PARSONS E&C

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TENNESSEE VALLEY AUTHORITY
CONTRACT 99998970
KINGSTON FOSSIL PLANT
SCRUBBER ADDITION
GYPSUM STACK
PHASE 1 STUDY
PR- 0637 – PCN FOS052

March 5, 2004
PP-7836-DL-C

Mr. H. L. Petty
Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402-2801

Dear Mr. Petty:

Parsons E&C is pleased to provide three copies of the Final Phase 1 Report Revision 0 for the gypsum stack study at Kingston Fossil Plant. The report and attachments are also being provided to you on CD ROM diskette for archival purposes.

Because a large number of sketches were created for this study, they were not all included with the report; however the CD ROM diskette contains sketches in both Autocad and Adobe Acrobat PDF formats, along with the report and attachments in electronic format.

Parsons E&C appreciates this opportunity to provide engineering services to TVA. If you have any questions, please feel free to contact me at (423) 757-8088.

Very truly yours,

Daniel R. Smith, P.E.
Project Manager

CC: Project Files
Attachment: Three copies of Report;
CD ROM Diskette

TENNESSEE VALLEY AUTHORITY
KINGSTON FOSSIL PLANT
PROPOSED SCRUBBER ADDITION
GYPSUM STACK DISPOSAL OPTIONS
PHASE I REPORT

PCN: FOS052
REVISION 0

FEBRUARY 27, 2004

Prepared/Approved by:

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1 INTRODUCTION

This study was initiated to develop preliminary concepts and costs for gypsum sludge disposal at a location on the Kingston Fossil Plant (KIF) Reservation southeast of the powerhouse (Figure 1-1). This area is bounded by the Emory and Clinch Rivers (Watts Bar Lake), and is distinguished by its peninsula shape. The study included a limited geotechnical investigation to determine the feasibility of its use as gypsum disposal facility. Throughout the study, scoping meetings were held with the Joint Project Team (JPT), a group of TVA employees and Contractors representing a cross section of Engineering, Environmental Affairs, Plant, and other operations personnel.

The results of the initial peninsula site study (Option 1) were presented to the JPT in March of 2003. Plant representatives and operations personnel desired that the ash pond location be studied for potential use as a combined ash/gypsum disposal area. Disposal configurations were developed (Options 2 and 3) and disposal capacities and preliminary order of magnitude costs for site development were determined for both the peninsula and ash pond locations. Both locations were determined to be feasible, but costs appeared to be higher for the ash pond, due to some assumptions made for the study, which were not verified.

In the fall of 2003, Ardaman and Associates participated in a two-day meeting with Parsons E&C (PE&C) and TVA to review the assumptions made, and to explore other concepts for combined ash/gypsum disposal. These meetings concluded that the ash pond location was feasible, and that some of the assumptions used in the cost basis were conservative in nature. Another concept was developed for disposal of ash and gypsum.

During this time, one of the existing ash dredge cells located at the north end of the pond experienced localized seepage of ash near the base of the stack, necessitating some operational changes in ash disposal pending a study of causes of the seepage. Further thought was then given to expansion of the ash disposal footprint into the pond, prior to the gypsum placement. Also during that time, PE&C performed a simplified study of ash settling in an effort to better understand how much pond area is necessary to allow continued wet ash disposal.

In a meeting held at TVA on January 29, 2004, PE&C presented another concept (Option 4) for ash/gypsum disposal. This concept allows gradual expansion into the pond so that free water volume requirements are met for the pond. Simplified ash settling characteristics were studied using Stokes Law, to help determine the limits of expansion and provide a rough correlation to free water volume. The result of this concept represents the likely limit of solid waste disposal, considering that the method of ash disposal is wet ash sluicing/wet ash stacking. The maximum volume for disposal can only be attained if conversion to dry ash handling is undertaken at some point in the process.

Study drawings were developed by PE&C throughout the study. Because a number of sub-options were studied within each option (i.e., volumetric differences between 3H:1V versus 4H:1V configurations, etc), and also because a number of drawings were developed for quantities to support cost estimates, a large number of drawings were developed for this study. A limited number of drawings are appended to this report. The entire set of drawings will be made available to TVA via electronic copy.

Figure 1-1 TVA Kingston Fossil Plant Peninsula and Ash Pond Sites

2 SCOPE OF WORK

2.1 Peninsula Site

A Phase I study was developed to determine the feasibility of the peninsula area site selection for disposal of gypsum. The scope of work included the following:

- Participate in a site walkdown and preliminary meeting with TVA and Tennessee Division of Solid Waste Management (DSWM). Determine the feasibility of attaining waivers on solid waste regulations, including buffer requirements and liner requirements.
- Calculate preliminary storage volumes for two scenarios, termed Options 1A and 1B, based on standard engineering practices.
- Evaluate existing boring logs, geoprobe data, and groundwater levels previously obtained by TVA. Prepare boring location plan and scope of geotechnical field and laboratory work to be performed by Mactech. Coordinate with Mactech and TVA during geotechnical evaluation of the new disposal site area.
- Evaluate geotechnical data and suitability of foundation material for stack development.
- Develop preliminary Autocad drawings for gypsum stacking plan..
- Develop quantities for construction and closure, based on the concepts developed. Quantities were provided to TVA for development of cost estimates.

<u>Assumptions made in study or exclusions</u>

- Preliminary annual gypsum production volumes were provided by TVA, and are estimated to be 350,000 tons. A density of 75 pcf (approximately 1 ton/cy) was initially assumed for gypsum in place. These assumptions were refined as the study progressed and as discussed herein.
- The study did not determine configurations of this facility for combinations of dry and wet stacking scenarios. Some concepts for stacking wet and dry gypsum, as well as concepts for converting from wet ash to dry ash were investigated late in the study. Concept sketches are included in this study, although this has not been explored in detail.
- Detailed calculations using computer programs to determine sediment pond routing and sizing were not performed during Phase I.
- Sufficient geotechnical data was obtained or available for the Phase I feasibility study to determine overall suitability for this type of facility at this location. The study considered the subsurface condition to the extent that this site could have a sufficient bearing capacity for supporting the stack, and addressed any potential fatal flaws (i.e., location of Holocene faults within 200 ft, or any distinguishing karst geologic features) that would prevent this site from being permitted as a solid waste disposal facility in Tennessee. However, the geotechnical data obtained so far for the site is not sufficient for the final design in accordance with the requirements of Tennessee Rule 1200-1-7.
- For volumetric computations and the cost estimate, the configuration of the stack will assume an earthen starter dike, and a 3H:1V slope for the gypsum stack, with 15 foot horizontal terraces placed at 30 foot vertical intervals. The overall stack height for the preliminary volume determination will be determined by the stack geometry. Subsequent engineering design will be required to determine the validity of this assumption.
- Disposal volumes for the 4(H) to 1(V) configurations at the ash pond site were determined in order to assess potential volume reduction due to the use of flatter slopes, in the event stability could be a limiting factor.
- TVA provided a digital copy of Kelsh topography.

- Concepts for conversion from wet ash stacking to dry ash stacking will be by others, and is not included in this scope.

2.2 Ash Pond Site

2.2.1 Options 2A and 2B

Perform a Phase I study to determine the volume of gypsum that can be disposed at the ash pond location. The scenario for gypsum stacking at the existing ash pond assumes that the Plant would convert to a dry ash stacking system at the inception of expansion of disposal into the pond, thus allowing the entire footprint of the pond (except for the stilling basin) to be utilized for gypsum stacking. Two different stack concepts, termed Option 2A and 2B were developed and studied for this location. Option 2A involves a free-standing stack in the existing ash pond area, separate from the ash stack (located on the north side of the gypsum stack). This option would not utilize available airspace between the two stacks. Option 2B utilizes the airspace between the two stacks. A perimeter dike would be tied into the ash stack to create an area to be utilized for the gypsum disposal. Gypsum would be dredged into this pond, and the available airspace would be maximized.

2.2.2 Options 3A and 3B

Two additional disposal scenarios for gypsum stacking at the existing ash pond, termed Options 3A and 3B assume that the Plant would continue wet ash stacking, and were evaluated to see whether this would reduce the footprint (and volume) for gypsum stacking arrangement determined for Options 2A and 2B. The scope of work was as follows:

- Develop preliminary Autocad drawings for Options 2A, 2B, 3A and 3B for stacking gypsum, and calculate preliminary storage volumes, based on standard engineering practices. For Options 3A and 3B, assume wet ash stacking rather than dry ash stacking. If there is a significant change in the stack footprint (due to the need for additional stilling pond volume), determine the reduction in volume.
- Develop quantities for construction and closure, based on the concepts developed. Provide quantities to TVA for development of cost estimates.
- For Options 3A and 3B, determine a configuration that will provide the minimum free water volume (FWV) currently required (504,655 cy).
- Perform a stability analysis to determine whether stability could limit the volume of gypsum that could be theoretically disposed, based on the geometry and areal extent of the stack. This analysis used existing TVA site specific data readily available from recent and previous subsurface investigations.
- Disposal volumes for 4(H) to 1(V) configurations for the ash pond site were determined in order to assess potential volume reduction due to the use of flatter slopes, in the event stability could be a limiting factor.
- A two-day meeting was initiated at TVA's request to review assumptions made and concepts regarding Options 3A and 3B. The meeting included TVA plant and operations personnel including engineering and environmental representatives, Ardaman and Associates, and PE&C.

2.2.3 Assumptions and Exclusions for Options 2 and 3 Study

- Preliminary annual gypsum production volumes were provided by TVA, and are estimated to be 350,000 tons. A density of 75 pcf (approximately 1 ton/cy) was assumed for the gypsum in place. These assumptions were refined as the study progressed..
- The study did not evaluate combinations of dry and wet gypsum stacking scenarios.
- The existing stilling basin would be assumed as the point of discharge for the pumped wet gypsum. The discharge criteria for NPDES discharges were not evaluated. The basis for establishing the footprint of the gypsum disposal areas of Options 3A and 3B was to provide minimum FWV for the facility to provide the maximum footprint. The FWV only considered the existing requirement for ash disposal, and did not factor in additional volume requirements due to flow for the sluiced gypsum.
- The configuration of the stack initially assumed a 3:1 slope for the gypsum stack, with 15-foot horizontal terraces placed at 30-foot vertical intervals. The overall stack height for the preliminary volume determination would be determined by the stack geometry. Subsequent engineering design would be required to determine the validity of this assumption.
- The concept of stacking gypsum in the ash pond was based on a similar concept developed by TVA for stacking gypsum at the Cumberland Fossil Plant (CUF). TVA provided drawings for use in developing an under drainage concept at KIF, and this was used as the basis for the cost estimate.
- Concepts for conversion from wet ash stacking to dry ash stacking would be by others, and is not included in this scope.
- Digital copy of Kelsh topography would be provided by TVA.
- The existing current topographic features of the ash disposal area using topography provided by TVA would be used to create a base drawing. Future ash placement would be modeled based on TVA design and permit drawings.
- The study did not consider the effects of combined ash/gypsum mixtures.
- The stability analyses used configurations developed by Parsons for stack geometry and height, as well as existing data for the site(s) that was readily available. No additional geotechnical field programs were required to complete this effort.
- The stability analysis is preliminary in nature, and is not sufficient for the final design and permitting purposes. TDEC requirements for seismic stability design were considered to the extent practicable, to assess the likelihood that seismic events could affect stability, and ultimately, the disposal volume. The existing dredge cells located at the north end of the ash pond were not studied for stability.

2.2.4 Option 4

In addition to options previously developed, TVA requested an additional option be developed to determine the disposal capacity if the FWV requirements were increased to include the minimum FWV plus one year of additional ash storage capacity. Additional ash disposal capacity is estimated to be 360,000 tons annually, and at 67 lb/cu ft density, equates to 398,010 cy. This significantly reduces the disposal capacity within the ash pond, if this free water volume is maintained, as discussed in Section 4.3.5. Parsons included a simplified ash settling study based on Stoke's Law, to assess the adequacy of the pond area relative to settling.

2.2.5 Assumptions Made in the Study or Exclusions for Option 4

The following assumptions were made:

- To achieve the FWV, the weirs in both the main ash pond and stilling basin would be raised to el 759 (from 754.3 and 757.9 for the stilling basin and ash pond respectively);
- The outer dikes of the disposal area could be constructed from wet cast gypsum instead of dry cast gypsum. However, an earthen starter dike should be assumed for the cost estimate. Careful staging and planning would be required to stack the ash to form a base for future gypsum disposal. This was not considered in the study herein.
- Other more rigorous methods are available for evaluating ash settling and sizing the pond. These methods require settling tests be performed as input into settling models. Due to the limited funding and time, this modeling was not performed.

3 PENINSULA SITE

3.1 Geology

The Kingston Fossil Plant is located in the Valley and Ridge Physiographic Province of the Appalachian Highland region, which extends as a continuous belt from central Alabama through Georgia and Tennessee northward into Pennsylvania. The formations that underlie this province consist primarily of limestone, dolomite, shale, and sandstone, which have been folded and faulted in the geologic past. These formations range in age from Cambrian to Pennsylvanian and have been subject to at least one extensive period of erosion since their formation. The erosion has produced a series of subparallel, alternating ridges and valleys. The valleys are formed over more soluble bedrock (interbedded limestone and limestone), whereas bedrock more resistant to solution weathering forms ridges (sandstone, shale, and cherty dolostone). In particular, the peninsula site is geologically mapped to be underlain by the Knox formation. The Knox formation is mainly composed of light gray to dark gray and olive-gray, siliceous dolomite with a few limestone layers in the upper part. The rock usually weathers to a reddish orange residuum containing chert fragments. Additional information is contained in a geotechnical investigation (Mactec, 2003).

The site topography consists of gently rolling hills. A ridge is located to the north of the site, and Watts Bar Lake (Clinch River) is located to the south. There are several small-sized topographically low areas or ground depressions (including a pond) at the site that may apparently indicate potential sinkhole activity. However, the top 30 feet of the bedrock cored in two exploratory borings located inside the pond area and near the depression was found to be sound and did not exhibit any sign of solutioning. Rock fracturing/faulting and buried ancient natural drainage channel along the western boundary of the site and associated solution activity may be one possibility for existence of the depressed topographic features. If the site is to be used for such a facility, this possibility may be investigated further.

3.2 Site Investigation

TVA met with representatives of the TDEC Knoxville Environmental Service Center and the Nashville office at the site in December 2002. The purpose of this visit was to provide TDEC an opportunity to be introduced to the project, and to discuss some potential permitting issues, such as the existence of the Wildlife Refuge, potential wetland areas, karst topography, buffer areas, etc. TDEC seemed receptive to TVA submitting a permit application, and requested TVA to apply for the appropriate permits with the required information to support the permit application.

The results of the subsurface investigation performed recently at this site are contained in the report by Mactec, dated March 26, 2003. Subsurface investigations have also been performed in the past at this site (See Attachment 4). Locations of exploratory borings drilled for these investigations are plotted on a topographic map of the site.

TVA engaged Mactech to perform field work in planning the investigation. PELA was selected as a consultant experienced in the local karst geology. The investigation by Mactech consisted of 31 geoprobes and six borings advanced by hollow stem auger flights and split spoon sampling (standard penetration test). Two of the borings were extended 30 feet into the underlying bedrock using HQ coring. The elevations of top of bedrock were determined for each geoprobe and boring location and, coupled with the previous investigation, were used to determine top of rock contours shown on SK PR-0637 C21.

The soil overburden at the site consists of residual silty fat clay (CH), generally of stiff consistency and contained variable amount of chert fragments. The soil overburden thickness at the boring locations varied from 17 feet to 68 feet. Hydraulic conductivity testing was not performed for this investigation, but such highly plastic clayey soils usually have very low hydraulic conductivities, and have been used to construct landfill liners throughout east Tennessee. The bedrock encountered in the borings was composed primarily of blue-gray shaly and dolomitic limestone. The recovered cores showed that rock encountered in the borings was sound and fresh to only slightly weathered. The report may be reviewed for detailed information on the rock quality and soil overburden characteristics.

3.3 Disposal Concepts

3.3.1 Option 1A

3.3.1.1 Description

The layout of Option 1A is shown on SK PR-0698 C01 and C03 (3:1 slopes). The site is located on a peninsula east of the powerhouse, and is bounded by Watts Bar Lake to the south, and an access road and an unnamed ridge to the north and east. There are 169 kV power lines that bound the site to the north and east, and limit the footprint for disposal. The access road must be preserved, because it provides access north across the ridge to the ash disposal area, and to Mahoney Cemetery. The site is within the TVA Kingston Fossil Plant Reservation; however, it is currently used as a wildlife management area and refuge in concert with the State of Tennessee. The area is depicted on USGS quadrangle maps (Harriman and Elverton quadrangles). The site has been used for agricultural purposes (evidence of row crops planted in the past exist), and approximately 70% of the footprint area has been cleared. The site does have a pond located within the boundary of waste disposal, as well as other topographically low areas or depressions.

Initial site activity would involve construction of stormwater controls. These would include some grading, construction of stormwater pond(s) and silt fencing, check dams, ditches, and temporary sediment traps as needed. Clearing and grubbing of large trees would be undertaken before grading the site. Construction would likely require phasing due to stormwater permitting requirements. Most likely, two stormwater ponds would be required because the shape of the site area is relatively long and narrow. At least one of the stormwater ponds would likely become a permanent stilling basin for final settling of process water during facility operations. Process discharges would be permitted under the Tennessee NPDES permitting program. The other pond may continue to be used as a stormwater detention facility, or abandoned after construction. Phase 2 design would determine the exact configuration and number of ponds. TVA has expressed a preference for a single pond for NPDES discharges, and this is discussed in the following paragraphs.

The starter perimeter dike is located to generally conform to Tennessee Department of Environmental Conservation (TDEC) rules for buffer requirements (1200-1-7-.04 (3). While the following is not a complete list of all limiting boundary requirements, those listed below apply to siting and location of landfills, and are summarized as follows:

- 100 feet from all property lines;
- 500 feet from all residences;
- 500 feet from all down gradient drinking water wells for human consumption or livestock;
- 200 feet from normal boundaries of springs and lakes;
- No construction within 50 feet of the property line.

The Phase 1 Study did not address each of these requirements to the degree necessary for permitting. For example, the dike layout shown does intrude into the 200 foot buffer adjacent to Watts Bar Lake, but the distance from the inside edge of the dike (boundary of gypsum material) is approximately 180 feet from the water's edge at the closest point, and thus a waiver is possible. It is also possible that the dike configuration could be altered to conform with the requirement, but that may require adjustments to the dike location in order to preserve the disposal capacity volume developed by this footprint.

Other TDEC requirements include, but are not limited to, karst geology, seismic impact zones, location in floodplains, and wetland requirements. Wetland areas were not delineated for this study, but likely exist based on observations made during site visits. The facility is not within the 100-year floodplain. It is located within a seismic impact area, and Phase 2 design should ensure that the stability is in accordance with the requirements. Attachment 4 contains the results of a limited stability analysis performed to address the project feasibility.

The starter perimeter dike would be constructed by excavating soil within the disposal area footprint to form the diked area shown. Portions of the facility would be constructed from earth excavated within the proposed pond area; and excavating earth to the 3H:1V slopes shown would form other portions of the facility. The dikes would be constructed by placing soil in thin lifts and compacting each lift using heavy mechanical equipment. For purposes of this study, as shown on SK PR-0698 C01, the bottom of the facility (i.e., top of natural clay) crowned at elevation 760, with a one percent slope to the east, and a one-half percent slope to the west. Tennessee solid waste regulations (1200-1-7- .04) require a geologic buffer of a minimum five feet thick liner with a hydraulic conductivity less than or equal to than 1×10^{-6} cm/sec. As the existing natural clay layer will form the base of the facility and as its hydraulic conductivity is likely to fulfill the regulatory requirement for the liner; there should be adequate geological buffer beneath the site. Phase 2 design would determine whether the top of liner (clay surface) would need to be adjusted after grading to fulfill the thickness requirement. The cost estimate conservatively assumed the uppermost three feet of the base of the facility (measured from top of clay) would be excavated and replaced, and recompacted to achieve a hydraulic conductivity less than 1.0×10^{-6}cm/sec, in case it is so necessary. This type of configuration would lend itself to potentially utilize gravity drainage to capture water (process water and stormwater) and convey it to ponds located east and west of the diked disposal area. This would require two separate NPDES permits for the disposal cell. As discussed earlier, TVA would prefer a single pond. Another aspect of design involves settlement of the site as the gypsum stack increases in height. Settlement was not investigated for this study, but would need to be considered for design because it is likely to be significantly large due to the natural clay compressibility and anticipated large stack load. Although the base is sloped, settlement may likely reduce the effective slope, and may cause water to pond in the bottom of the stack. Phase two design would evaluate this probability. If necessary, the design can be reconfigured such that the slope can be reversed, and a low point constructed where the crown presently exists. Sumps can be placed on the outer dikes, and connected to the low point. Drainage to the sumps would be by gravity, and effluent pumped to a single pond for and discharge. The cost estimate did not include costs for sumps and pumping.

The volume for Option 1A was determined to be approximately 9.3 million cubic yards (cy), assuming 3H:1V slopes and 15-foot wide benches every 30 feet in vertical height. The volume for 4H:1V slopes (and the same benching scheme) was determined to be 7.3 million cy. Section 5 addresses the disposal life of this option compared with other options. Gypsum production is expected to vary depending on the sulfur content of the coal, and this is discussed in more detail in Section 5.

