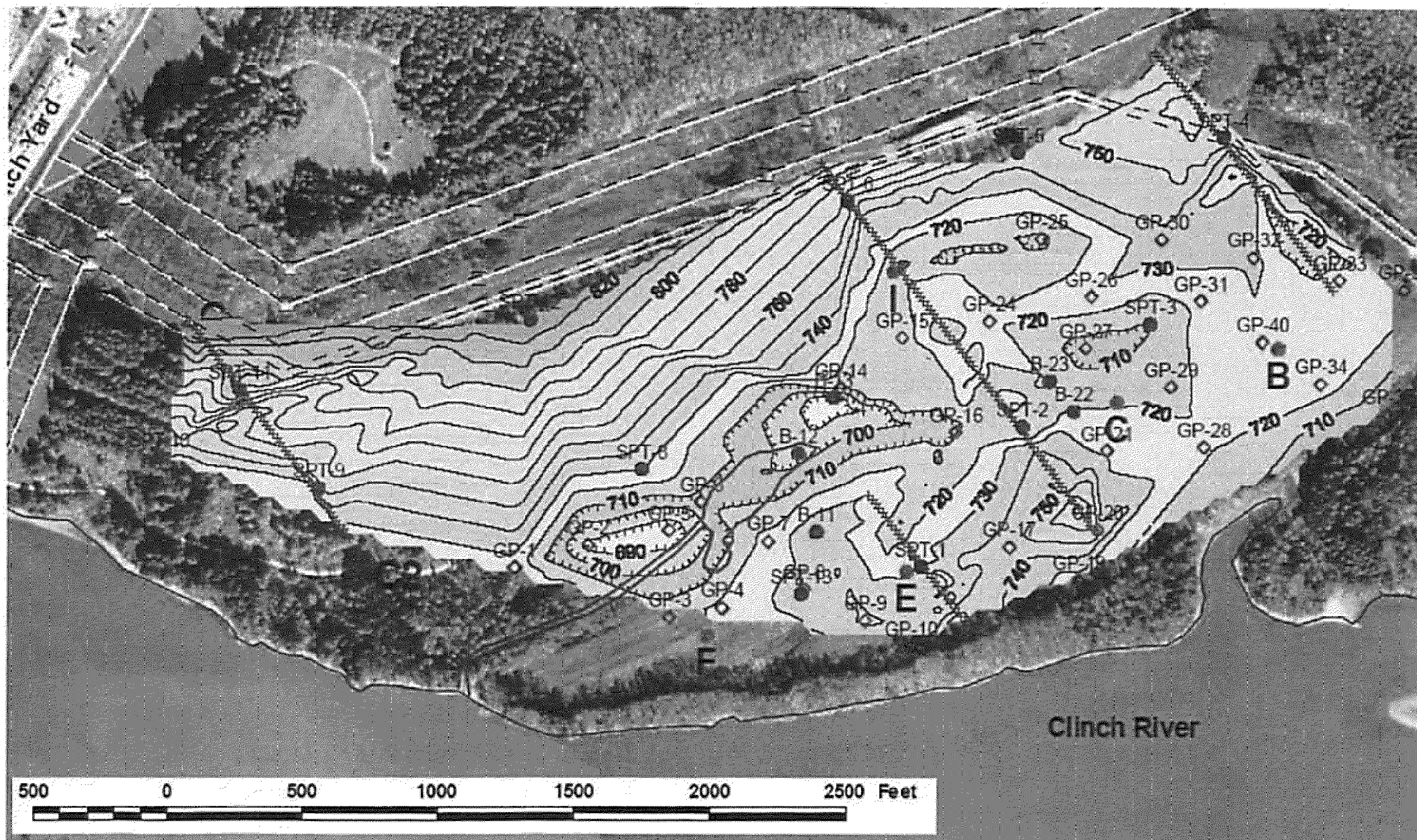


Figure 8. Top of Bedrock Based on Borings and Seismic Refraction Data (contour interval 10 ft)