3.3.2 Option 1B

Option 1B is shown on SK PR-0698 C08, and represents a modification in that the footprint is truncated. This eliminates having the existing pond within the waste disposal footprint. Otherwise, the design is similar to Option 1A. Because the footprint for this option is shorter than for Option 1A, it may be possible to utilize a single pond for process and stormwater discharges. The final contours are depicted on SK PR-0698 C09. The volume for Option 1B was determined to be approximately 7.0 million cubic yards (cy), assuming 3H:1V slopes and a 15-foot wide bench for every 30 feet of vertical height. The capacity of this footprint with 4H:1V slopes was not calculated.

3.4 Stability

Attachment 4 contains the results of limited stability analysis conducted for the peninsula site. Because this is a feasibility study, the analysis was based on limited subsurface data and the available data on gypsum disposal. Static and pseudostatic (for seismic condition) analysis was performed to determine overall global factors of safety for various phreatic surface conditions. Pseudostatic modeling assumed somewhat conservative values. Overall, the stability analysis concluded that it is feasible to dispose of gypsum by wet stacking or dry stacking at this site. However, for the final design in accordance with the permit requirements, additional field investigation will be required to better ascertain foundation conditions and the presence of solution cavities. Attachment 4 and Section 5 address the differences between the peninsula and the ash pond sites.

4 ASH POND AREA

4.1 Geology and Overview of Facility Construction

This section briefly summarizes information currently available regarding the geological setting of this site. The ash pond site is permitted as a solid waste disposal facility by the State of Tennessee. For additional information, see *Hydraulic Evaluation of the Ash Pond* Site, Appendix D (TVA, 1995) of the Solid Waste Permit for the Dredge Cells (TVA, 1994). As discussed earlier, the plant site is located in the Valley and Ridge physiographic province of the Appalachian Highland region. The ash pond area is underlain by the Conasauga Group (middle to upper Cambrian Age) with the exception of the northern tip of the area, where the Rome formation (lower Cambrian Age) is present. Specific geologic groups within the Conasauga Group represented at the site include the Maynardville, Nolichucky, Maryville, Rogersville, Rutledge, and Pumpkin Valley formations. These formations are locally of low water-producing capacity, and predominantly consist of shale with interbedded siltstones, limestones, and conglomerates. Total thickness of the Consauga Group beneath the site is unknown, but is estimated to be approximately 1500 ft. Pine Ridge, which borders the ash pond area to the northwest, is underlain by interbedded shale, sandstone, and siltstone of the Rome formation.

A mantle of predominantly alluvial soils generally lies above bedrock in the ash pond site. Thickness of natural soil overburden is apparently variable, ranging from approximately fifteen feet at the north end of the existing dredge cell area and gradually increasing to approximately twenty five feet at the southern edge of the existing stilling pond. The soil overburden is unconsolidated, and consists of primarily a clay layer at the top underlain by a perhaps lenticular silt and sand deposits below. A thin layer of residuum is occasionally present directly above bedrock. The residuum is composed of clay and silt with weathered shale fragments. The thickness of ash and soil fill materials present above the natural soil overburden range from approximately 10 feet (in the existing ash pond area) to 70 ft (in the existing dredge cell area), except below the dike tops and inside the stilling pond...

The ash pond site has been historically used for ash disposal at KIF since the plant started operation, as depicted on drawings 10N400 and 10N420. The pond was originally constructed within a triangular shaped area marked "Initial Ash Disposal Area" on the drawing 10N400, located to the east of the rail yard and north of the power plant. This was operated as a dredge cell until a larger dredge pond was constructed north of the initial pond. Dikes consisting of compacted earthen fill were constructed, with the western boundary along what is now Swan Pond Road (parallel to Dike B).

Ash deposits consist almost entirely of fly ash; bottom ash is estimated to comprise less than ten percent of the ash fill, although bottom ash was used to construct outer dikes of the dredge cells (Dike B) as the dikes were raised above the elevation of the original earthen dike. Dike C was originally constructed from compacted clayey soils to about elevation 748. The dike was later raised to its present elevation of 765 perhaps using dredged ash or ash and earth materials. The dike raising utilized the upstream method of construction, whereby the dikes are raised progressively upward and into the pond, with the interior portion of the raised dike supported on dredged ash (10N400). Dike B, located along the northern side of the ash pond, is apparently constructed of bottom ash (10N400).

As the pond was progressively filled with dredged ash, ash stacking began at the northern end of the pond (opposite the stilling basin). Ash was stacked to form two separate cells (existing Cell 1 and Cell 3 to an elevation of about 790 (10W425-1). Bottom ash was used to construct the outer dikes, although no underdrain system was incorporated into these dikes. At this point, a solid waste permit was obtained to stack the ash higher (10W425 series drawings). Stages A, B, and C (10W425-1 through 10W425-6) were initially constructed north of the two cells previously constructed, and this provided three separate dredge cells (existing Cells 1 through 3). These dikes were built using compacted bottom ash, and incorporated an underdrain system within the outer dikes. Ash is dredged from the pond using a floating dredge into each of the cells. Active dredging can occur in one or two cells at a time, and can alternate between cells. Because the underdrain system is built into the outer dikes, the water within the cells slowly drains out and allowing dikes to be raised in the inactive cells. Stacking has thus proceeded to the present elevation of about 810 (end of Stage C).

4.2 Site Investigation

No site investigation was conducted at the ash pond for this study. Sketch SK PR-0698 C80 shows locations of exploratory borings drilled for three previous site investigations. Reports for the three site investigations provided by TVA are: First in 1975 for raising the dikes around the entire ash site; second in 1984 to define conditions along Dike C, and third in 1994 around the dredge cell area to provide information for a solid waste permit closure plan. Additionally, a hydrogeologic evaluation report for the ash pond area is provided by TVA that includes data on monitoring wells J4, J5 and J6 (drilled in 1976) and J13 and J16 (drilled in 1988) around and in the immediate vicinity of the ash site. Phase 2 design would require additional geotechnical investigation to adequately define subsurface condition in the entire area. Requirements for this additional investigation are not addressed in this report.

4.3 Disposal Concepts

4.3.1 Option 2A

4.3.1.1 Description

Because the ash pond is currently a permitted waste disposal facility, there is no liner existing beneath the ash fill or at the bottom of the pond. However, based on the subsurface data reviewed it appears that an approximately 7 to 10 feet thick natural clayey soil layer exists at the bottom of the existing ash fill and at the bottom of the stilling basin. Other siting requirements for landfills are discussed in Section 4.2.1.1. The ash pond does not currently meet the 200-foot buffer distance from a lake or stream; however, preliminary concepts for additional gypsum disposal depict the outer dike set back 200 feet from the existing Dike C. It is anticipated that the State would allow existing variances to these newer permit requirements.

The following contains a description of facility construction assumed as the basis for the cost estimate. As discussed in the introduction to the report, results of the study were presented to the JPT as it progressed, and comments were received. Some of these comments dealt with construction techniques, and associated costs. The cost estimates were not revised in response to these comments, but some adjustments to the cost estimate can be made in order to examine cost reductions if certain assumptions are revised. These comments are addressed in Section 5.

Because the ash pond is an existing facility, and there is an existing pond, conventional stormwater controls usually needed for construction activities would not require installation here. The base of the gypsum disposal area would need to be built up in order to allow equipment to work in dry conditions. Bottom ash and fly ash material would be utilized to prepare a suitable base. The base would be sloped to promote drainage for an overlying drainage system to be installed beneath the gypsum stack. The disposal area footprint is about 80 acres. Once a suitable base is established, geotextile and a drainage layer (gravel or even bottom ash) would be installed to provide drainage at the base of the stack.

In order to build the gypsum stack as shown, this option would require that KIF convert to dry ash disposal, because majority of the pond footprint would be eliminated. The stilling basin would remain as a way to discharge process water from gypsum sluicing, and as a surge pond for stormwater events. Sketch SK PR-0698 C40 depicts an earthen starter dike constructed within the main ash pond area. SK PR-0698 C70 depicts a concept whereby gypsum disposal would occur in two separate ponds. Gypsum is sluiced to the first pond and as the pond fills with gypsum, sluicing commences in the second pond. While the second pond is being filled, the dikes are raised in the first pond to provide additional disposal capacity. This approach is termed "rim ditching" because, as the outer dike is raised using wet-cast gypsum material, gypsum is sluiced within an inner ditch. Properly constructed, the ditch allows coarser gypsum to settle out and finer gypsum to settle within the pond area. Sluicing is alternated between the ponds, and the dikes continue to be raised.

The final configuration of Option 2A depicting finished grade contours is shown on SK PR-0698 C42. This configuration has a separate "stand alone" stack for gypsum, and it has an approximate capacity of 12 million cy.

4.3.2 Option 2B

4.3.2.1 Description

This concept is shown on SK PR-0698 C43, and would require conversion to dry ash disposal for its implementation. This concept is a variation of Option 2A, in that the starter dike would basically be tied into the existing ash dredge cells located at the north end of the ash ponds, providing an 112 acre footprint. Gypsum would be sluiced and stacked in much the same manner as described previously for Option 2A. This concept would eventually reach the final elevation contours as shown on SK PR-0698 C44. The gypsum stack would be integrally tied into the dredge cells. The pond area could be subdivided as described earlier and gypsum stacked. This configuration yields an estimated disposal capacity of approximately 18 million cy.

Because of the large disposal capacity available for this configuration, the JPT expressed a desire for a flexible design that would accommodate wet gypsum from KIF, and possibly dry gypsum disposal from Bull Run Fossil Plant (BRF), located approximately 40 miles from KIF. Even factoring in maximum gypsum disposal from BRF, there is capacity beyond the expected end of ash disposal at the dredge cells (planned completion of dredge cell disposal is 2015). Attachment 6 includes a range of annual gypsum and fly ash quantities assuming BRF gypsum is disposed at the ash pond over a range of sulfur content of coal, and includes the disposal volumes estimated for KIF gypsum and ash only. It is very likely that TVA would consider switching to higher sulfur coals if the scrubber systems are installed at KIF and BRF. While these are estimates, it can be seen that the sulfur content of coal plays an important part in forecasting annual waste quantity generation volumes. Disposal capacity for gypsum at BRF is limited, due to site restrictions. However, TVA is optimistic that the BRF gypsum can be marketed, and the study is considering this possibility. TVA will make a decision whether to include dry gypsum disposal capacity for gypsum wastes from BRF for Phase 2 design at KIF.

Thus, gypsum disposal at the ash pond site for Option 3B is more complex than that at the peninsula site, due to the desire for combining ash and gypsum at a single location. SK PR-0698 C71 – C75 depict a couple of concepts for disposing of combined gypsum and ash. These concepts were developed during a two-day meeting among TVA, PE&C, and Ardaman and Associates. Concept 1 shows a dedicated area for ash disposal, while Concept 2 shows a more flexible arrangement for disposing of ash and gypsum. Both concepts use wet-stacked gypsum in an outer dike to contain the pond. Concept 2 includes a double dike; the outer dike is wet-cast, and the inner dike is constructed by placing dry gypsum transported from BRF if TVA can not market all the gypsum and needs to retain disposal capacity at BRF. Ash disposal will continue to occur in the existing dredge cells until they reach capacity, then ash disposal will begin within the diked area. The diked area can be subdivided to allow separate ash and gypsum disposal.

4.3.3 Option 3A

4.3.3.1 Description

Option 3A is similar to Option 2A, except that this option would allow continued slucing of wet ash from the plant into the pond. The minimum free water volume (FWV) for the current NPDES permit is 102 x 10^6 gallons (approximately 312.8 acre-feet). The stilling basin capacity is insufficient to achieve the minimum FWV by itself; however, using a portion of the main ash pond may barely achieve this requirement, provided the water surface elevation is raised to 759 in both the stilling basin and the main ash pond. Operations personnel at the ash pond prefer to have additional FWV to allow three months to one year of ash storage (360,000 tons), as the dredge is operated intermittently throughout the year. This volume represents 246.7 acre-feet of storage, or an additional 79 percent volume. The FWV shown for this option is considered marginal for operational purposes. Gypsum sluicing operations will likely require an increase in FWV; however, this increase is expected to be about one percent (See Attachment 7). The disposal volume estimated for this option is the same as that estimated for Option 2A.

4.3.4 Option 3B

4.3.4.1 Description

Option 3B is similar to Option 2B, and also considers continued sluicing of wet ash from the plant to the pond. The volume is the same as Option 2B, and considerations with respect to waste disposal flexibility apply to this option as well. As is the case for Option 3A, FWV is considered marginal for this option. Table 5.1 depicts the expected life of this facility based on estimated gypsum and ash annual generation volumes over a range of sulfur content of coal. In the fall of 2003, P E&C analyzed the settling characteristics of ash in the pond using simplified methods based on Stoke's Law to determine the disposal volume capacity if smaller pond area is utilized for combined ash/gypsum disposal.

There are commercially available computer programs available for modeling particle settlement of suspended solids. Because these methods require settling tests be performed to establish modeling parameters, simplified modeling was performed. Attachment 5 contains the results of the simplified modeling. The modeling predicted that for the smallest particle size (0.0015 mm) and 33 mgd flow, a pond area of 120 acres would be required. Obviously, the pond thus meets the TSS requirements with the total existing pond area (estimated at approximately 75 acres), and a particle size between 0.002 mm and 0.003 mm is likely the size that correlates with recorded results. This suggests that an approximately 55-acre overall pond (25- acre stilling basin, 25-acre pond, and five-acre channel area) area may provide a workable approach for expanding the ash disposal area. However, if the pond area is reduced from its present size, additional administrative controls or other methods might be necessary to prevent violation of TSS requirements. Attachment 7 contains the minutes of a meeting held with TVA where this was discussed.

4.3.5 Option 4

4.3.5.1 Description

Option 4 was developed to provide additional ash storage within the ash pond area in the event dredging to the existing dredge cells was curtailed. In November 2003, a localized excessive seepage and a consequent loss of dike material through piping was observed approximately between elevation 770 and 780 on the outside slope of Dike B, in the vicinity of Cell 3 (the center dredge cell). Dredging to the existing dredge cells was suspended, pending further review. TVA has investigated different approaches for providing a remedy. A discussion of these is beyond the scope of this study. For purposes of this study, an assumption is being made that the dredge cells will be filled in accordance with the plans outlined in the existing solid waste permit.

Option 4 (See SK PR-0637 C80) represents the likely maximum extent of ash or gypsum disposal within the pond while wet ash sluicing is the method of ash disposal. Approximately 9 million cy of disposal volume is available using this concept, but converting to dry ash disposal would enable the plant to expand and utilize the entire footprint for disposal, as was discussed for Option 2A earlier.

4.4 Stability

Attachment 7 contains the results of limited stability analyses conducted for the ash pond site. These analyses were performed prior to the aforementioned Dike B seepage. Because this is a feasibility study, the analysis was based the available incomplete subsurface information. The analysis focused on the gypsum stack exclusively for both wet and dry stacking, and did not consider the stability of the existing dredge cells. The critical section was assumed to be across Dike C. Static and pseudostatic (for seismic condition) models were used to determine overall global factors of safety for various phreatic surface conditions. Pseudostatic analysis assumed somewhat conservative values. Overall, the stability analysis concluded that it is feasible to dispose of gypsum by wet stacking or dry stacking at this site. However, additional field investigation will be required to better ascertain foundation conditions and conditions along Dike B. Also, properties of gypsum and ash will have to be defined better than done in this study. Attachment 4 and Section 5 address the differences between the peninsula and the ash pond sites.

5 EVALUATION OF OPTIONS

For evaluation purposes, Option 1A is compared with Option 3B. Options 2A and 2B represent an option that is not likely to be constructed (dry fly ash and dry gypsum placement). Over time, Option 3B has evolved into a hybrid option to be built in multiple stages (first flyash, then gypsum placement). To maximize utilization of the pond footprint, eventually, dry fly ash disposal would need to be implemented. The cost of this conversion is not included. Option 4 is not separately evaluated because it represents an intermediate step in the overall development process for Option 3B. It also represents the limit of ash placement within the pond for wet ash stacking. Table 5.1 contains a tabulated summary of various factors for evaluation including volumes, costs, permitting issues, and advantages/disadvantages.

5.1 Volume

Option 3B offers the most volume for disposal of all options studied. It has approximately 30 percent more volume than Option 3A, and 50 percent more than Option 1A. Volume should also be examined in the context of how much life a disposal facility will provide. Table 5.1 presents a summary of projected volumes over time, including projected life of each facility, assuming gypsum from only KIF and also for the addition of all gypsum from BRF to depict both the low and high rate of volume production. Assumptions include that the dredge cells continue to be utilized until they reach capacity, and gypsum production begins in 2008. Attachment 6 presents tabulated data for projected waste streams over time for all disposal options studied.

Table 5.1

OPTION	KIF GYPSUM[3] (million cy)	BRF GYPSUM[3] (million cy)	KIF ASH[4,5]	TOTAL CAPACITY (million cy)	PROJECTED YEAR CAPACITY ACHIEVED[3]
1A[1]	9.3	—	—	9.3	2026
1A[2]	6.2	3.1	—	9.3	2020
3B[1]	11.4	—	7.3	18.7	2030
3B[2]	9.0	4.5	5.2	18.7	2025
1A+3B[1]	16.0	—	12.0	28.0	2040
1A+3B[2]	12.6	6.3	9.1	28.0	2033

[1]KIF Gypsum Only.
[2]KIF + BRF Gypsum.
[3]This is the cumulative total gypsum produced between the initial year of assumed operation (2008) and the projected year. capacity is achieved. Gypsum annual volumes based on 2% Sulfur (See Attachment 6 for detailed information).
[4]Assumes Continued Dredge Cell Operation.
[5]Under Option 3B, ash disposal would reach 57% of disposal capacity in the year 2042 if ash only is continued to be disposed.

Assuming a 25 year life (i.e., 2008 – 2033) for the scrubber addition, no option shown (either 1A or 3B alone) provides sufficient disposal capacity, even if BRF gypsum is not disposed at KIF. The only way that a 25 year capacity can be reached is by utilizing both sites for disposal.

5.2 Costs

Costs are shown in Table 5.1. Cost comparisons are difficult due to uncertainties for both the peninsula site and ash pond site (see Section 5.4). Cost comparisons are also difficult because the Options 3A and 3B would require conversion to dry fly ash disposal in order to maximize the available space within the ash pond. The cost of converting the plant to dry fly ash was not included in this study for cost comparison purposes.

Costs for Options 3A and 3B were substantially higher than those for Options 1A and 1B. However, when compared on a unit cost basis (cost per cy), the costs are relatively equal, given the uncertainty inherent in this study ($1.23/cy for Option 3B vs $1.01/cy for Option 1A). Attachment 2 contains a summary level cost comparison between the peninsula site and the ash pond assuming less conservative costs for the ash pond. Attachment 3 contains a cost analysis of the uncertainties regarding construction for additional capacity at the ash pond site. Assuming a two-foot thick drainage layer and eliminating the earthen starter dikes would reduces costs to about half (approximately $12 million). The ash pond cost estimate did not include costs for a synthetic liner and other geosynthetic material to strengthen the underlying ash during dike construction, bringing the total to $14.5 million.

5.3 Feasibility

The peninsula site is feasible for solid waste disposal, but the exact configuration would require additional field investigation. Also, it requires an analysis to confirm more accurate volume predictions. The ash pond area can support additional disposal capacity, but the magnitude of additional capacity depends on being able to stack gypsum in the configuration that yields the greatest volume, as well as conversion to dry fly ash. If the plant does not convert to dry fly ash, the volumes are approximately the same, although both ash and gypsum would be disposed at the ash pond location. The following section discusses uncertainties.

5.4 Uncertainties

The uncertainties discussed in this section relate to cost uncertainties. As discussed previously, both sites appear to be feasible for disposal of gypsum, but uncertainties were identified with respect to costs.

5.4.1 Peninsula site

The preliminary stability analysis (Attachment 4) determined that a gypsum disposal facility could be permitted at this location; however, uncertainties in ground conditions exist at both the peninsula site and the ash-pond site. These uncertainties are reflected in the costs developed for disposal facilities at this location. The uncertainties for the peninsula site are specifically:

- Extent and nature of apparently soft and compressible soil layer. This layer overlies bedrock and is approximately 20 ft thick, but the areal extent is unknown. Slope stability modeling has determined that the characteristics of this layer may affect the overall stability of the gypsum disposal facility at this location if the extent is sufficiently large in which case it may need stabilization. However, due to the gradual process of gypsum stacking, it is feasible to improve its strength by employing suitable means so as to obtain overall stack stability within permissible limits.. As stated earlier, this site is considered feasible for gypsum disposal, but the cost of having to stabilize this layer of soil is currently unknown without additional data.

- Solution activity in the bedrock and its extent. Presence of significant-sized solution cavities in the bedrock immediately below the stack area may require measures to mitigate sinkhole situation. However, based on the preliminary information, serious solutioning beneath the stack area is not suspected. The cost for such measures, if required, can not be determined in absence of adequate information.
- Verification or validation of gypsum geotechnical properties.
- Gypsum property changes over time.