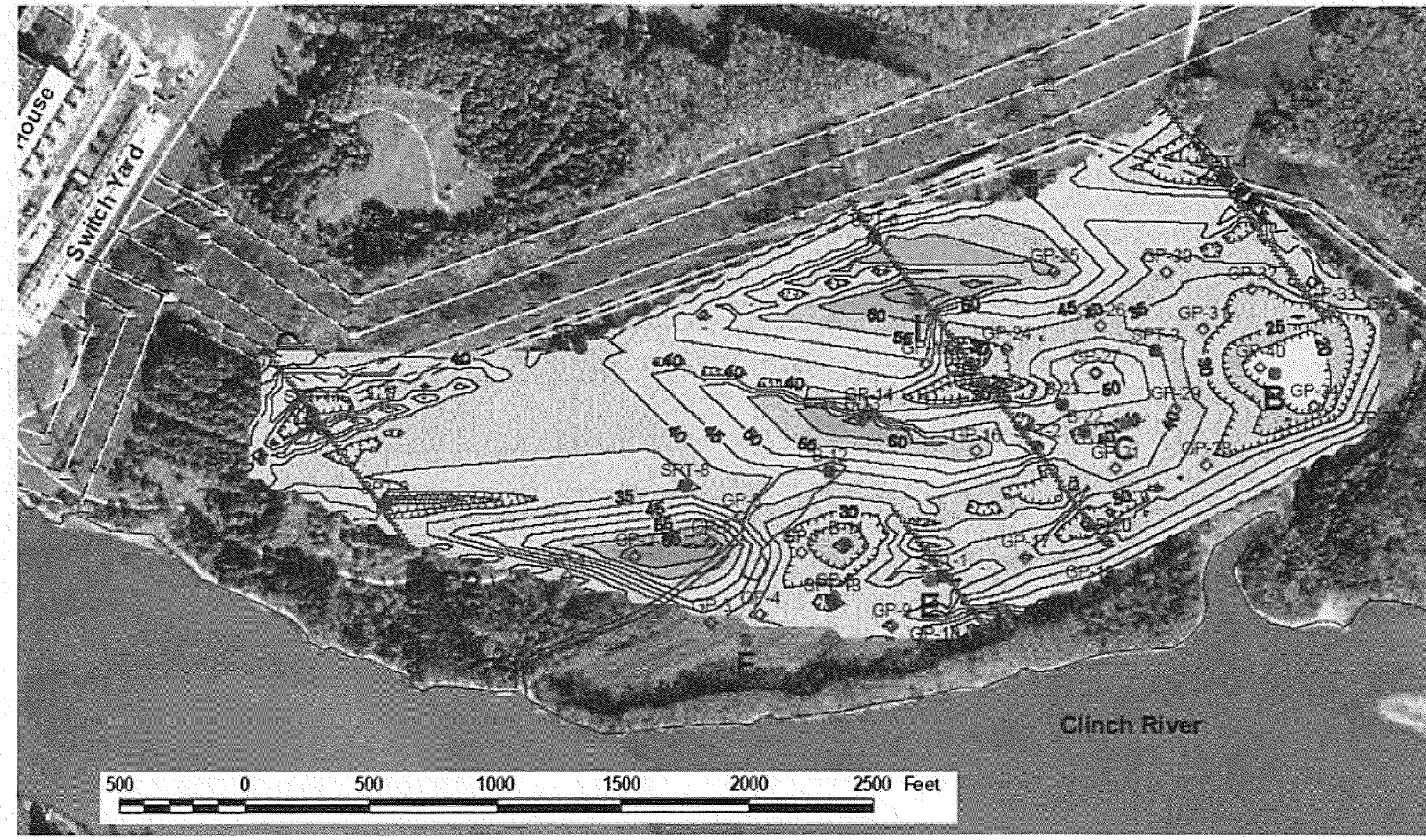


Figure 9. Overburden Thickness Based on Borings and Seismic Refraction Data (contour interval 5 ft)

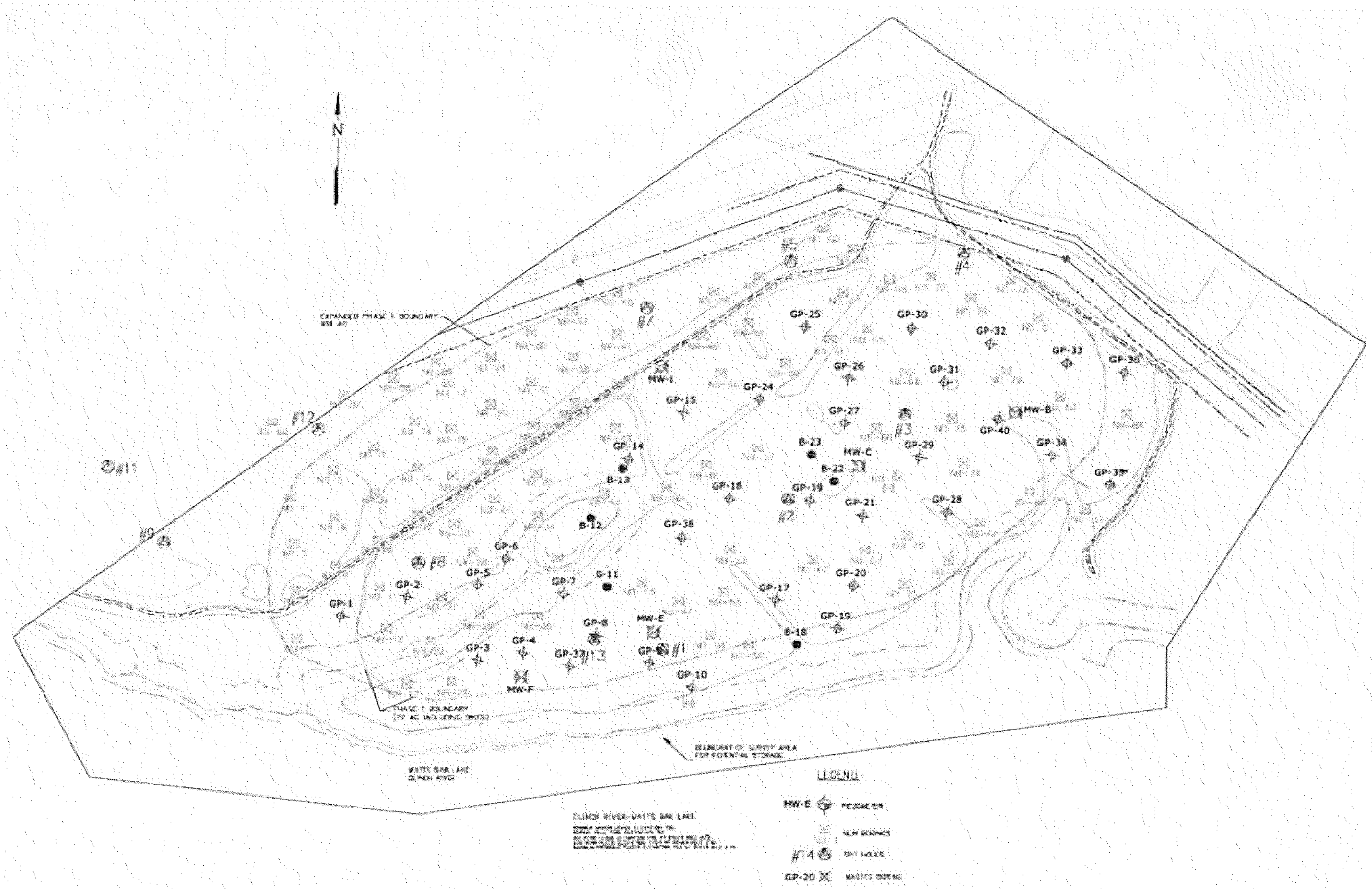


Figure 10. Site Map Showing Proposed Exploratory Borehole and Geoprobe Locations

References

Benziger, C.P. and J.M. Kellberg, 1951, "Preliminary geological investigations for Eastern Area Steam Plant", Division of Water Control Planning, Geologic Branch, Tennessee Valley Authority, Knoxville, Tennessee.

Boggs, J.M, and H.E. Julian, 2004, "Kingston Fossil Plant, Hydrogeologic Evaluation of Coal-Combustion Byproduct Disposal Facility Expansion", Report No. WR2004-2-36-130, TVA, Research and Technology Applications, Knoxville, Tennessee.

Carpenter, W.C., and C. Bohac, 1988, "Kingston environmental assessment for fly ash disposal", TVA Engineering Laboratory Report, Norris, Tennessee.

USACE, H. C., 1924, "Topographic Map of Clinch and Emory River Valleys", TVA Map Files.

MACTEC, 2003, "Report of geotechnical exploration, proposed scrubber stack disposal area, Kinston Fossil Plant, Kingston, Tennessee", MACTEC Engineering and Consulting of Georgia, Inc., Knoxville, Tennessee.

Singleton, 1988, "Kingston Steam Plant ground water assessment," SME-SOI-88-006, Division of Nuclear Engineering, Materials Technology Branch, Singleton Materials Engineering Laboratory, Knoxville, Tennessee.