5.4.2 Ash Pond Site

No additional subsurface investigation was performed at this site to support the stability analysis for this study. Existing information for the dredged ash and the existing earthen dikes was utilized and is summarized in Attachment 4. Geotechnical properties for the gypsum were assumed as was done for the peninsula site. Additional hydrogeological information is contained in the existing solid waste permit for the ash disposal facility already existing at this site.
Most of the data from the past geotechnical investigations focused on the outer perimeter dikes. Some data was available for ash, where ash was encountered in borings adjacent to the dikes. No information was available for subsurface condition along Dike B, except a log of boring J14 drilled for the monitoring-well installation. Additional data for the dikes and interior areas of the dredge cells and ash pond was assumed.

In addition, an assumption was made for the cost estimate involving the placement of a four-foot thick stone drainage layer for the gypsum disposal area located within the ash pond. The size/configuration for this stone drainage layer was modeled after a similar project performed at TVA's Cumberland Fossil Plant (CUF). Additional analysis will be required in order to validate this assumption.

5.5 Additional Data Needs for Phase 2 Design

Peninsula Site:

- Groundwater elevations;
- Groundwater monitoring wells;
- Hydrogeological investigation for solid waste permit;
- Assessment of karstic features;
- Determination of characteristics and extent of soft clayey soil underlying the site;
- Additional topo surveying (limited for study – will need additional for design if this location is chosen);
- Latest information available on gypsum/sludge geotechnical characteristics;
- Development of remedial measures necessary to satisfy design and TDEC permitting requirements;

Ash Pond Area:

- Supplemental data for defining subsurface conditions adequately over the entire site, especially locations not included in the previous investigations and for verifying conditions at locations where the data obtained is very old;
- Latest information available on gypsum/sludge geotechnical characteristics;
- Review of existing permit for determination of required design objectives.

5.6 Summary

Evaluation of options is summarized in Table 5.2. Volumes, costs, and feasibility were discussed earlier. The advantages of the peninsula site include providing an additional area within the reservation for disposal capacity, and this is a disadvantage for the ash pond site, because it does not add additional space. It may become more difficult to obtain a solid waste permit for the peninsula site. The disadvantage for the peninsula site is that there may be some underlying foundation conditions that may make permitting and construction, while feasible, more difficult than the ash pond site. The ash pond site already has a solid waste permit.

TABLE 5.1
Kingston Fossil Plant - Summary of Gypsum Disposal Options

	DESCRIPTION	POTENTIAL VOLUME[1] (million cy)	SITE PREP COSTS[5,6] (1000$)	PERMITTING ISSUES	ADVANTAGES	DISADVANTAGES
1A	New facility located in greenfield site at the peninsula area	3:1 Slope: 9.3 4:1 slope: 7.5	$9,400[2,4]	▪▪Karst geology not impediment to permit.	▪▪Adds additional disposal capacity to plant.	▪▪Unknown extent of soft soil layer may reduce stack height and volume; foundation drain beneath liner may be required.
1B	New facility located in greenfield site at the peninsula area – reduced footprint	3:1 Slope: 7.0 4:1 slope: Not computed	$7,400[2,4]	▪▪Karst geology not impediment to permit.	▪▪Adds additional disposal capacity to plant ▪▪Smaller footprint may offset disadvantages associated with underlying soft soils.	▪▪Unknown extent of soft soil layer may reduce stack height and volume; foundation drain beneath liner may be required. ▪▪Smaller footprint sacrifices about 30% volume compared with 1A.
3A	Gypsum stack segregated from ash stack; gypsum co-located with ash disposal in existing ash pond – continue wet ash stacking	3:1 Slope: 12.1 4:1 slope: 9.8	$25,000[3]	▪▪Already has permit for ash disposal.	▪▪Site is favorable for wet stacking. ▪▪Disposal volume is greater than either Option 1A or 1B.	▪▪Does not add disposal capacity to plant. ▪▪Conversion to dry flyash required to achieve capacity shown.
3B	Gypsum stack and ash stack combined; gypsum co-located with ash disposal in existing ash pond – continue wet ash stacking	3:1 Slope: 18.7 4:1 slope: 15.2 Option 4: 8.75[7]	$23,000[3]	▪▪Already has permit for ash disposal.	▪▪Offers the largest potential for disposal volume. ▪▪Site is favorable for wet stacking.	▪▪Does not add disposal capacity to plant. ▪▪Conversion to dry flyash required to achieve capacity shown.

Footnotes:

1. Volume is measured in cubic yards.
2. Costs for Options 1A and 1B do not include a foundation drain beneath the facility liner.
3. Costs for Options 3A and 3B include costs for a 4 foot thick underdrain installed beneath the gypsum (installed at CUF). This represents a significant cost difference (about 20% of the total). Detailed design can address the appropriate size of the underdrain. Costs for these options do not include construction of liner.
4. Additional costs for addressing karst issues are unknown.
5. Costs don't include drainage features built into the stack as it develops. Closure costs are also excluded.
6. See Attachment 3 for a complete discussion of cost uncertainties.
7. Approximately 9 million cy are available in ash pond if plant does not convert to dry ash disposal.

6 CONCLUSION

This report has presented the results of a study conducted to determine disposal options at KIF for ash and gypsum. This report will be made available to decision makers within TVA (i.e., the JPT) for use in future planning. This report is not all-inclusive regarding cost estimates because inclusion of dry ash disposal was beyond the scope of this study. The main conclusions drawn from this study are:

- Both the peninsula site and the ash pond site are feasible for disposal of gypsum;
- The study did not address construction of a liner at the ash pond;
- Disposal capacity at the ash pond site is about equal to the peninsula site if dry ash conversion does not occur at KIF;
- Construction costs were developed for both sites; however, uncertainties at both sites require additional data and engineering design to reduce uncertainties and improve the accuracy of cost estimates.

7 REFERENCES

Mactec 2003, *Report of Geotechnical Exploration, Proposed Scrubber Stack Disposal Area, Kingston Fossil Plant, Kingston, TN,* March 26, 2003. Prepared for Tennessee Valley Authority, Chattanooga, TN

TVA 1995, *Hydraulic Evaluation of the Ash Pond* Site, Appendix D of A Closure Plan Prepared as Part of a Solid Waste Permit Application to TDEC, 1995.

ATTACHMENT 1

Selected Phase 1 Study Sketches

ATTACHMENT 2

Cost Estimate Backup

KINGSTON FOSSIL PLANT
SCRUBBER GYPSUM STACK
(OPTION 1A)

Project name	KIF/03163O1A/GYPSUM STACK
Engineer	Daniel Smith (Parsons) 757-8088
Estimator	C. L. TONEY
Labor rate table	KIF 40 2003
Equipment rate table	TVA Equipment
Project	SCRUBBER GYPSUM STCK
Locatn Code(4 Dig)	KINGSTON FOSSIL
EST No./Rev:	03163O1A
Agreement Type	PMMA
Notes	Option 1A is located at the peninsula area east of the plant. This is a greenfield area. This option will spoil material for future final cover installation, but will require additional earthen material at closure. The ponds (stilling basins) are shown as rectangular areas. Basically, they would be constructed with earthen dikes and water would flow from the ponds. Estimate does not include any cost for stack closure nor future borrow area development. For comparison purpose all work is assumed to be in present day (2003) dollars.
Report format	*Sorted by 'Location/Activity'* *'Detail' summary*

Location	Activity	Description	Takeoff Quantity	Labor Productivity	Labor Man-hours	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
01												
	Clear And Grub											
		Remove Trees	13.50 ac	250.000	3,375.00	78,749	-	-	82,181	-	11,920.75	160,930
		Clear And Grub	90.00 ac	72.000	6,480.00	151,198	-	-	157,788	-	3,433.18	308,986
		Strip 1 ft Vegetation And Topsoil - Spoil At Stockpile	129,000.00 cy	0.020	2,580.00	62,165	-	-	80,625	-	1.11	142,790
		Clear And Grub			**12,435.00**	**292,112**			**320,594**			**612,706**
		01			***12,435.00***	***292,112***			***320,594***			***612,706***
02												
	Erosion Controls											
		Erect Silt Fence (Trench Bottom OF Fence, 10% Hay Bales)	4,900.00 lf	0.069	335.99	7,619	2,421	-	1,523	-	2.36	11,562
		Cut For Stormwater Runoff Pond	2,000.00 cy	800.000	2.50	2,086	-	-	2,063	-	2.07	4,148
		Cleanout Stormwater Runoff Pond	2,300.00 cy	383.333	6.00	2,503	-	-	1,920	-	1.92	4,423
		Fill For Stormwater Runoff Pond (12,000 bcy)	14,400.00 cy	1,904.000	7.56	17,869	-	-	24,240	-	2.92	42,109
		Riprap For Stormwater Runoff Pond	4,300.00 tn	0.200	860.00	20,019	43,000	-	18,079	-	18.86	81,098
		Pipe Bedding	20.00 tn	0.500	10.00	225	184	-	33	-	22.11	442
		72 " Dia. CMP For Outlet Structure	6.00 lf	2.000	12.00	263	1,800	-	69	-	355.22	2,131
		48 " Dia. CMP For Riser For Outlet Structure	7.00 lf	1.091	7.64	167	910	-	44	-	160.13	1,121
		48 " Dia. CMP Outlet Pipe (Principle Spillway)	150.00 lf	0.620	93.00	2,036	7,280	-	531	-	65.65	9,848
		Cut Holes In Riser	3.00 ea	1.000	3.00	58	-	-	15	-	24.28	73
		Composite Concrete For Riser Base (Assume 7' x 7' x 2')	4.00 cy	10.000	40.00	1,009	800	-	103	-	477.99	1,912
		Anti-Seep Collars (Assume Concrete)	7.00 ea	75.000	525.00	13,248	4,935	-	1,346	-	2,789.91	19,529
		Erosion Controls			**2,728.18**	**67,102**	**61,330**		**49,965**			**178,397**
		02			***2,728.18***	***67,102***	***61,330***		***49,965***			***178,397***
03												
	Roads											
		Bottom Ash (South Access Road)	2,400.00 cy	1,904.000	1.26	2,395	-	-	3,057	-	2.27	5,452
		Crushed Stone Base (South Access Road)	2,900.00 tn	0.120	348.00	8,878	25,883	-	3,350	-	13.14	38,111
		Crushed Stone Base (Permanent Parking Lot Paved Stone)	340.00 tn	0.120	40.80	1,041	3,035	-	393	-	13.14	4,468
		Roads			**479.56**	**12,314**	**28,917**		**6,799**			**48,031**
		03			***479.56***	***12,314***	***28,917***		***6,799***			***48,031***
07												
	Fencing											
		New Fencing (Including Grounding)	200.00 lf		-	-	-	4,000	-	-	20.00	4,000
		Personnel Swinging Gate	1.00 ea		-	-	-	350	-	-	350.00	350
		Sliding Gate, 20 Ft Wide, With Motorized Operator	1.00 ea		-	-	-	16,500	-	-	16,500.00	16,500
		Fencing						**20,850**				**20,850**
		07						***20,850***				***20,850***
11												
	Seed/Mulch											
		Seed / Mulch Disturbed Areas	25.00 ac		-	-	-	58,080	-	-	2,323.20	58,080
		Seed/Mulch						**58,080**				**58,080**
		11						***58,080***				***58,080***
20												
	Gypsum Disp Facility											
		Clear And Grub Area For Select Spoil	7.00 ac	72.000	504.00	11,760	-	-	12,272	-	3,433.18	24,032
		Cut And Fill Balance (189,719 bcy)	227,663.00 cy	2,800.000	81.31	192,109	-	-	260,596	-	1.99	452,705
		Cut & Spoil Select Cut For Future 1 Ft Clay Layer In Final Cover	82,890.00 cy	1,904.000	43.53	74,632	-	-	110,143	-	2.23	184,775
		Perimeter Road Surfacing - Bottom Ash	2,400.00 cy	1,904.000	1.26	2,395	-	-	3,057	-	2.27	5,452
		Compacted Clay Liner, 6" Lifts (339,000 bcy)	406,800.00 cy	1,200.000	339.00	800,962		-	1,086,509	-	4.64	1,887,471
		Drainage Layer (1 Ft Thick) For Liner (No. 57 Stone)	168,000.00 tn	0.096	16,128.00	397,765	1,428,000	-	252,000	-	12.37	2,077,765
		Perimeter Road Surfacing - Crushed Stone	2,900.00 tn	0.120	348.00	8,878	25,883	-	3,350	-	13.14	38,111
		Riprap For Ditch	23,500.00 tn	0.200	4,700.00	109,407	235,000	-	98,805	-	18.86	443,211
		Ditch For Riprap (24' wide x 2' deep)	7,300.00 lf	0.044	320.03	8,572	-	-	12,651	-	2.91	21,224
		Geotextile (If Riprap Is Used)	19,500.00 sy	0.015	292.50	6,578	25,594	-	975	-	1.70	33,147
		Geotextile Fabric For Underdrain Pipe	5,700.00 sy	0.011	59.85	1,346	7,481	-	200	-	1.58	9,027
		8" Dia. HDPE, SDR 17 Perforated Pipe	6,400.00 lf	0.200	1,280.00	27,229	10,416	-	5,333	-	6.72	42,978
		8" Dia. HDPE Standard Fittings	50.00 ea	0.200	10.00	193	400	-	-	-	11.86	593
		Concrete Anchors For Underdrain Piping	85.00 ea	12.500	1,062.50	26,812	9,988	-	2,724	-	464.98	39,524
		Proofroll Subgrade	70.00 ac	7.000	10.00	6,666	-	-	4,000	-	152.37	10,666
		Seed / Mulch Selected Spoil Material Area	7.00 ac		-	-	-	16,262	-	-	2,323.20	16,262
		Gypsum Disp Facility			**64,808.98**	**1,675,304**	**1,742,761**	**16,262**	**1,852,614**			**5,286,941**
		20			***64,808.98***	***1,675,304***	***1,742,761***	***16,262***	***1,852,614***			***5,286,941***
50												
	Construction Parking											
		Silt Fence	1,000.00 lf	0.020	20.00	409	315	-	-	-	0.72	724
		Cut And Fill Balance (500 bcy)	600.00 cy	2,800.000	0.21	506	-	-	687	-	1.99	1,193

Location	Activity	Description	Takeoff Quantity	Productivity	Labor Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
	Construction Parking											
		Cut & Spoil Additional Material	400.00 cy	1,904.000	0.21	360	-	-	532	-	2.23	892
		Crushed Stone Base	1,400.00 tn	0.120	168.00	4,286	12,495	-	1,617	-	13.14	18,398
		Construction Parking			**220.30**	**5,561**	**12,810**		**2,835**			**21,207**
		50			***220.30***	***5,561***	***12,810***		***2,835***			***21,207***
xCONST FACILITY												
	Construct Facilities											
		Mobilization	1.00 ls	400.000	400.00	10,560	-	-	4,002		14,561.20	14,561
		Admin Time (Employee proc, etc)	1.00 ls	256.000	256.00	6,588	-	-			6,588.16	6,588
		General Clean Up	1.00 ls	600.000	600.00	12,358	-	-	1,626		13,984.20	13,984
		Maintain Roads	1.00 ls	6,372.000	6,372.00	129,524	-	-	50,540		180,063.16	180,063
		Drinking Water	1.00 ls	531.000	531.00	11,286	-	-	2,159		13,444.93	13,445
		Hauling	1.00 ls	531.000	531.00	12,335	-	-	4,317		16,652.16	16,652
		Portable Toilet Service	1.00 ls		-	-	-	8,500	-	-	8,500.00	8,500
		Demobilization	1.00 ls	240.000	240.00	6,336	-	-	2,401		8,736.72	8,737
		Construct Facilities			**8,930.00**	**188,987**		**8,500**	**65,044**			**262,531**
		xCONST FACILITY			***8,930.00***	***188,987***		***8,500***	***65,044***			***262,531***
zNON MANUAL												
	Non-Manual											
		Non Manual	1.00 ls	11,200.000	11,200.00	560,000	-	-	-	-	560,000.00	560,000
		Non-Manual			**11,200.00**	**560,000**						**560,000**
		zNON MANUAL			***11,200.00***	***560,000***						***560,000***

Estimate Totals

Labor	2,801,381		100,802.014	hrs
Material	1,845,818			
Subcontract	103,692			
Equipment	2,297,852		53,577.274	hrs
	7,048,743	7,048,743		
Small Tools Expense	40,213		0.450	$/hr
Consumables & Expendables	89,402		4.000	%
Office Supplies & Expense	16,800		3.000	%
	146,415	7,195,158		
Partner Insurance (FY03)	83,851		3.000	%
Partner Award Fee (FY03)	139,752		5.000	%
	223,603	7,418,761		
Engineering @ 8% Of Constr	575,613			
	575,613	7,994,374		
Field QA/QC @ 2% Of Constr	155,626			
	155,626	8,150,000		
Contingency @ +/-15%	1,250,000		15.337	%
	1,250,000	9,400,000		
	Total	***9,400,000***		

KINGSTON FOSSIL PLANT
SCRUBBER GYPSUM STACK
(OPTION 1B)

Project name	KIF/03163O1B/GYPSUM STACK
Engineer	Daniel Smith (Parsons) 757-8088
Estimator	C. L. TONEY
Labor rate table	KIF 40 2003
Equipment rate table	TVA Equipment
Project	SCRUBBER GYPSUM STCK
Locatn Code(4 Dig)	KINGSTON FOSSIL
EST No./Rev:	03163O1B
Agreement Type	PMMA
Notes	Option 1B is located at the peninsula area east of the plant. This is a greenfield area. This option will need much less additional earthen material at final closure, because it has a shorter earthen dike and is located primarily in the cut area, whereas 1A is located in the lower topographic area, and requires more initial fill for the dike than this option. The ponds (stilling basins) are shown as rectangular areas. Basically, they would be constructed with earthen dikes and water would flow from the ponds. Estimate does not include any cost for stack closure nor future borrow area development. For comparison purpose all work is assumed to be in present day (2003) dollars.
Report format	*Sorted by 'Location/Activity'* *'Detail' summary*

Location	Activity	Description	Takeoff Quantity	Labor Productivity	Labor Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
01												
	Clear And Grub											
		Remove Trees	7.00 ac	250.000	1,750.00	40,833	-	-	42,613	-	11,920.75	83,445
		Clear And Grub	70.00 ac	72.000	5,040.00	117,598	-	-	122,724	-	3,433.18	240,322
		Strip 1 ft Vegetation And Topsoil - Spoil At Stockpile	113,000.00 cy	0.020	2,260.00	54,455	-	-	70,625	-	1.11	125,080
		Clear And Grub			**9,050.00**	**212,886**			**235,962**			**448,847**
		01			***9,050.00***	***212,886***			***235,962***			***448,847***
02												
	Erosion Controls											
		Erect Silt Fence (Trench Bottom OF Fence, 10% Hay Bales)	3,300.00 lf	0.069	227.01	5,147	1,630	-	1,029	-	2.37	7,807
		Cut For Stormwater Runoff Pond	2,000.00 cy	800.000	2.50	2,086	-	-	2,063	-	2.07	4,148
		Cleanout Stormwater Runoff Pond	2,300.00 cy	383.333	6.00	2,503	-	-	1,920	-	1.92	4,423
		Fill For Stormwater Runoff Pond (12,000 bcy)	14,400.00 cy	1,904.000	7.56	17,869	-	-	24,240	-	2.92	42,109
		Riprap For Stormwater Runoff Pond	4,300.00 tn	0.200	860.00	20,019	43,000	-	18,079	-	18.86	81,098
		Pipe Bedding	20.00 tn	0.500	10.00	225	184	-	33	-	22.11	442
		72 " Dia. CMP For Outlet Structure	6.00 lf	2.000	12.00	263	1,800	-	69	-	355.22	2,131
		48 " Dia. CMP For Riser For Outlet Structure	7.00 lf	1.091	7.64	167	910	-	44	-	160.13	1,121
		48 " Dia. CMP Outlet Pipe (Principle Spillway)	150.00 lf	0.620	93.00	2,036	7,280	-	531	-	65.65	9,848
		Cut Holes In Riser	3.00 ea	1.000	3.00	58	-	-	15	-	24.28	73
		Composite Concrete For Riser Base (Assume 7' x 7' x 2')	4.00 cy	10.000	40.00	1,009	800	-	103	-	477.99	1,912
		Anti-Seep Collars (Assume Concrete)	7.00 ea	75.000	525.00	13,248	4,935	-	1,346	-	2,789.91	19,529
		Erosion Controls			**2,619.19**	**64,631**	**60,539**		**49,471**			**174,641**
		02			***2,619.19***	***64,631***	***60,539***		***49,471***			***174,641***
03												
	Roads											
		Bottom Ash (South Access Road)	2,400.00 cy	1,904.000	1.26	2,395	-	-	3,057	-	2.27	5,452
		Crushed Stone Base (South Access Road)	2,900.00 tn	0.120	348.00	8,878	25,883	-	3,350	-	13.14	38,111
		Crushed Stone Base (Permanent Parking Lot Paved Stone)	340.00 tn	0.120	40.80	1,041	3,035	-	393	-	13.14	4,468
		Roads			**479.56**	**12,314**	**28,917**		**6,799**			**48,031**
		03			***479.56***	***12,314***	***28,917***		***6,799***			***48,031***
07												
	Fencing											
		New Fencing (Including Grounding)	200.00 lf		-	-	-	4,000	-	-	20.00	4,000
		Personnel Swinging Gate	1.00 ea		-	-	-	350	-	-	350.00	350
		Sliding Gate, 20 Ft Wide, With Motorized Operator	1.00 ea		-	-	-	16,500	-	-	16,500.00	16,500
		Fencing						**20,850**				**20,850**
		07						***20,850***				***20,850***
11												
	Seed/Mulch											
		Seed / Mulch Disturbed Areas	17.40 ac		-	-	-	40,424	-	-	2,323.20	40,424
		Seed/Mulch						**40,424**				**40,424**
		11						***40,424***				***40,424***
20												
	Gypsum Disp Facility											
		Clear And Grub Area For Select Spoil	7.00 ac	72.000	504.00	11,760	-	-	12,272	-	3,433.18	24,032
		Cut And Fill Balance (83,113 bcy)	99,736.00 cy	2,800.000	35.62	84,160	-	-	114,164	-	1.99	198,324
		Cut & Spoil Select Cut For Future 1 Ft Clay Layer In Final Cover	84,539.00 cy	1,904.000	44.40	76,117	-	-	112,334	-	2.23	188,451
		Cut & Spoil Additional Material	67,131.00 cy	1,904.000	35.26	60,443	-	-	89,202	-	2.23	149,646
		Perimeter Road Surfacing - Bottom Ash	1,900.00 cy	1,904.000	1.00	1,896	-	-	2,420	-	2.27	4,316
		Compacted Clay Liner, 6" Lifts (254,000 bcy)	304,800.00 cy	1,200.000	254.00	600,131		-	814,080	-	4.64	1,414,211
		Drainage Layer (1 Ft Thick) For Liner (No. 57 Stone)	125,600.00 tn	0.096	12,057.60	297,377	1,067,600	-	188,400	-	12.37	1,553,377
		Perimeter Road Surfacing - Crushed Stone	2,300.00 tn	0.120	276.00	7,041	20,528	-	2,657	-	13.14	30,226
		Riprap For Ditch	23,500.00 tn	0.200	4,700.00	109,407	235,000	-	98,805	-	18.86	443,211
		Ditch For Riprap (24' wide x 2' deep)	7,300.00 lf	0.044	320.03	8,572	-	-	12,651	-	2.91	21,224
		Geotextile (If Riprap Is Used)	19,500.00 sy	0.015	292.50	6,578	25,594	-	975	-	1.70	33,147
		Geotextile Fabric For Underdrain Pipe	3,800.00 sy	0.011	39.90	897	4,988	-	133	-	1.58	6,018
		8" Dia. HDPE, SDR 17 Perforated Pipe	4,300.00 lf	0.200	860.00	18,295	6,998	-	3,583	-	6.72	28,876
		8" Dia. HDPE Standard Fittings	35.00 ea	0.200	7.00	135	280	-	-	-	11.86	415
		Concrete Anchors For Underdrain Piping	60.00 ea	12.500	750.00	18,926	7,050	-	1,923	-	464.98	27,899
		Proofroll Subgrade	52.00 ac	7.000	7.43	4,952	-	-	2,971	-	152.37	7,923
		Seed / Mulch Selected Spoil Material Area	7.00 ac		-	-	-	16,262	-	-	2,323.20	16,262
		Gypsum Disp Facility			**50,641.88**	**1,306,687**	**1,368,037**	**16,262**	**1,456,570**			**4,147,557**
		20			***50,641.88***	***1,306,687***	***1,368,037***	***16,262***	***1,456,570***			***4,147,557***
50												
	Construction Parking											
		Silt Fence	1,000.00 lf	0.020	20.00	409	315	-	-	-	0.72	724

[illegible]	Activity	Description	Takeoff Quantity	[illegible]	Labor Quantity	[illegible]	[illegible] Amount	Sub Amount	[illegible] Amount	[illegible] Amount	[illegible]	[illegible] Amount
	Construction Parking											
		Cut And Fill Balance (500 bcy)	600.00 cy	2,800.000	0.21	506	-	-	687	-	1.99	1,193
		Cut & Spoil Additional Material	400.00 cy	1,904.000	0.21	360	-	-	532	-	2.23	892
		Crushed Stone Base	1,400.00 tn	0.120	168.00	4,286	12,495	-	1,617	-	13.14	18,398
		Construction Parking			**220.30**	**5,561**	**12,810**		**2,835**			**21,207**
		50			***220.30***	***5,561***	***12,810***		***2,835***			***21,207***
xCONST FACILITY												
	Construct Facilities											
		Mobilization	1.00 ls	400.000	400.00	10,560	-	-	4,002		14,561.20	14,561
		Admin Time (Employee proc, etc)	1.00 ls	256.000	256.00	6,588	-	-			6,588.16	6,588
		General Clean Up	1.00 ls	456.000	456.00	9,392	-	-	1,236		10,627.99	10,628
		Maintain Roads	1.00 ls	4,848.000	4,848.00	98,545	-	-	38,452		136,997.21	136,997
		Drinking Water	1.00 ls	404.000	404.00	8,587	-	-	1,642		10,229.28	10,229
		Hauling	1.00 ls	404.000	404.00	9,385	-	-	3,285		12,669.44	12,669
		Portable Toilet Service	1.00 ls		-	-	-	6,460	-	-	6,460.00	6,460
		Demobilization	1.00 ls	240.000	240.00	6,336	-	-	2,401		8,736.72	8,737
		Construct Facilities			**7,008.00**	**149,393**		**6,460**	**51,017**			**206,870**
		xCONST FACILITY			***7,008.00***	***149,393***		***6,460***	***51,017***			***206,870***
zNON MANUAL												
	Non-Manual											
		Non Manual	1.00 ls	8,752.000	8,752.00	437,600	-	-	-	-	437,600.00	437,600
		Non-Manual			**8,752.00**	**437,600**						**437,600**
		zNON MANUAL			***8,752.00***	***437,600***						***437,600***

Estimate Totals

Labor	2,189,073		78,770.927	hrs
Material	1,470,303			
Subcontract	83,996			
Equipment	1,802,655		41,123.268	hrs
	5,546,027	5,546,027		
Small Tools Expense	31,401		0.450	$/hr
Consumables & Expendables	69,805		4.000	%
Office Supplies & Expense	13,128		3.000	%
	114,334	5,660,361		
Partner Insurance (FY03)	65,482		3.000	%
Partner Award Fee (FY03)	109,137		5.000	%
	174,619	5,834,980		
Engineering @ 8% Of Constr	466,799			
	466,799	6,301,779		
Field QA/QC @ 2% Of Constr	117,221			
	117,221	6,419,000		
Contingency @ +/-15%	981,000		15.283	%
	981,000	7,400,000		
	Total	***7,400,000***		

KINGSTON FOSSIL PLANT
SCRUBBER GYPSUM STACK
(OPTION 2A)

Project name	KIF/03163O2A/GYPSUM STACK
Engineer	Daniel Smith (Parsons) 757-8088
Estimator	C. L. TONEY
Labor rate table	KIF 40 2003
Equipment rate table	TVA Equipment
Project	SCRUBBER GYPSUM STCK
Locatn Code(4 Dig)	KINGSTON FOSSIL
EST No./Rev:	03163O2A
Agreement Type	PMMA
Notes	The concept for this design will stack the gypsum in the existing ash pond area. This option (2A) is a standalone gypsum occupying the exisitng ash pond area. Construction of the earthen dike will require material from on site borrow area. Estimate does not include any cost for stack closure. For comparison purpose all work is assumed to be in present day (2003) dollars.
Report format	*Sorted by 'Location/Activity'* *'Detail' summary*

Location	Activity	Description	Takeoff Quantity	Labor Productivity	Labor Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
02												
	Erosion Controls											
		Erect Silt Fence (Trench Bottom OF Fence, 10% Hay Bales)	2,200.00 lf	0.069	150.85	3,421	1,087	-	684	-	2.36	5,191
		Rock Ck Dams	100.00 tn	0.200	20.00	466	1,000	-	420	-	18.86	1,886
		Construct Temporary Pond Within Pond To Detain Stormwtr During Constr	14,400.00 cy	0.036	512.06	12,625	-	-	10,084	-	1.58	22,709
		72 " Dia. CMP For Outlet Structure	6.00 lf	2.000	12.00	263	1,800	-	69	-	355.22	2,131
		48 " Dia. CMP For Riser For Outlet Structure	7.00 lf	1.091	7.64	167	910	-	44	-	160.13	1,121
		48 " Dia. CMP Outlet Pipe (Principle Spillway)	150.00 lf	0.620	93.00	2,036	7,280	-	531	-	65.65	9,848
		Cut Holes In Riser	3.00 ea	1.000	3.00	58	-	-	15	-	24.28	73
		Remove Temporary Pond Within Pond To Detain Stormwater During Constr	14,400.00 cy	0.047	672.05	16,162	-	-	10,382	-	1.84	26,544
		Composite Concrete For Riser Base (Assume 7' x 7' x 2')	4.00 cy	10.000	40.00	1,009	800	-	103	-	477.99	1,912
		Anti-Seep Collars (Assume Concrete)	7.00 ea	75.000	525.00	13,248	4,935	-	1,346	-	2,789.91	19,529
		Erosion Controls			**2,035.60**	**49,456**	**17,812**		**23,677**			**90,944**
		02			***2,035.60***	***49,456***	***17,812***		***23,677***			***90,944***
03												
	Roads											
		Bottom Ash (South Access Road)	2,400.00 cy	1,904.000	1.26	2,395	-	-	3,057	-	2.27	5,452
		Crushed Stone Base (South Access Road)	2,900.00 tn	0.120	348.00	8,878	25,883	-	3,350	-	13.14	38,111
		Roads			**438.76**	**11,273**	**25,883**		**6,407**			**43,562**
		03			***438.76***	***11,273***	***25,883***		***6,407***			***43,562***
11												
	Seed/Mulch											
		Seed / Mulch Disturbed Areas	26.00 ac		-	-	-	60,403	-	-	2,323.20	60,403
		Seed/Mulch						**60,403**				**60,403**
		11						***60,403***				***60,403***
20												
	Gypsum Disp Facility											
		Earthwork Fill - 1,132,296 bcy (Obtain From Nearby Borrow Area)	1,358,756.00 cy	1,120.000	1,213.18	3,432,509	-	-	3,130,089	-	4.83	6,562,597
		Drainage Layer (4 Ft Thick) For Liner (No. 57 Stone)	738,000.00 tn	0.096	70,848.00	1,747,324	6,273,000	-	1,107,000	-	12.37	9,127,324
		Geotextile Layer To Seperate Gypsum From Rock	372,680.00 sy	0.015	5,590.20	125,724	465,850	-	18,634	-	1.64	610,208
		Riprap For Ditch	18,200.00 tn	0.200	3,640.00	84,732	182,000	-	76,521	-	18.86	343,253
		Geotextile (If Riprap Is Used)	14,400.00 sy	0.015	216.00	4,858	18,900	-	720	-	1.70	24,478
		Geotextile Fabric For Underdrain Pipe	6,900.00 sy	0.011	72.45	1,629	9,056	-	242	-	1.58	10,927
		8" Dia. HDPE, SDR 17 Perforated Pipe	7,700.00 lf	0.200	1,540.00	32,760	12,532	-	6,416	-	6.72	51,708
		8" Dia. HDPE Standard Fittings	60.00 ea	0.200	12.00	231	480	-	-	-	11.86	711
		Concrete Anchors For Underdrain Piping	102.00 ea	12.500	1,275.00	32,175	11,985	-	3,269	-	464.98	47,428
		Gypsum Disp Facility			**219,069.25**	**5,461,942**	**6,973,803**		**4,342,890**			**16,778,635**
		20			***219,069.25***	***5,461,942***	***6,973,803***		***4,342,890***			***16,778,635***
40												
	Borrow Area Develop											
		Disc Future Borrow Area	56.00 ac	6.000	9.33	4,317	-	-	2,427	-	120.43	6,744
		Seed / Fertilize / Lime Future Borrow Area	56.00 ac		-	-	-	130,099	-	-	2,323.20	130,099
		Borrow Area Develop			**149.33**	**4,317**		**130,099**	**2,427**			**136,843**
		40			***149.33***	***4,317***		***130,099***	***2,427***			***136,843***
50												
	Construction Parking											
		Silt Fence	1,000.00 lf	0.020	20.00	409	315	-	-	-	0.72	724
		Cut And Fill Balance (500 bcy)	600.00 cy	2,800.000	0.21	506	-	-	687	-	1.99	1,193
		Cut & Spoil Additional Material	400.00 cy	1,904.000	0.21	360	-	-	532	-	2.23	892
		Crushed Stone Base	1,400.00 tn	0.120	168.00	4,286	12,495	-	1,617	-	13.14	18,398
		Construction Parking			**220.30**	**5,561**	**12,810**		**2,835**			**21,207**
		50			***220.30***	***5,561***	***12,810***		***2,835***			***21,207***
xCONST FACILITY												
	Construct Facilities											
		Mobilization	1.00 ls	400.000	400.00	10,560	-	-	4,002		14,561.20	14,561
		Admin Time (Employee proc, etc)	1.00 ls	200.000	200.00	5,112	-	-			5,112.00	5,112
		General Clean Up	1.00 ls	1,560.000	1,560.00	32,131	-	-	4,228		36,358.92	36,359
		Maintain Roads	1.00 ls	16,572.000	16,572.00	336,859	-	-	131,441		468,299.86	468,300
		Drinking Water	1.00 ls	1,381.000	1,381.00	29,353	-	-	5,614		34,966.93	34,967
		Hauling	1.00 ls	1,381.000	1,381.00	32,081	-	-	11,228		43,308.16	43,308
		Portable Toilet Service	1.00 ls		-	-	-	22,100	-	-	22,100.00	22,100
		Demobilization	1.00 ls	240.000	240.00	6,336	-	-	2,401		8,736.72	8,737
		Construct Facilities			**21,734.00**	**452,432**		**22,100**	**158,912**			**633,444**

[illegible]	Activity	Description	Takeoff Quantity	Labor Productivity	Labor Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
		xCONST FACILITY			***21,734.00***	***452,432***		***22,100***	***158,912***			***633,444***
zNON MANUAL												
	Non-Manual											
		Non Manual	1.00 ls	30,456.000	30,456.00	1,522,800	-	-	-	-	1,522,800.00	1,522,800
		Non-Manual			**30,456.00**	**1,522,800**						**1,522,800**
		zNON MANUAL			***30,456.00***	***1,522,800***						***1,522,800***

Estimate Totals

Labor	7,507,781		274,103.245	hrs
Material	7,030,307			
Subcontract	212,602			
Equipment	4,537,148		141,342.248	hrs
	19,287,838	19,287,838		
Small Tools Expense	109,533		0.450	$/hr
Consumables & Expendables	239,146		4.000	%
Office Supplies & Expense	45,684		3.000	%
	394,363	19,682,201		
Partner Insurance (FY03)	225,043		3.000	%
Partner Award Fee (FY03)	375,072		5.000	%
	600,115	20,282,316		
Engineering @ 4% Of Constr	811,293			
	811,293	21,093,609		
Field QA/QC @ 2% Of Constr	406,391			
	406,391	21,500,000		
Contingency @ +/-15%	3,500,000		16.279	%
	3,500,000	25,000,000		
	Total	***25,000,000***		

KINGSTON FOSSIL PLANT
SCRUBBER GYPSUM STACK
(OPTION 2B)

Project name	KIF/03163O2B/GYPSUM STACK
Engineer	Daniel Smith (Parsons) 757-8088
Estimator	C. L. TONEY
Labor rate table	KIF 40 2003
Equipment rate table	TVA Equipment
Project	SCRUBBER GYPSUM STCK
Locatn Code(4 Dig)	KINGSTON FOSSIL
EST No./Rev:	03163O2B
Agreement Type	PMMA
Notes	The concept for this design will stack the gypsum in the existing ash pond area. This option (2B) stacks gypsum like 2A, but also fills the void area between the ash disposal portion and the gypsum stack depicted in Option 1A. Construction of the earthen dike will require material from on site borrow area. Estimate does not include any cost for stack closure. For comparison purpose all work is assumed to be in present day (2003) dollars.
Report format	*Sorted by 'Location/Activity'* *'Detail' summary*

Location	Activity	Description	Takeoff Quantity	Labor Productivity	Labor Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
02												
	Erosion Controls											
		Erect Silt Fence (Trench Bottom OF Fence, 10% Hay Bales)	2,200.00 lf	0.069	150.85	3,421	1,087	-	684	-	2.36	5,191
		Rock Ck Dams	100.00 tn	0.200	20.00	466	1,000	-	420	-	18.86	1,886
		Construct Temporary Pond Within Pond To Detain Stormwtr During Constr	14,400.00 cy	0.036	512.06	12,625	-	-	10,084	-	1.58	22,709
		72 " Dia. CMP For Outlet Structure	6.00 lf	2.000	12.00	263	1,800	-	69	-	355.22	2,131
		48 " Dia. CMP For Riser For Outlet Structure	7.00 lf	1.091	7.64	167	910	-	44	-	160.13	1,121
		48 " Dia. CMP Outlet Pipe (Principle Spillway)	150.00 lf	0.620	93.00	2,036	7,280	-	531	-	65.65	9,848
		Cut Holes In Riser	3.00 ea	1.000	3.00	58	-	-	15	-	24.28	73
		Remove Temporary Pond Within Pond To Detain Stormwater During Constr	14,400.00 cy	0.047	672.05	16,162	-	-	10,382	-	1.84	26,544
		Composite Concrete For Riser Base (Assume 7' x 7' x 2')	4.00 cy	10.000	40.00	1,009	800	-	103	-	477.99	1,912
		Anti-Seep Collars (Assume Concrete)	7.00 ea	75.000	525.00	13,248	4,935	-	1,346	-	2,789.91	19,529
		Erosion Controls			**2,035.60**	**49,456**	**17,812**		**23,677**			**90,944**
		02			***2,035.60***	***49,456***	***17,812***		***23,677***			***90,944***
03												
	Roads											
		Bottom Ash (South Access Road)	2,400.00 cy	1,904.000	1.26	2,395	-	-	3,057	-	2.27	5,452
		Crushed Stone Base (South Access Road)	2,900.00 tn	0.120	348.00	8,878	25,883	-	3,350	-	13.14	38,111
		Roads			**438.76**	**11,273**	**25,883**		**6,407**			**43,562**
		03			***438.76***	***11,273***	***25,883***		***6,407***			***43,562***
11												
	Seed/Mulch											
		Seed / Mulch Disturbed Areas	26.00 ac		-	-	-	60,403	-	-	2,323.20	60,403
		Seed/Mulch						**60,403**				**60,403**
		11						***60,403***				***60,403***
20												
	Gypsum Disp Facility											
		Earthwork Fill - 728,296 bcy (Obtain From Nearby Borrow Area)	873,956.00 cy	1,120.000	780.32	2,207,800	-	-	2,013,283	-	4.83	4,221,083
		Drainage Layer (4 Ft Thick) For Liner (No. 57 Stone)	820,900.00 tn	0.096	78,806.40	1,943,602	6,977,650	-	1,231,350	-	12.37	10,152,602
		Geotextile Layer To Seperate Gypsum From Rock	540,144.00 sy	0.015	8,102.16	182,218	675,180	-	27,007	-	1.64	884,405
		Riprap For Ditch	18,200.00 tn	0.200	3,640.00	84,732	182,000	-	76,521	-	18.86	343,253
		Geotextile (If Riprap Is Used)	14,400.00 sy	0.015	216.00	4,858	18,900	-	720	-	1.70	24,478
		Geotextile Fabric For Underdrain Pipe	10,000.00 sy	0.011	105.00	2,361	13,125	-	350	-	1.58	15,836
		8" Dia. HDPE, SDR 17 Perforated Pipe	11,200.00 lf	0.200	2,240.00	47,652	18,228	-	9,332	-	6.72	75,212
		8" Dia. HDPE Standard Fittings	90.00 ea	0.200	18.00	347	720	-	-	-	11.86	1,067
		Concrete Anchors For Underdrain Piping	150.00 ea	12.500	1,875.00	47,316	17,625	-	4,807	-	464.98	69,748
		Gypsum Disp Facility			**182,398.16**	**4,520,885**	**7,903,428**		**3,363,370**			**15,787,684**
		20			***182,398.16***	***4,520,885***	***7,903,428***		***3,363,370***			***15,787,684***
40												
	Borrow Area Develop											
		Disc Future Borrow Area	36.00 ac	6.000	6.00	2,775	-	-	1,560	-	120.43	4,335
		Seed / Fertilize / Lime Future Borrow Area	36.00 ac		-	-	-	83,635	-	-	2,323.20	83,635
		Borrow Area Develop			**96.00**	**2,775**		**83,635**	**1,560**			**87,971**
		40			***96.00***	***2,775***		***83,635***	***1,560***			***87,971***
50												
	Construction Parking											
		Silt Fence	1,000.00 lf	0.020	20.00	409	315	-	-	-	0.72	724
		Cut And Fill Balance (500 bcy)	600.00 cy	2,800.000	0.21	506	-	-	687	-	1.99	1,193
		Cut & Spoil Additional Material	400.00 cy	1,904.000	0.21	360	-	-	532	-	2.23	892
		Crushed Stone Base	1,400.00 tn	0.120	168.00	4,286	12,495	-	1,617	-	13.14	18,398
		Construction Parking			**220.30**	**5,561**	**12,810**		**2,835**			**21,207**
		50			***220.30***	***5,561***	***12,810***		***2,835***			***21,207***
xCONST FACILITY												
	Construct Facilities											
		Mobilization	1.00 ls	400.000	400.00	10,560	-	-	4,002		14,561.20	14,561
		Admin Time (Employee proc, etc)	1.00 ls	200.000	200.00	5,112	-	-			5,112.00	5,112
		General Clean Up	1.00 ls	1,320.000	1,320.00	27,188	-	-	3,577		30,765.24	30,765
		Maintain Roads	1.00 ls	14,028.000	14,028.00	285,147	-	-	111,263		396,410.24	396,410
		Drinking Water	1.00 ls	1,169.000	1,169.00	24,847	-	-	4,752		29,599.09	29,599
		Hauling	1.00 ls	1,169.000	1,169.00	27,156	-	-	9,504		36,659.84	36,660
		Portable Toilet Service	1.00 ls		-	-	-	18,700	-	-	18,700.00	18,700
		Demobilization	1.00 ls	240.000	240.00	6,336	-	-	2,401		8,736.72	8,737
		Construct Facilities			**18,526.00**	**386,346**		**18,700**	**135,499**			**540,544**