TVA, 1950, "Preliminary report on the Kingston site for Steam Plant A", Tennessee Valley Authority, Knoxville, Tennessee.

ATTACHMENT 1

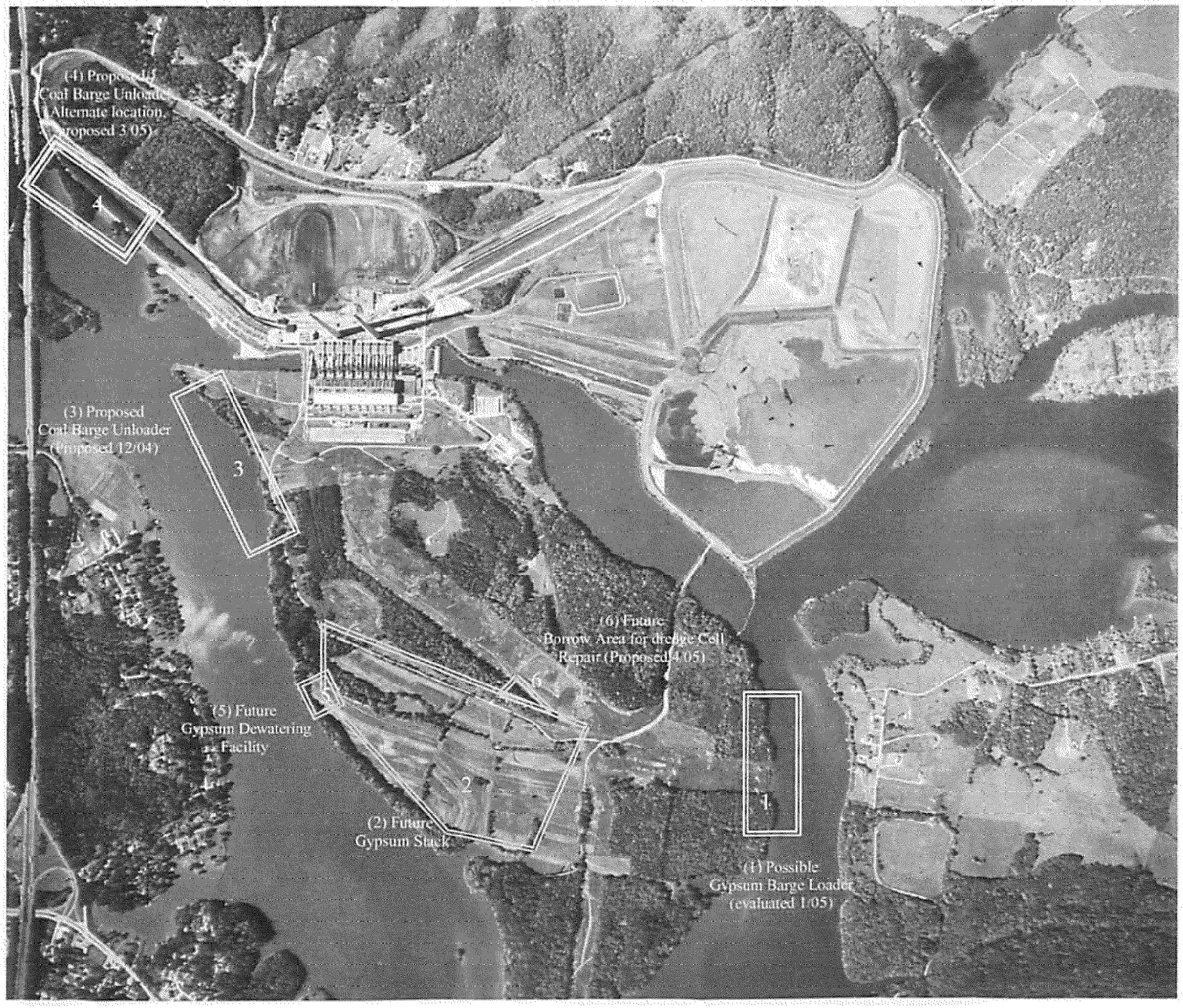
Kingston Fossil Plant – Peninsula Site Phase 1 Geotechnical Investigation, April 2005

This attachment describes briefly the Phase 1 Geotechnical Investigation of the Kingston Fossil Plant Peninsula site. This investigation will assist in determining the feasibility of siting a CCB (gypsum) disposal facility at this location. This investigation complies with TN Rule 1200-7-.04 (2) q, Karst Terrain as discussed in the main document to this attachment. This geotechnical investigation will characterize the engineering properties and conditions necessary to perform preliminary and conceptual evaluations of a gypsum landfill configuration (including max height, loading, and approximate elevation of the bottom of the facility). This information will be provided to the vendor early in the investigation.