TVA-00004750

[illegible]	Activity	Description	Takeoff Quantity	Labor Productivity	Labor Quantity	[illegible]	Material Amount	[illegible]	[illegible] Amount	Other Amount	Total Cost/Unit	[illegible]
		xCONST FACILITY			***18,526.00***	***386,346***		***18,700***	***135,499***			***540,544***
zNON MANUAL												
	Non-Manual											
		Non Manual	1.00 ls	25,464.000	25,464.00	1,273,200	-	-	-	-	1,273,200.00	1,273,200
		Non-Manual			**25,464.00**	**1,273,200**						**1,273,200**
		zNON MANUAL			***25,464.00***	***1,273,200***						***1,273,200***

Estimate Totals

Labor	6,249,497		229,178.822	hrs
Material	7,959,932			
Subcontract	162,738			
Equipment	3,533,348		104,578.577	hrs
	17,905,515	17,905,515		
Small Tools Expense	91,564		0.450	$/hr
Consumables & Expendables	198,798		4.000	%
Office Supplies & Expense	38,196		3.000	%
	328,558	18,234,073		
Partner Insurance (FY03)	187,295		3.000	%
Partner Award Fee (FY03)	312,158		5.000	%
	499,453	18,733,526		
Engineering @ 4% Of Constr	749,341			
	749,341	19,482,867		
Field QA/QC @ 2% Of Constr	377,134			
	377,134	19,860,001		
Contingency @ +/-15%	3,139,999		15.811	%
	3,139,999	23,000,000		
	Total	***23,000,000***		

ATTACHMENT 3

Ash Pond Area Cost Estimate Analysis

ATTACHMENT 3
COST ANALYSIS OF OPTION 3B – ASH POND SITE

The JPT requested a review of assumptions made in the cost estimate for Option 3B. TVA's method of estimating adds up the cost of equipment, labor, and material to determine an unburdened cost. Then percentages are added to estimate the total construction cost (including contingency). To reconcile the construction costs and allow cost deductions to be made to examine the impact of conservative assumptions, percentages of costs are developed using ratios to estimate the total project costs utilizing the reduced construction line item costs. The table below represents an approximate total of unburdened costs.

Table A3-1, Total of Unburdened Costs

Line Item No.	Description	Amount ($)
02	Erosion controls	90,944
03	Road construction	43,562
11	Seeding	60,403
20	Gypsum disposal facilities[1]	15,787,684
40	Borrow area development	87,791
50	Construction parking	21,207
	Construction facilities	540,544
	Total	16,632,315

[1]This includes $10,152,602 for 4 ft thick drainage layer, $884,405 for geotextile, and $4,221,083 for earthwork related to construction of earthen starter dikes.

The total compares with the total unburdened amount of $17, 905,515. This does not include engineering, insurance, QA/QC, and contingency.

Cost savings due to reduction of drainage layer thickness, and elimination of earthen starter dikes

- Because the 4 ft thickness for drainage layer was thought to be conservative, assume the drainage layer is 2 ft thick. Cost would be $10,152,602/2 = $5,076,301 (potential cost savings).
- Eliminate costs of earthen starter dikes ($4,221,083).

Total savings = $9,297,384.

Recalculate burdened costs taking credit for cost reductions

$17,905,515 - $9,297,384 = $8,608,131

Ratio of unburdened costs to burdened costs: $17,905,515/$23,000,000 = 0.7785

$8,608,131/0.7785 = $11,057,330 or savings of $11,942,670, or about half.

This cost analysis does not include costs for placement of geosynthetic materials (liners) that would make the ash pond site equivalent to the peninsula site. The cost a synthetic liner (HDPE) is expected to be $0.40/sf @75 ac = $1.3 million. Additional cost for composite a tensar grid reinforcement layer to stabilize and strengthen the pond to support construction of dikes would be $1.3 million, placing the ash pond cost at $14.5 million, versus $9.4 million.

ATTACHMENT 4

Preliminary Stability Analysis for Peninsula Site and Ash Pond Site

PARSONS

REVIEW AND APPROVAL RECORD	1.0 PROJECT: Kingston Power Plant	JOB NO./WBS NO.:	IDENTIFIER
	ENGINEERING DOCUMENT (TITLE): Preliminary Slope Stability Analysis – Gypsum Stack Options 1, 2, and 3		
	RESPONSIBLE DISCIPLINE: Civil Engineering	CLASSIFICATION	

2. REVISION LEVEL	A				
3. ORIGINATOR/ DATE	Wade Anundson 5-5-03 WA				
4. INTERFACE REVIEWERS/ DATE	N/A				
REVIEWER/DATE	Yogesh Shah 5-5-03 WA for				
APPROVAL/DATE	Dan Smith				

FOR INTERNAL USE AND RECORD Form EP9-1 12/96

General

A preliminary stability analysis was performed for the proposed Options 1, 2, or 3 gypsum or gypsum-fly ash stacks at TVA's Kingston Fossil (Power) Plant near Knoxville, Tennessee. The preliminary stability analysis was performed for the following purposes:

- To examine if construction of the stacks to the proposed heights and configurations are likely to be stable, especially during a design seismic event, as required by the Tennessee Division of Solid Waste Management (TDSWM) (see Reference 9).
- To help identify specific factors that will affect stack stability and to determine whether these factors can be mitigated by engineering solutions.
- To help select the most appropriate option(s) for a detailed investigation and design if the project is to be implemented.

Two alternate sites within the plant property, namely the Peninsula site and the existing ash disposal site, were considered for the stack. Options 1A and 1B are at the Peninsula site and 2A, 2B, 3A and 3B are at the ash site. The stack height, configuration, etc. and the topographical features are shown on the drawings (Reference 1).

A preliminary pseudostatic global slope stability analysis was performed using the computer program PCSTABL5M. This computer program was developed at Purdue University and uses the STED preprocessor. For the stability analysis we selected two critical sections of the proposed maximum heights of the stack (Options 1A and 2B), one at each of the two sites.

The analysis was performed using subsurface profiles and properties of subsurface materials interpreted from the available subsurface and geological data for the two sites (References 2, 5, 6, and 7). Limited data regarding the properties of FGD sludge or sedimented gypsum was also made available from TVA records (References 3,4 and 8).

It should be noted that the plant is located in a probable high-seismic zone of the eastern continental United States (USGS maximum horizontal acceleration, a_{max}, of approximately 0.22g). Therefore, for locating a new solid waste facility at this plant, a detailed static and seismic stability evaluation is required for obtaining a construction permit. The evaluation should be performed using appropriate subsurface data for the selected site and data for the gypsum to be deposited or placed in the selected manner.

Critical Sections and Subsurface Profiles

Following a review of all options and considering the existing subsurface and topographical conditions, two sections, one each at Options 1A and 2B, were determined to be critical for the preliminary analysis. The locations of these critical sections are shown on Figures 1 and 2. The subsurface profiles at the two locations were developed from the subsurface data pertinent to the locations and are shown on Figures 3 and 4. The subsurface profiles are also shown on the results of the stability evaluation (STED printouts attached).

The profile at the Peninsula site (Option 1A) was based on data from Reference 2 and that at the ash site (Option 2B) was based on data from References 5, 6 and 7. The profiles were simplified for the computer evaluation. The combination of foundation condition and the stack height/configuration at these locations appear to be the most critical for the two sites.

For the stability evaluation, the dry stack was assumed to consist of two primary layers: The top layer consisting of gypsum deposited in the final approximately 3-year period, and the lower layer consisting of earlier deposits.

The wet-stack was assumed to consist of a 150 feet wide (horizontally) exterior shell of stronger material (perimeter dike and compacted deposits below the dikes) and an interior portion of wet placed material represented by three gypsum layers. The top interior layer consists of gypsum deposited for the final approximately two years. The middle layer consists of gypsum deposited during the next three earlier years, and the bottom layer consists of gypsum deposited at least five years before the closure. This layering allows accounting for consolidation and strength-gain with time in the analytical models.

Subsoil, Fly Ash and Gypsum Properties

The subsoil properties used in the stability analysis for the Peninsula site (Option 1A) were interpreted based on the standard penetration test (SPT) and laboratory test data provided in Reference 2. The subsoil and ash properties for the ash site (Option 2B) were obtained from the data presented in References 5, 6, and 7 that included the SPT results and laboratory triaxial shear testing of samples. Judgment was required to determine appropriateness of data presented in these references due to the time elapsed since it was procured.

A significant variation in the scrubber-sludge (gypsum) data was noticed during a review of References 3, 4 and 8. It is known that gypsum crystallizes in the presence of water and hardens as time passes; that is, it attains greater cohesion with time. However, the magnitude of these effects, especially on its strength under variable confinement and moisture conditions that can be anticipated when it will be stacked as high as 220 feet, is difficult to assess as the literature in that regard is scarce or non-existent. Therefore, due to lack of consistent or reliable data for gypsum, the design properties used in the analysis are the best guesses and may need to be verified in the future.

The material properties used in the analysis are shown on the attached Figures 3 and 4 and on the attached STED model printouts. It should be noted that the properties used for the static and seismic conditions are not different, primarily because the stack and foundation materials under the sustained weight of the proposed high stacks built over a period of more than 20 years will be well consolidated and generally more cohesive than assumed in the analysis. Furthermore, strength reduction of such materials during short-duration shaking would have been inconsequential, especially if proper drainage measures are installed. Consideration of such a reduction in the assumed material strength for the dynamic analysis also would have hampered a proper visualization of the effect of other important factors (such as phreatic-surface and ground-acceleration variations and slope flattening). Consideration of soil strength reduction during seismic conditions may be included in the final design if deemed necessary.

Discussion of Stability Analysis

The stability analysis results for the Peninsula site are summarized in Table 1; those for the ash site are summarized in Table 2. The results are also illustrated in the attached STED printouts.

For this preliminary feasibility study, the stack was assumed to consist primarily of gypsum. The modeling of ash layers within the stacks was not considered. As gypsum mixed with 50% or less fly ash is known to attain greater strength than gypsum alone due to pozzolonic effect, it is conservative to ignore the presence of ash in the stack.

In the pseudostatic method used for evaluating stability during an earthquake, generally the earthquake coefficient used is one-half of the maximum ground acceleration. However, the USGS maximum acceleration (a_{max}) indicated in Reference 9 corresponds to that at the top of rock in a free-field condition, and not within the sliding mass of a slope. Therefore, it is assumed somewhat conservatively that this acceleration will be 0.15g (= 2/3 x 0.22g). Some analysis shown attached also used acceleration values of 0.11g and 0.22g to evaluate the effect of the acceleration on the factor of safety. The results are shown in Tables 1 and 2.

It should be noted that the stability analysis (as is generally the case) was performed using a two-dimensional model of the stack and the ground profile, neither of which are so in reality. The actual factor of safety should be significantly greater than those obtained theoretically. For the Peninsula site, the ratio of the actual to theoretical factor of safety may be at least 1.2 times greater (or more) due to the three-dimensional effect of the site topography and the subsurface conditions. For the ash site, the ratio will be somewhat smaller due to a more uniform subsurface condition.

Conclusions and Recommendations

General

The results of the two-dimensional stability analysis shown on Tables 1 and 2 provide factors of safety ranging from 0.79 to 1.95. In general, the results show that for a given condition, a factor of safety during the design seismic event (0.15g) of 1.0 can be obtained when a static factor of safety of about 1.6 to 1.8 is achieved for the same condition. It is clear that if the three-dimensional effect is considered, it is feasible to engineer the stack design to attain a factor of safety against global slope failure during seismic conditions greater than 1.0. The engineering measures include adequate stack-drainage to lower the phreatic surface sufficiently within the stack and foundation improvement to stiffen soft foundation soil adequately as indicated from this stability evaluation.

Additional discussions of the results of the two-dimensional stability analysis for the two sites are provided below. Additional general conclusions are as follows:

- Flattening the stack slope from 3H:1V to 4H:1V improves stability somewhat, but apparently is not required if adequate bench width is provided with 3H:1V slopes.
- Low-friction cohesive foundation soil (such as at the Peninsula site) is apparently less favorable for the proposed stack heights than a low-cohesion frictional soil (such as at the Ash site).
- Control of the water table within the stack itself is critical at both sites. Final design of a dry or wet stack system should include drainage design based on the anticipated hydraulic properties of the stack materials. Ground water control measures within the pile will be much more elaborate and expensive for wet stacking than with dry stacking.

Specifically for Peninsula Site

Based on Reference 2 data, an approximately 20-foot thick soft soil layer (soil layer 4 in the STED model) may exist approximately 20 feet below existing ground surface. This layer, if large in extent may have a significant effect on the overall stack stability. Future investigation should verify the extent, in-situ strength and deformation characteristics of this soil as well as those of the overlying stiffer soil. The top of rock contours should also be closely verified, along with the presence of solution cavities. Measures such as gravel columns along with a stone blanket below the impervious liner may be required to stiffen the soft soil if its extent is large and significant to the stack stability.

The design of a dry stack system to the configurations shown on the drawings should be feasible from a global stability standpoint.

A wet stacking system should be feasible at the Peninsula site; however, the wet stack may need to be modified from the stack configurations currently shown on the drawings. The final design of a wet stack may include flatter slopes and/or a shorter stack to obtain an adequate global factor of safety during a design seismic event, especially if the soft foundation soil beneath the stack extends over a significantly large area.

Specifically for Ash Site

Based on the results of our analysis, it appears the ash site is suitable for both dry and wet stacking to the heights and configurations shown on the drawings. Some additional geotechnical field and laboratory testing will be necessary for the final design but probably not to the extent needed for the Peninsula Site.

References:

1. Options 1A, 1B, 2A, and 2B sketches (SK PR0637 series drawings), including other corresponding sketches showing details of the options.
2. MACTECH report titles, "Report of Geotechnical Exploration for Proposed Scrubber Stack Disposal Area", dated March 26, 2003, along with revised page and top of rock contour plans provided by MACTECH.
3. Data on sludge and sludge-ash mixtures provided by Dan Smith (ATTACHMENT A, Pages 3-26 through 3-30).
4. Law Engineering's "FINAL REPORT – Fly Ash, Bottom Ash and Scrubber Gypsum Study" – to TVA dated November 7, 1995, along with transmittal letter dated November 10, 1995.
5. Singleton Laboratories' report titled "KINGSTON FOSSIL PLANT – DREDGE CELLS CLOSURE SOILS INVESTIGATION", dated September 29, 1994.
6. U.S. Government reports titled, "KINGSTON STEAM PLANT – DIKE C, SOILS INVESTIGATION, EN DES SOIL SCHEDULE 82.3", dated June 22, 1984, and January 10, 1985.
7. Reports on ASH DISPOSAL AREA DIKE RAISING - SOIL INVESTIGATION:
   A. Evaluation, by O.H. Raine, dated 11/12/75.
   B. Investigation data report by Gene Farmer, dated November 3, 1975.
   C. RFP for investigation, by W.W. Engle, dated June 26, 1974.
8. Ardaman & Associates, Inc., "Interim Report on Evaluation of the FGD Gypsum-Flyash Waste Wet-Stacking Disposal facility, Widows Creek Steam Plant, Stevenson, Alabama", dated April 22, 1991.
9. Tennessee Division of Solid waste management, Technical Guidance Document – Earthquake Evaluation Guidance Policy

Appendix

Tables, Figures, STED Models and Attachment A

Table 1 – Summary of Stability Analysis Models – Peninsula Site

Model Description	Water Table	Top of Stack (feet, NGVD)	Stacking Method	Slopes	Horizontal Earthquake Coefficient	Factor of Safety
1A - Soft Foundation Soils	2/3 Stack +880’	950	Dry	3H:1V with 15’ benches	0	0.97
1A - Stiff Foundation Soils	2/3 Stack +880’	950	Dry	3H:1V with 15’ benches	0	1.21
1A - Very Stiff Foundation Soils	2/3 Stack +880’	950	Dry	3H:1V with 15’ benches	0	1.40
1A - Very Stiff Foundation Soils	2/3 Stack +880’	950	Dry	3H:1V with 15’ benches	0.15g	0.83
1A - Very Stiff Foundation Soils	Lowered to +795’	950	Dry	3H:1V with 15’ benches	0.15g	1.00
1A - Stiff Foundation Soils	2/3 Stack +860’	910	Dry	4H:1V with 15’ benches	0.15g	0.82
1A - Very Stiff Foundation Soils	2/3 Stack +860’	910	Dry	4H:1V with 15’ benches	0.15g	1.05
1A - Stiff Foundation Soils	Lowered to +800’	910	Dry	4H:1V with 15’ benches	0.15g	1.01
1A - Very Stiff Foundation Soils	+905’ at High Point	950	Wet	3H:1V with 15’ benches	0	1.36
1A - Very Stiff Foundation Soils	+905’ at High Point	950	Wet	3H:1V with 15’ benches	0.15g	0.79
1A - Very Stiff Foundation Soils	+905’ at High Point	950	Wet	3H:1V with 15’ benches	0.11g	0.90

Table 2 – Summary of Stability Analysis Models – Existing Ash Disposal Site

Water Table	Top of Stack (feet, NGVD)	Stacking Method	Slopes	Horizontal Earthquake Coefficient	Factor of Safety
2/3 Stack +900’	980	Dry	3H:1V with 10’ benches	0	1.95
2/3 Stack +900’	980	Dry	3H:1V with 10’ benches	0.15g	1.22
2/3 Stack +900’	980	Dry	3H:1V with 10’ benches	0.22g	1.02
+980’	980	Wet	3H:1V with 10’ benches	0	1.90
+980’	980	Wet	3H:1V with 10’ benches	0.15g	1.17
+980’	980	Wet	3H:1V with 10’ benches	0.22g	0.96

Appendix

Tables, Figures, STED Models and Attachment A

PARSONS

REVIEW AND APPROVAL RECORD	1.0 PROJECT Kingston Power Plant	JOB NO./WBS NO.:	IDENTIFIER
	ENGINEERING DOCUMENT (TITLE) Preliminary Slope Stability Analysis – Gypsum Stack Options 1, 2, and 3		
	RESPONSIBLE DISCIPLINE Civil Engineering	CLASSIFICATION	

2. REVISION LEVEL	A				
3. ORIGINATOR/ DATE	Wade Anundson WA 5-5-03				
4. INTERFACE REVIEWERS/ DATE	N/A				
REVIEWER/DATE	Yogesh Shah 5-5-03 WA for				
APPROVAL/DATE	Dan Smith				

FOR INTERNAL USE AND RECORD Form EP9-1 12/96

General

A preliminary stability analysis was performed for the proposed Options 1, 2, or 3 gypsum or gypsum-fly ash stacks at TVA's Kingston Fossil (Power) Plant near Knoxville, Tennessee. The preliminary stability analysis was performed for the following purposes:

- To examine if construction of the stacks to the proposed heights and configurations are likely to be stable, especially during a design seismic event, as required by the Tennessee Division of Solid Waste Management (TDSWM) (see Reference 9).
- To help identify specific factors that will affect stack stability and to determine whether these factors can be mitigated by engineering solutions.
- To help select the most appropriate option(s) for a detailed investigation and design if the project is to be implemented.

Two alternate sites within the plant property, namely the Peninsula site and the existing ash disposal site, were considered for the stack. Options 1A and 1B are at the Peninsula site and 2A, 2B, 3A and 3B are at the ash site. The stack height, configuration, etc. and the topographical features are shown on the drawings (Reference 1).

A preliminary pseudostatic global slope stability analysis was performed using the computer program PCSTABL5M. This computer program was developed at Purdue University and uses the STED preprocessor. For the stability analysis we selected two critical sections of the proposed maximum heights of the stack (Options 1A and 2B), one at each of the two sites.

The analysis was performed using subsurface profiles and properties of subsurface materials interpreted from the available subsurface and geological data for the two sites (References 2, 5, 6, and 7). Limited data regarding the properties of FGD sludge or sedimented gypsum was also made available from TVA records (References 3,4 and 8).

It should be noted that the plant is located in a probable high-seismic zone of the eastern continental United States (USGS maximum horizontal acceleration, a_{max}, of approximately 0.22g). Therefore, for locating a new solid waste facility at this plant, a more detailed and rigorous static and seismic stability evaluation should be performed. The evaluation should be performed using appropriate subsurface data for the selected site and data for the gypsum to be deposited or placed in the selected manner. This detailed analysis may be required for obtaining a permit for construction.

Critical Sections and Subsurface Profiles

Following a review of all options and considering the existing subsurface and topographical conditions, two sections, one each at Options 1A and 2B, were determined to be critical for the preliminary analysis. The locations of these critical sections are shown on Figures 1 and 2. The subsurface profiles at the two locations were developed from the subsurface data pertinent to the locations and are shown on Figures 3 and 4. The subsurface profiles are also shown on the results of the stability evaluation (STED printouts attached).

The profile at the Peninsula site (Option 1A) was based on data from Reference 2 and that at the ash site (Option 2B) was based on data from References 5, 6 and 7. The profiles were simplified for the computer evaluation. The combination of foundation condition and the stack height/configuration at these locations appear to be the most critical for the two sites.

For the stability evaluation, the dry stack was assumed to consist of two primary layers: The top layer consisting of gypsum deposited in the final approximately 3-year period, and the lower layer consisting of earlier deposits.

The wet-stack was assumed to consist of a 150 feet wide (horizontally) exterior shell of stronger material (perimeter dike and compacted deposits below the dikes) and an interior portion of wet placed material represented by three gypsum layers. The top interior layer consists of gypsum deposited for the final approximately two years. The middle layer consists of gypsum deposited during the next three earlier years, and the bottom layer consists of gypsum deposited at least five years before the closure. This layering allows accounting for consolidation and strength-gain with time in the analytical models.

Subsoil, Fly Ash and Gypsum Properties

The subsoil properties used in the stability analysis for the Peninsula site (Option 1A) were interpreted based on the standard penetration test (SPT) and laboratory test data provided in Reference 2. The subsoil and ash properties for the ash site (Option 2B) were obtained from the data presented in References 5, 6, and 7 that included the SPT results and laboratory triaxial shear testing of samples. Judgment was required to determine appropriateness of data presented in these references due to the time elapsed since it was procured.

A significant variation in the scrubber-sludge (gypsum) data was noticed during a review of References 3, 4 and 8. It is known that gypsum crystallizes in the presence of water and hardens as time passes; that is, it attains greater cohesion with time. However, the magnitude of these effects, especially on its strength under variable confinement and moisture conditions that can be anticipated when it will be stacked as high as 220 feet, is difficult to assess as the literature in that regard is scarce or non-existent. Therefore, due to lack of consistent or reliable data for gypsum, the design properties used in the analysis are the best guesses and may need to be verified in the future.

The material properties used in the analysis are shown on the attached Figures 3 and 4 and on the attached STED model printouts. It should be noted that the properties used for the static and seismic conditions are not different, primarily because the stack and foundation materials under the sustained weight of the proposed high stacks built over a period of more than 20 years will be well consolidated and generally more cohesive than assumed in the analysis. Furthermore, strength reduction of such materials during short-duration shaking would have been inconsequential, especially if proper drainage measures are installed. Consideration of such a reduction in the assumed material strength for the dynamic analysis also would have hampered a proper visualization of the effect of other important factors (such as phreatic-surface and ground-acceleration variations and slope flattening). Consideration of soil strength reduction during seismic conditions may be included in the final design if deemed necessary.

Discussion of Stability Analysis

The stability analysis results for the Peninsula site are summarized in Table 1; those for the ash site are summarized in Table 2. The results are also illustrated in the attached STED printouts.

For this preliminary feasibility study, the stack was assumed to consist primarily of gypsum. The modeling of ash layers within the stacks was not considered. As gypsum mixed with 50% or less fly ash is known to attain greater strength than gypsum alone due to pozzolonic effect, it is conservative to ignore the presence of ash in the stack.

In the pseudostatic method used for evaluating stability during an earthquake, generally the earthquake coefficient used is one-half of the maximum ground acceleration. However, the USGS maximum acceleration (a_{max}) indicated in Reference 9 corresponds to that at the top of rock in a free-field condition, and not within the sliding mass of a slope. Determination of the probable average acceleration within such a sliding mass requires more rigorous analysis and precise information on several conditions and is not in the scope of this analysis. Therefore, it is assumed somewhat conservatively that this acceleration will be 0.15g (= 2/3 x 0.22g). Some analysis shown attached also used acceleration values of 0.11g and 0.22g to evaluate the effect of the acceleration on the factor of safety. The results are shown in Tables 1 and 2.

It should be noted that the stability analysis (as is generally the case) was performed using a two-dimensional model of the stack and the ground profile, neither of which are so in reality. The actual factor of safety should be significantly greater than those obtained theoretically. For the Peninsula site, the ratio of the actual to theoretical factor of safety may be at least 1.2 times greater (or more) due to the three-dimensional effect of the site topography and the subsurface conditions. For the ash site, the ratio will be somewhat smaller due to a more uniform subsurface condition.

Conclusions and Recommendations

General

The results of the two-dimensional stability analysis shown on Tables 1 and 2 provide factors of safety ranging from 0.79 to 1.95. In general, the results show that for a given condition, a factor of safety during the design seismic event (0.15g) of 1.0 can be obtained when a static factor of safety of about 1.6 to 1.8 is achieved for the same condition. It is clear that if the three-dimensional effect is considered, it is feasible to engineer the stack design to attain a factor of safety against global slope failure during seismic conditions greater than 1.0. The engineering measures include adequate stack-drainage to lower the phreatic surface sufficiently within the stack and foundation improvement to stiffen soft foundation soil adequately as indicated from this stability evaluation.

Additional discussions of the results of the two-dimensional stability analysis for the two sites are provided below. Additional general conclusions are as follows:

- Flattening the stack slope from 3H:1V to 4H:1V improves stability somewhat, but apparently is not required if adequate bench width is provided with 3H:1V slopes.
- Low-friction cohesive foundation soil (such as at the Peninsula site) is apparently less favorable for the proposed stack heights than a low-cohesion frictional soil (such as at the Ash site).
- Control of the water table within the stack itself is critical at both sites. Final design of a dry or wet stack system should include drainage design based on the anticipated hydraulic properties of the stack materials. Ground water control measures within the pile will be much more elaborate and expensive for wet stacking than with dry stacking.
- For the final design, the properties of gypsum, especially the effect of aging on strength gain, should be properly evaluated.

Specifically for Peninsula Site

Based on Reference 2 data, an approximately 20-foot thick soft soil layer (soil layer 4 in the STED model) may exist approximately 20 feet below existing ground surface. This layer, if large in extent may have a significant effect on the overall stack stability. Future investigation should verify the extent, in-situ strength and deformation characteristics of this soil as well as those of the overlying stiffer soil. The top of rock contours should also be closely verified, along with the presence of solution cavities. Measures such as gravel columns along with a stone blanket below the impervious liner may be required to stiffen the soft soil if its extent is large and significant to the stack stability.

The design of a dry stack system to the configurations shown on the drawings should be feasible from a global stability standpoint.

A wet stacking system should be feasible at the Peninsula site; however, the wet stack may need to be modified from the stack configurations currently shown on the drawings. The final design of a wet stack may include flatter slopes and/or a shorter stack to obtain an adequate global factor of safety during a design seismic event, especially if the soft foundation soil beneath the stack extends over a significantly large area.

Specifically for Ash Site

Based on the results of our analysis, it appears the ash site is suitable for both dry and wet stacking to the heights and configurations shown on the drawings. Some additional geotechnical field and laboratory testing will be necessary for the final design but probably not to the extent needed for the Peninsula Site.

References:

1. Options 1A, 1B, 2A, and 2B sketches (SK PR0637 series drawings), including other corresponding sketches showing details of the options.
2. MACTECH report titles, "Report of Geotechnical Exploration for Proposed Scrubber Stack Disposal Area", dated March 26, 2003, along with revised page and top of rock contour plans provided by MACTECH.
3. Data on sludge and sludge-ash mixtures provided by Dan Smith (ATTACHMENT A, Pages 3-26 through 3-30).
4. Law Engineering's "FINAL REPORT – Fly Ash, Bottom Ash and Scrubber Gypsum Study" – to TVA dated November 7, 1995, along with transmittal letter dated November 10, 1995.
5. Singleton Laboratories' report titled "KINGSTON FOSSIL PLANT – DREDGE CELLS CLOSURE SOILS INVESTIGATION", dated September 29, 1994.
6. U.S. Government reports titled, "KINGSTON STEAM PLANT – DIKE C, SOILS INVESTIGATION, EN DES SOIL SCHEDULE 82.3", dated June 22, 1984, and January 10, 1985.
7. Reports on ASH DISPOSAL AREA DIKE RAISING - SOIL INVESTIGATION:
    - A. Evaluation, by O.H. Raine, dated 11/12/75.
    - B. Investigation data report by Gene Farmer, dated November 3, 1975.
    - C. RFP for investigation, by W.W. Engle, dated June 26, 1974.
8. Ardaman & Associates, Inc., "Interim Report on Evaluation of the FGD Gypsum-Flyash Waste Wet-Stacking Disposal facility, Widows Creek Steam Plant, Stevenson, Alabama", dated April 22, 1991.
9. Tennessee Division of Solid waste management, Technical Guidance Document – Earthquake Evaluation Guidance Policy

Table 1 – Summary of Stability Analysis Models – Peninsula Site

Model Description	Water Table	Top of Stack (feet, NGVD)	Stacking Method	Slopes	Horizontal Earthquake Coefficient	Factor of Safety
1A - Soft Foundation Soils	2/3 Stack +880’	950	Dry	3H:1V with 15’ benches	0	0.97
1A - Stiff Foundation Soils	2/3 Stack +880’	950	Dry	3H:1V with 15’ benches	0	1.21
1A - Very Stiff Foundation Soils	2/3 Stack +880’	950	Dry	3H:1V with 15’ benches	0	1.40
1A - Very Stiff Foundation Soils	2/3 Stack +880’	950	Dry	3H:1V with 15’ benches	0.15g	0.83
1A - Very Stiff Foundation Soils	Lowered to +795’	950	Dry	3H:1V with 15’ benches	0.15g	1.00
1A - Stiff Foundation Soils	2/3 Stack +860’	910	Dry	4H:1V with 15’ benches	0.15g	0.82
1A - Very Stiff Foundation Soils	2/3 Stack +860’	910	Dry	4H:1V with 15’ benches	0.15g	1.05
1A - Stiff Foundation Soils	Lowered to +800’	910	Dry	4H:1V with 15’ benches	0.15g	1.01
1A - Very Stiff Foundation Soils	+905’ at High Point	950	Wet	3H:1V with 15’ benches	0	1.36
1A - Very Stiff Foundation Soils	+905’ at High Point	950	Wet	3H:1V with 15’ benches	0.15g	0.79
1A - Very Stiff Foundation Soils	+905’ at High Point	950	Wet	3H:1V with 15’ benches	0.11g	0.90

Table 2 – Summary of Stability Analysis Models – Existing Ash Disposal Site

Water Table	Top of Stack (feet, NGVD)	Stacking Method	Slopes	Horizontal Earthquake Coefficient	Factor of Safety
2/3 Stack +900’	980	Dry	3H:1V with 10’ benches	0	1.95
2/3 Stack +900’	980	Dry	3H:1V with 10’ benches	0.15g	1.22
2/3 Stack +900’	980	Dry	3H:1V with 10’ benches	0.22g	1.02
+980’	980	Wet	3H:1V with 10’ benches	0	1.90
+980’	980	Wet	3H:1V with 10’ benches	0.15g	1.17
+980’	980	Wet	3H:1V with 10’ benches	0.22g	0.96

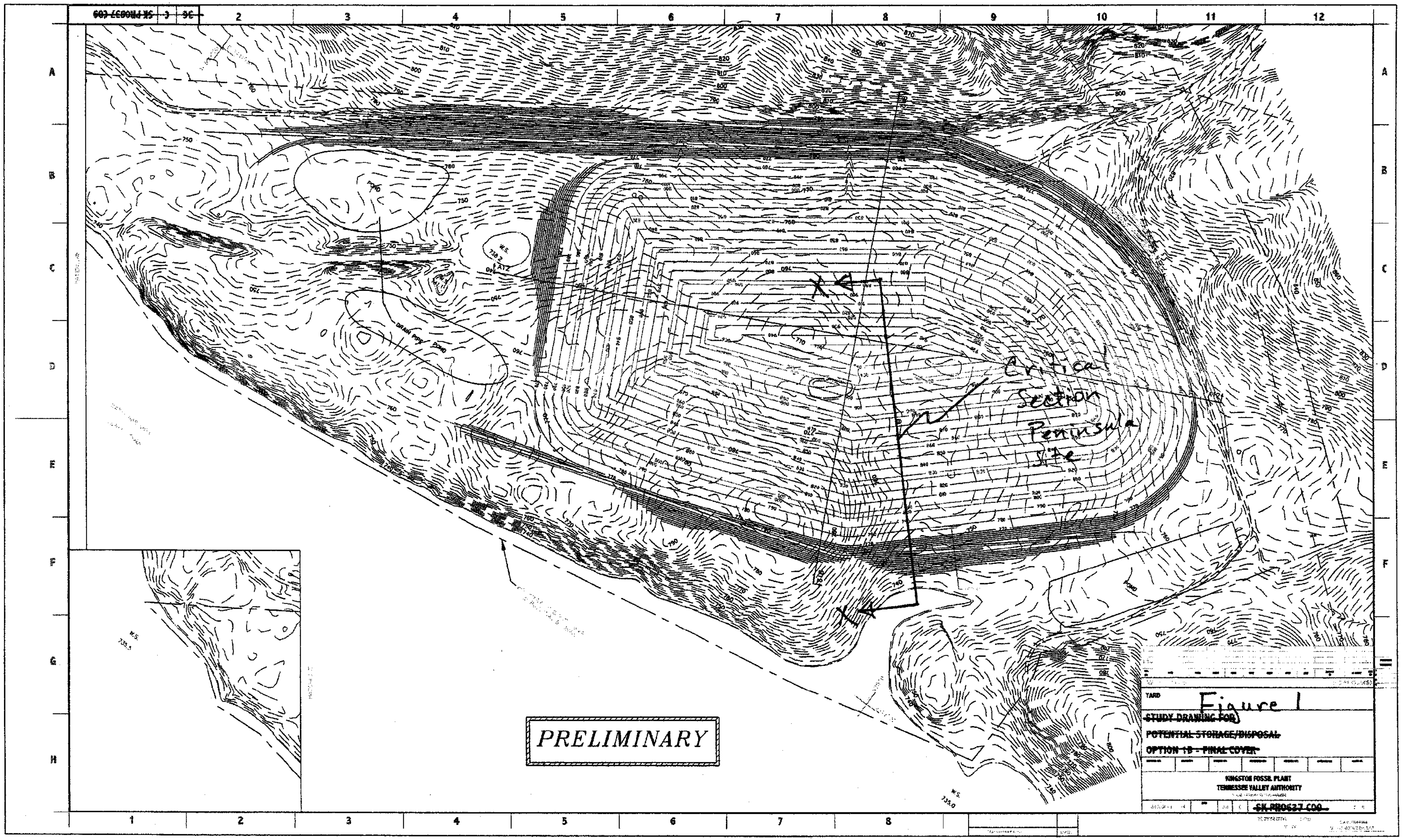
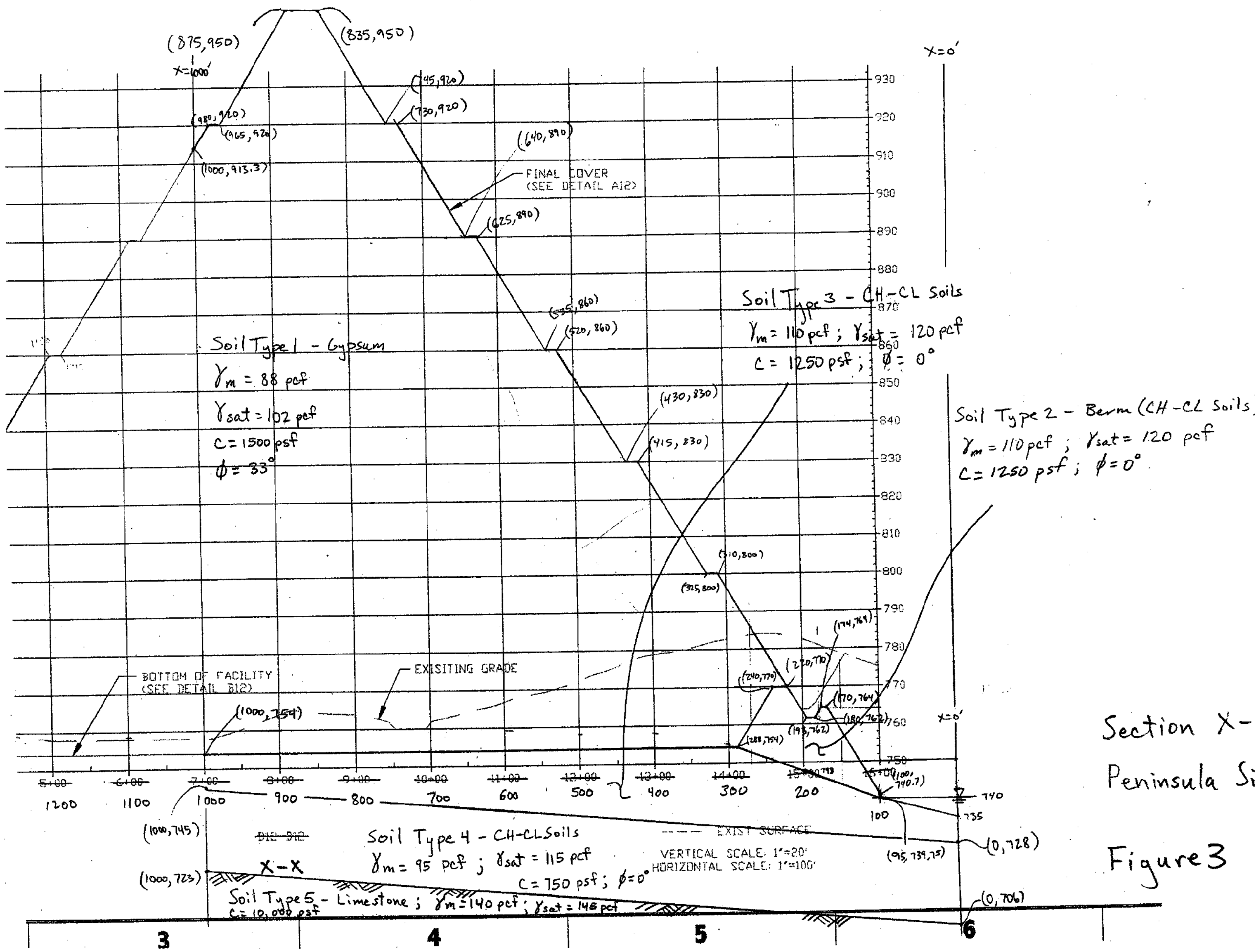