The Phase 1 geotechnical investigation will include:

1. Site surveys, walkovers, and reconnaissance as necessary to look for distinguishing features.
2. Figure 10 gives layout of site with indicated Geoprobe™, boring, sampling, and monitoring well locations. Some of these locations may change during the course of the field work.
3. Geoprobe™ holes at 8 to 12 locations over two working days to characterize soil thickness.
4. Auger borings and sampling locations as shown on the attached spreadsheet.
5. Sample types taken in the field include SPT, Shelby tubes, 5-gallons buckets, large and ½ gallon bags for the for following tests :
   A. Five gallon buckets, 3 each, 80-percent full with soil (no topsoil allowed, dig down pass root zone) for ASTM D-698 **5-point moisture** density tests (NOT FOUR POINT TESTS).
   B. Moisture content samples on all SPT and Shelby tube samples, ASTM D2216 Oven Dry Method
   C. Bag, SPT, or Shelby tube samples or soils from triaxial and permeability tests shall be used for grain size D 422 + D1140-200mm + hydrometer to - 0.002mm and Atterberg Limits tests using 3 point procedure in D-4318.
   D. Four Pinhole Tests for Erodibility of Clays – D-4647.
   E. 4 inches soil for each Flexible Wall Permeameter Hydraulic Conductivity Test Specimen D-5084.
   F. 24 inches soil for each Three Point Q Type D-2850 Triaxial Tests.
   G. 24 inches soil for each Three Point CU D-4767 Triaxial Tests.
6. As the spreadsheet indicates, monitoring wells and pump tests or slug/ or more likely in well flow meter tests will be conducted.
7. Use hollow stem augers and NX coring for exploratory borings.
8. As indicated, obtain sufficient (24-inches) of soil from **each layer** for **EACH** triaxial test (Q or CU) and at least **another 4-inches for hydraulic conductivity testing.** If necessary, offset to new boring location to obtain sufficient Shelby tubes of each target layer to ensure sufficient sample length exists upon deliver of Shelby tubes to laboratory.
9. Licensed Geotechnical Engineer or Professional Geologist experienced in geotechnical explorations shall **confirm in writing before leaving each hole** that the total recovery for each soil layer meets or exceeds the REQUISITE MINIMUM REQUIREMENTS outlined by ASTM for east test by a comfortable margin of safety.

10. All Shelby tubes shall be sealed with BEE's wax according to the attached procedure, packed, sealed as indicated, AND transported to the testing laboratory in an UPRIGHT position.
11. Rock depths are minimums.
12. Must grout the boreholes in accordance with TN Rule 1200-1-7 and as stipulated in this scope of work.
13. Obtain ground water levels in all borings both after completion and 24 hours after completion of drilling.
14. Atterberg Limits tests shall use 3 point procedure as outlined in D-4318 and plotted results shall be presented with the report.
15. Consolidation testing will start loadings at no greater that 0.1 or the in situ effective stress, whichever is lower, unless authorized in writing by Project Manager. All consolidation test data shall be reduced by the square root of time method to avoid influence of secondary effects. All time deflection data, initial machine deflections, conversion factors, etc, shall be turned over in printed and readable electronic format to allow independent review of results.
16. Contractor shall provide adequate personnel to ensure drilling progresses in expeditious manner, for example, to allow for steam cleaning of augers and other "house keeping" activities.
17. Allow two full working days of CPT work and estimate 8-12 CPTs to be installed. Locations indicated on attached spreadsheet are preliminary.
18. Field classification of soil and bedrock core samples shall be performed by a Professional Engineer (geotechnical by training) or Professional Geologist (PG) licensed in the state of Tennessee.


(4) Proposed
Coal Barge Unloader
(Alternate location,
Proposed 3/05)
4
(3) Proposed
Coal Barge Unloader
(Proposed 12/04)
3
(6) Future
Borrow Area for dredge Cell
Repair (Proposed 4/05)
6
(5) Future
Gypsum Dewatering
Facility
2
(2) Future
Gypsum Stack
1
(1) Possible
Gypsum Barge Loader
(evaluated 1/05)