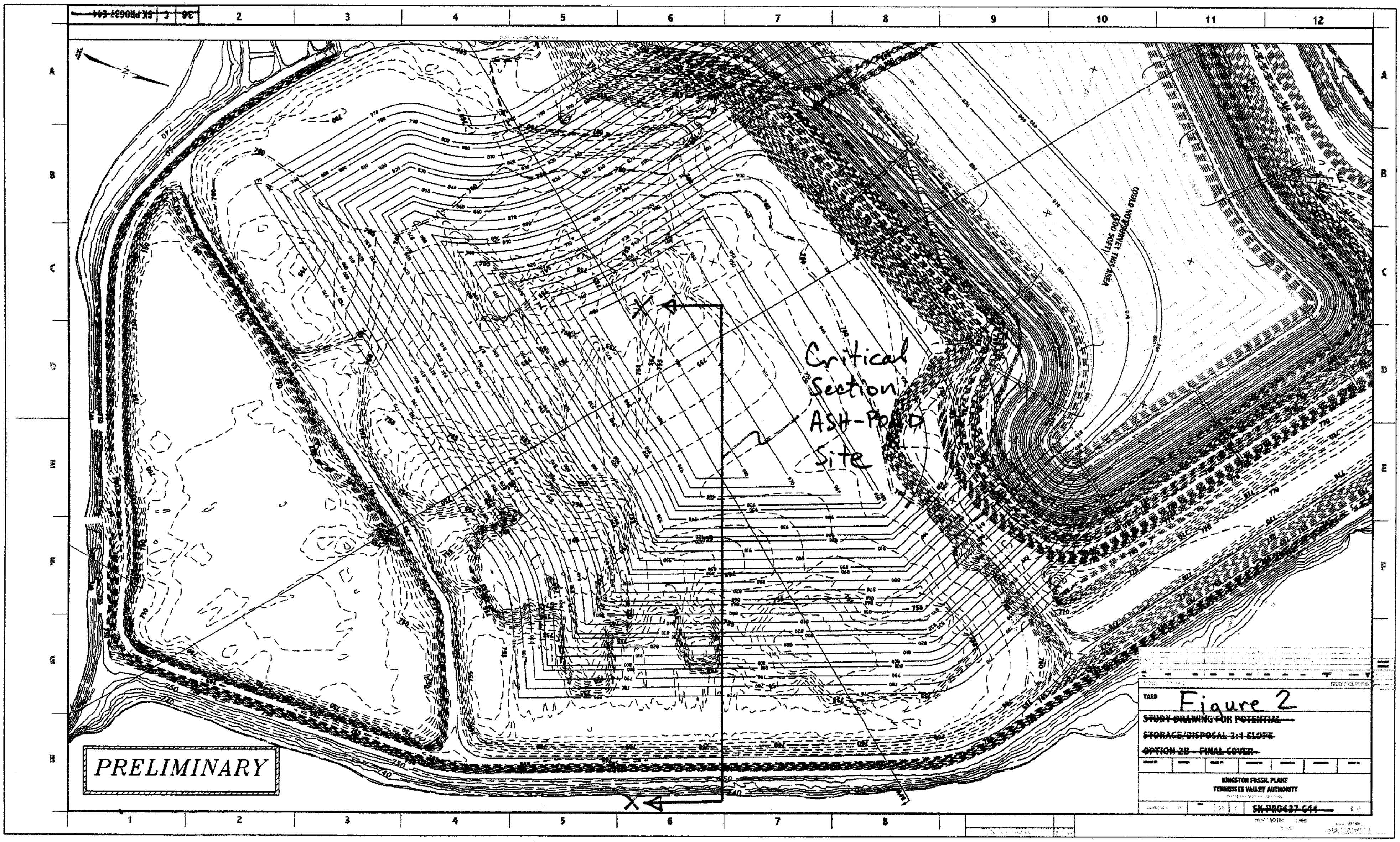
Figure 1
Critical Section Peninsula Site
PRELIMINARY
YARD
STUDY DRAWING FOR
POTENTIAL STORAGE/DISPOSAL
OPTION 1B - FINAL COVER
KINGSTON FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
SK-PR0637 C00



Section X-X
Peninsula Site

Figure 3

TVA-00004778


PRELIMINARY
Critical Section ASH-POND Site
COULD NOT SURVEY THIS AREA (TOO SOFT)
Figure 2
STUDY DRAWING FOR POTENTIAL
STORAGE/DISPOSAL 3:4 SLOPE
OPTION 2B - FINAL COVER
KINGSTON FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
SK-PRO637-C44

PARSONS

STANDARD CALCULATION SHEET

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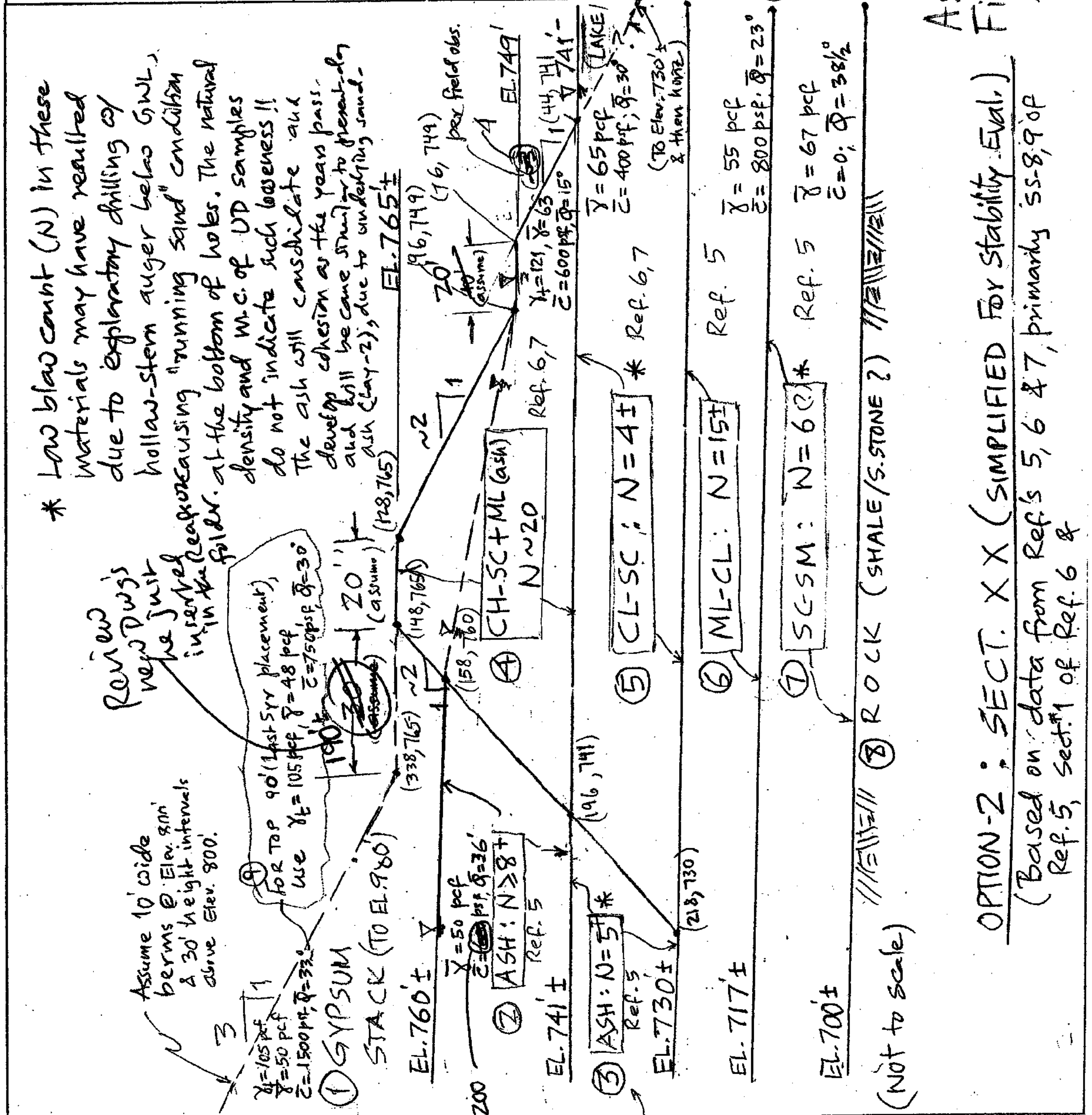
PROJECT NAME: Kingston – Gypsum Stack – Feasibilty Study				
SUBJECT: Global Stablity Evaluation				CALC NO.:
REVISION	0	1	2	3
ORIGINATOR:	Y.S.Shah			
REVIEWER:	Anundson			
DATE:	04-22-03			

Page
Of

Ash-Pond Site
Figure 4
x=0



OPTION-2 : SECT. XX (SIMPLIFIED For Stability Eval.)
(Based on data from Ref.'s 5, 6 & 7, primarily SS-8,9 of Ref. 5, Sect.#1 of Ref. 6 &

THIS IS A DESIGN RECORD

EP3-2 12/96

TVA-00004780

TVA Kingston - Option 1B - X_X Dry Stack - Static - Soil 4 Soft

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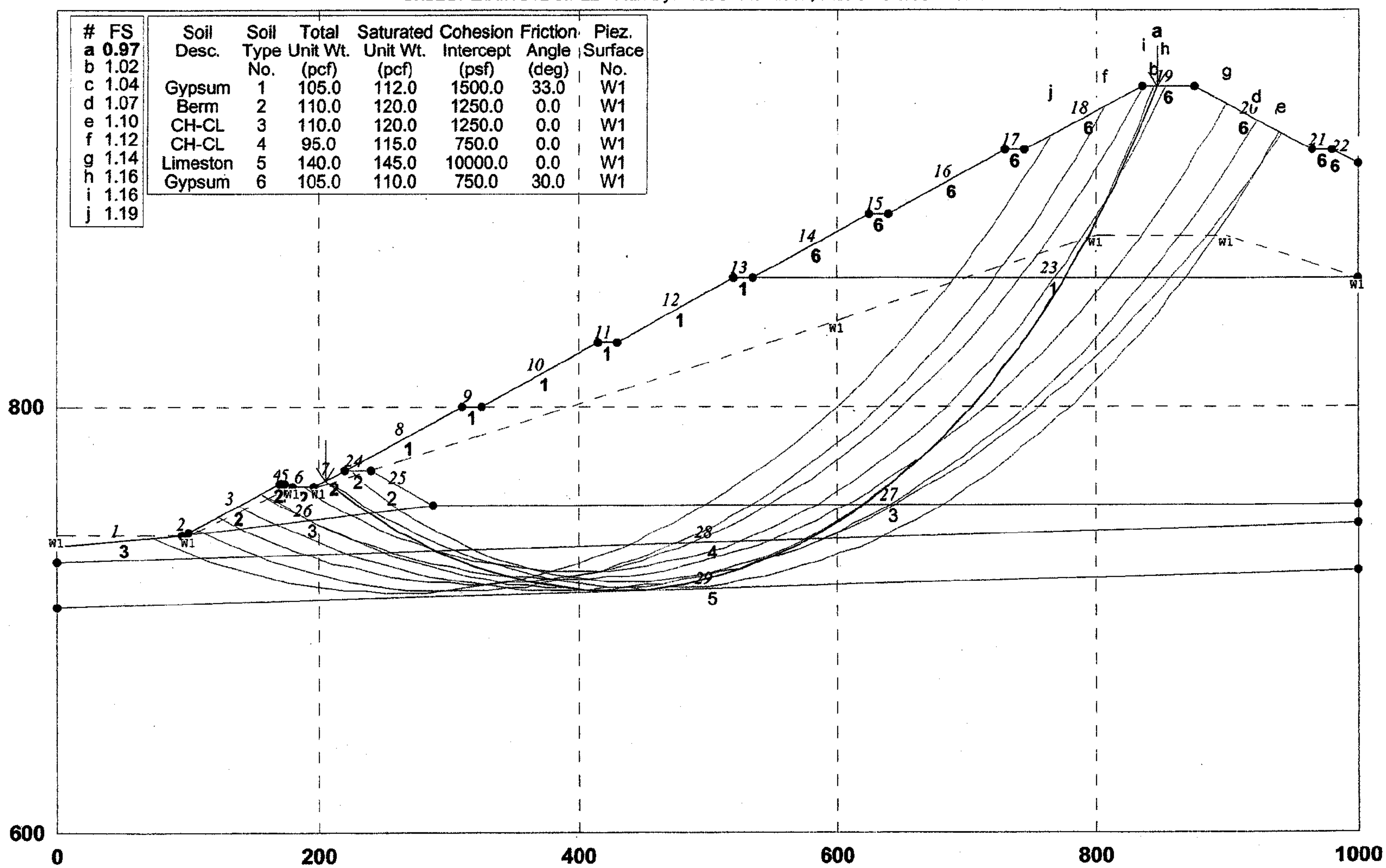

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d	1.07
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f	1.12
g	1.14
h	1.16
i	1.16
j	1.19

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gypsum	1	105.0	112.0	1500.0	33.0	W1
Berm	2	110.0	120.0	1250.0	0.0	W1
CH-CL	3	110.0	120.0	1250.0	0.0	W1
CH-CL	4	95.0	115.0	750.0	0.0	W1
Limeston	5	140.0	145.0	10000.0	0.0	W1
Gypsum	6	105.0	110.0	750.0	30.0	W1

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Safety Factors Are Calculated By The Modified Bishop Method

STED

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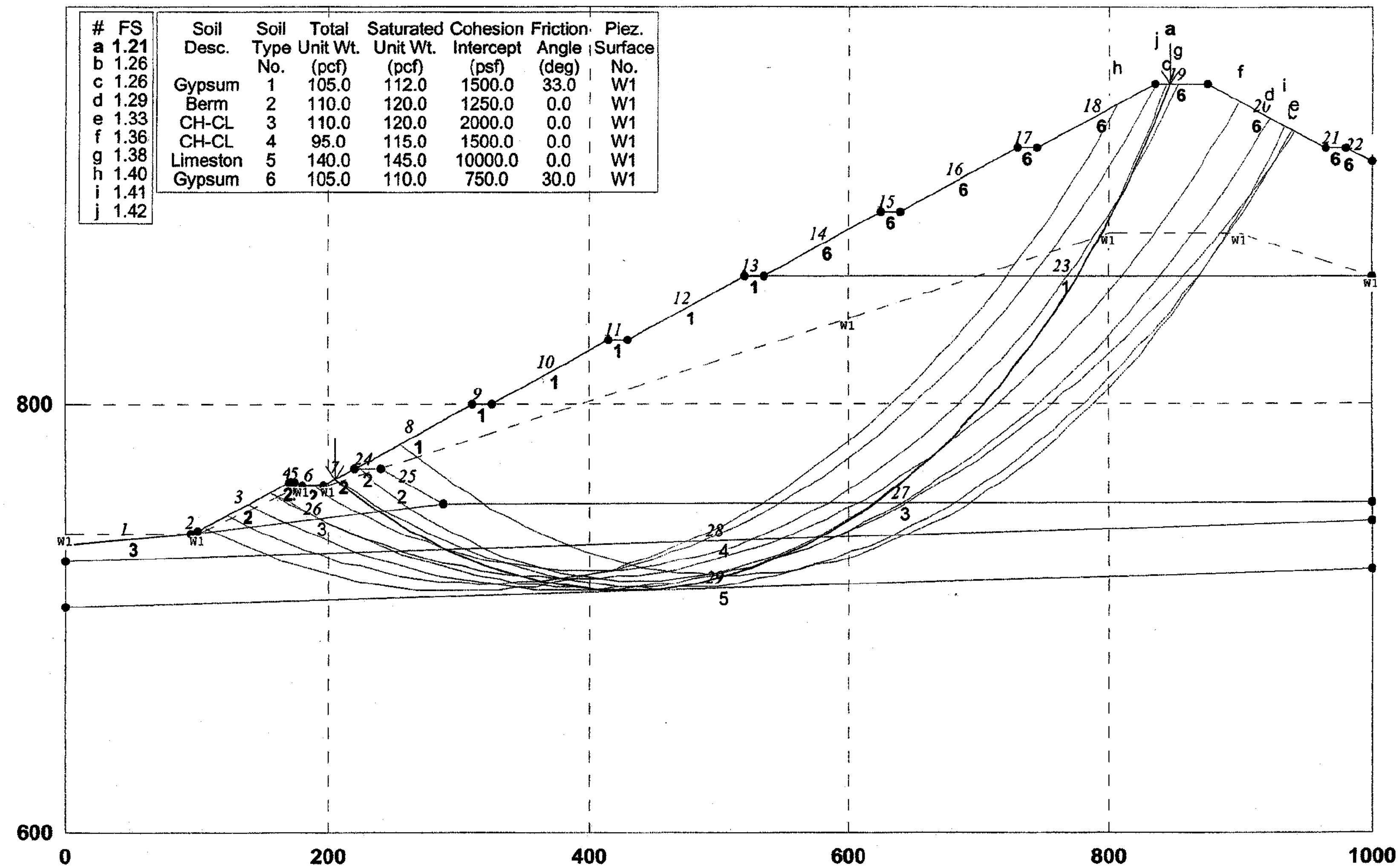

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d	1.29
e	1.33
f	1.36
g	1.38
h	1.40
i	1.41
j	1.42

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gypsum	1	105.0	112.0	1500.0	33.0	W1
Berm	2	110.0	120.0	1250.0	0.0	W1
CH-CL	3	110.0	120.0	2000.0	0.0	W1
CH-CL	4	95.0	115.0	1500.0	0.0	W1
Limeston	5	140.0	145.0	10000.0	0.0	W1
Gypsum	6	105.0	110.0	750.0	30.0	W1

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Safety Factors Are Calculated By The Modified Bishop Method

STED

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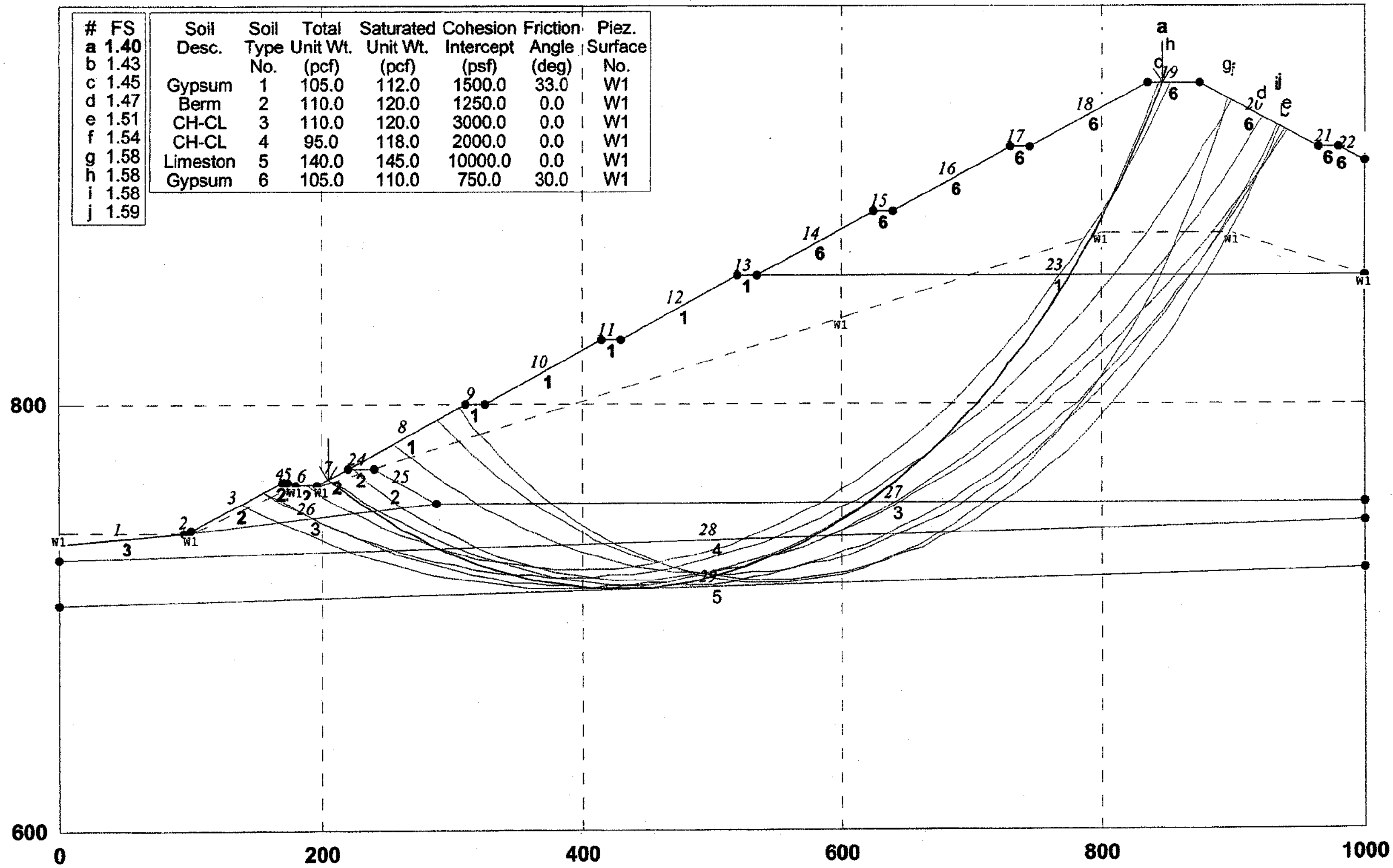

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Safety Factors Are Calculated By The Modified Bishop Method

STED

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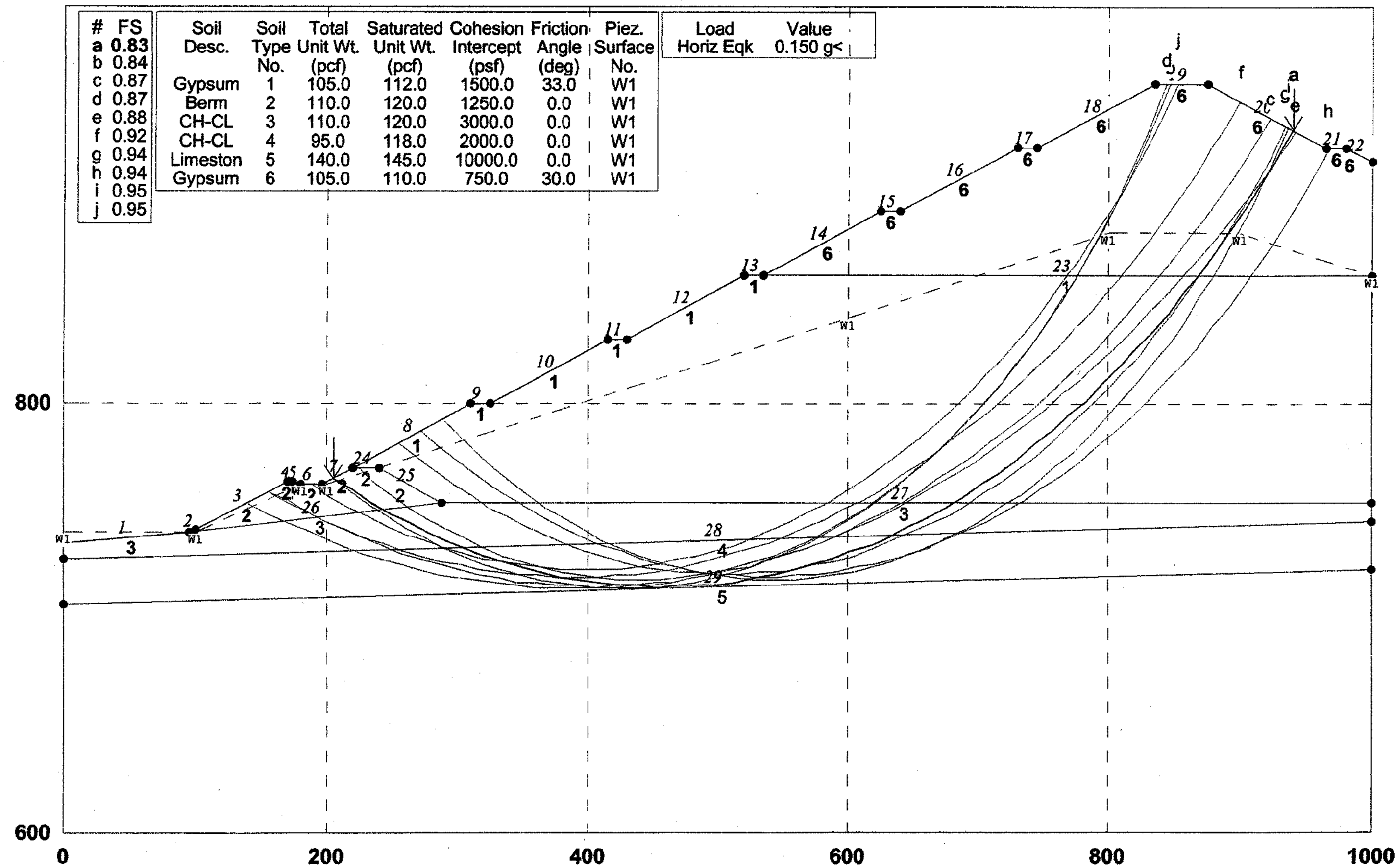

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d	0.87
e	0.88
f	0.92
g	0.94
h	0.94
i	0.95
j	0.95

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gypsum	1	105.0	112.0	1500.0	33.0	W1
Berm	2	110.0	120.0	1250.0	0.0	W1
CH-CL	3	110.0	120.0	3000.0	0.0	W1
CH-CL	4	95.0	118.0	2000.0	0.0	W1
Limeston	5	140.0	145.0	10000.0	0.0	W1
Gypsum	6	105.0	110.0	750.0	30.0	W1

Load	Value
Horiz Eqk	0.150 g<

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Safety Factors Are Calculated By The Modified Bishop Method

STED

TVA Kingston - Option 1B - X_X Dry Stack - E'quake - Soil 4 Very Stiff

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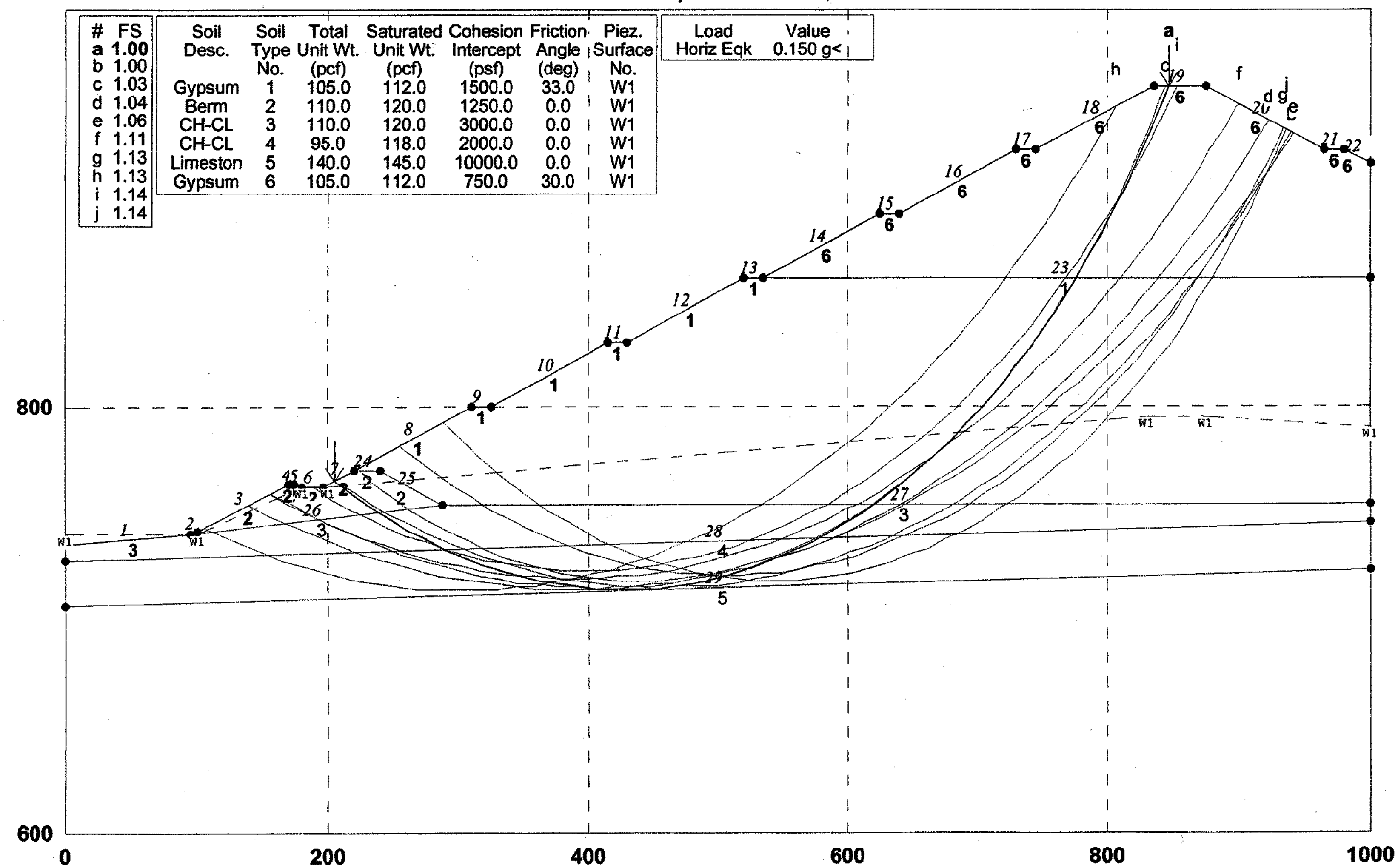

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e	1.06
f	1.11
g	1.13
h	1.13
i	1.14
j	1.14

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gypsum	1	105.0	112.0	1500.0	33.0	W1
Berm	2	110.0	120.0	1250.0	0.0	W1
CH-CL	3	110.0	120.0	3000.0	0.0	W1
CH-CL	4	95.0	118.0	2000.0	0.0	W1
Limeston	5	140.0	145.0	10000.0	0.0	W1
Gypsum	6	105.0	112.0	750.0	30.0	W1

Load	Value
Horiz Eqk	0.150 g<

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Safety Factors Are Calculated By The Modified Bishop Method

STED

TVA Kingston - Option 1A (4:1) - X_X Dry Stack - E'quake - Soil 4 Stiff

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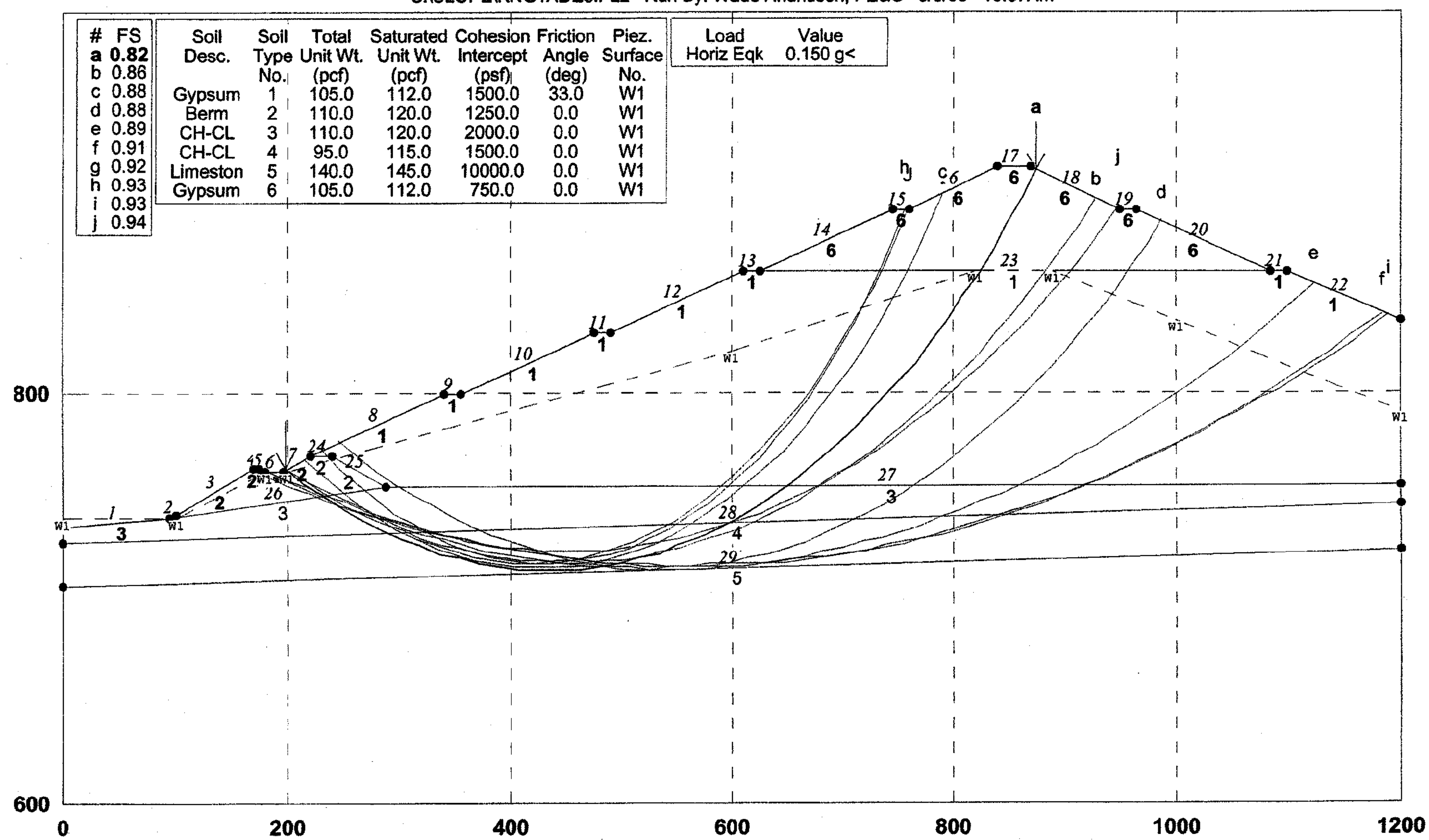
c	0.88
d	0.88
e	0.89
f	0.91
g	0.92
h	0.93
i	0.93
j	0.94

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gypsum	1	105.0	112.0	1500.0	33.0	W1
Berm	2	110.0	120.0	1250.0	0.0	W1
CH-CL	3	110.0	120.0	2000.0	0.0	W1
CH-CL	4	95.0	115.0	1500.0	0.0	W1
Limeston	5	140.0	145.0	10000.0	0.0	W1
Gypsum	6	105.0	112.0	750.0	0.0	W1

Load	Value
Horiz Eqk	0.150 g<



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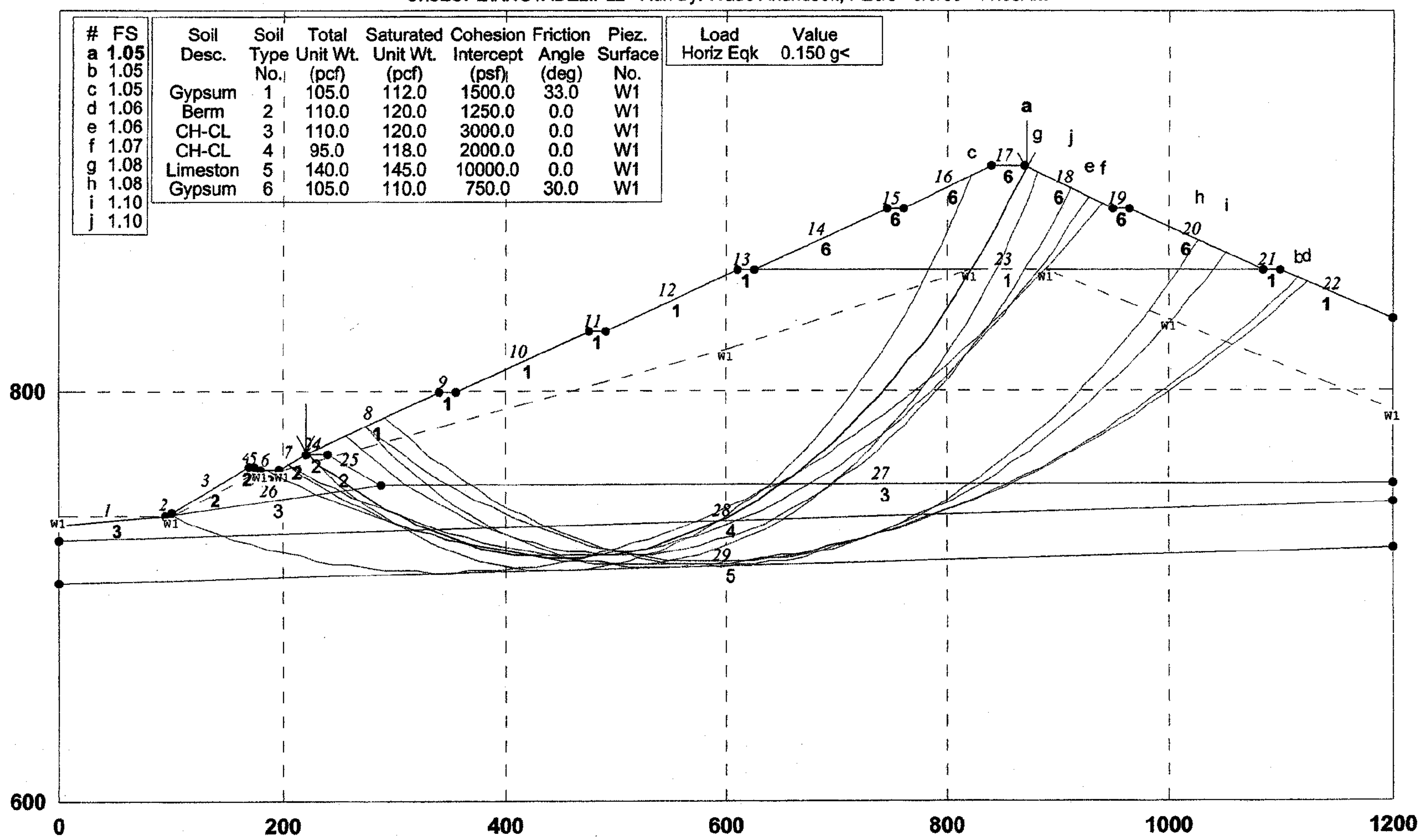
Safety Factors Are Calculated By The Modified Bishop Method

STED

TVA Kingston - Option 1A (4:1) - X_X Dry Stack - E'quake - Soil 4 Very Stiff

C:\SLOPE\KNG1ADE2.PL2 Run By: Wade Anundson, PE&C 5/5/03 11:03AM



#	FS
a	**1.05**
b	1.05
c	1.05
d	1.06
e	1.06
f	1.07
g	1.08
h	1.08
i	1.10
j	1.10

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gypsum	1	105.0	112.0	1500.0	33.0	W1
Berm	2	110.0	120.0	1250.0	0.0	W1
CH-CL	3	110.0	120.0	3000.0	0.0	W1
CH-CL	4	95.0	118.0	2000.0	0.0	W1
Limeston	5	140.0	145.0	10000.0	0.0	W1
Gypsum	6	105.0	110.0	750.0	30.0	W1

Load	Value
Horiz Eqk	0.150 g<

PCSTABL5M/si FSmin=1.05

Safety Factors Are Calculated By The Modified Bishop Method

STED

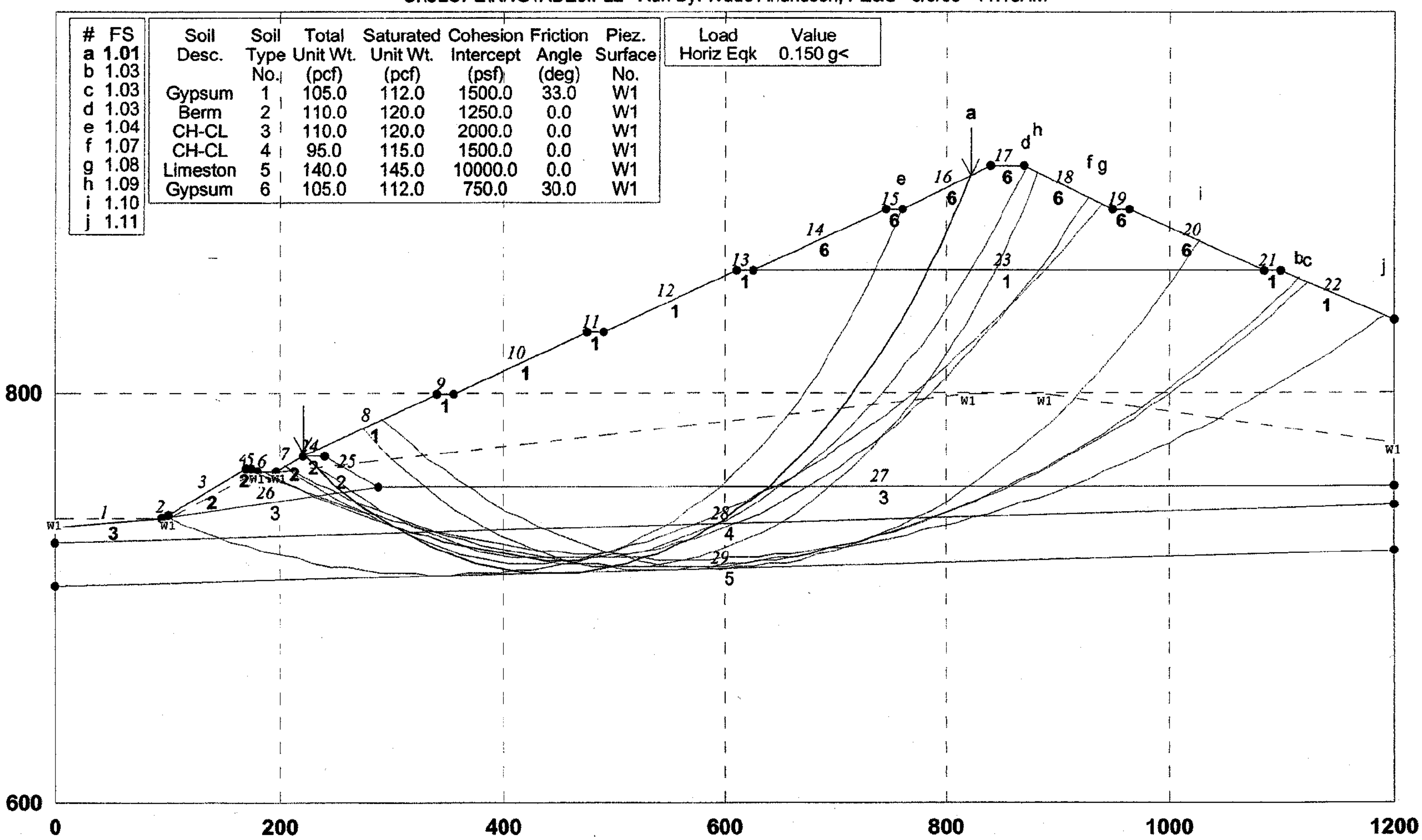
TVA Kingston - Option 1A (4:1) - X_X Dry Stack - E'quake - Soil 4 Stiff

C:\SLOPE\KNG1ADE5.PL2 Run By: Wade Anundson, PE&C 5/5/03 11:13AM

#	FS
a	**1.01**
b	1.03
c	1.03
d	1.03
e	1.04
f	1.07
g	1.08
h	1.09
i	1.10
j	1.11

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gypsum	1	105.0	112.0	1500.0	33.0	W1
Berm	2	110.0	120.0	1250.0	0.0	W1
CH-CL	3	110.0	120.0	2000.0	0.0	W1
CH-CL	4	95.0	115.0	1500.0	0.0	W1
Limeston	5	140.0	145.0	10000.0	0.0	W1
Gypsum	6	105.0	112.0	750.0	30.0	W1

Load	Value
Horiz Eqk	0.150 g<



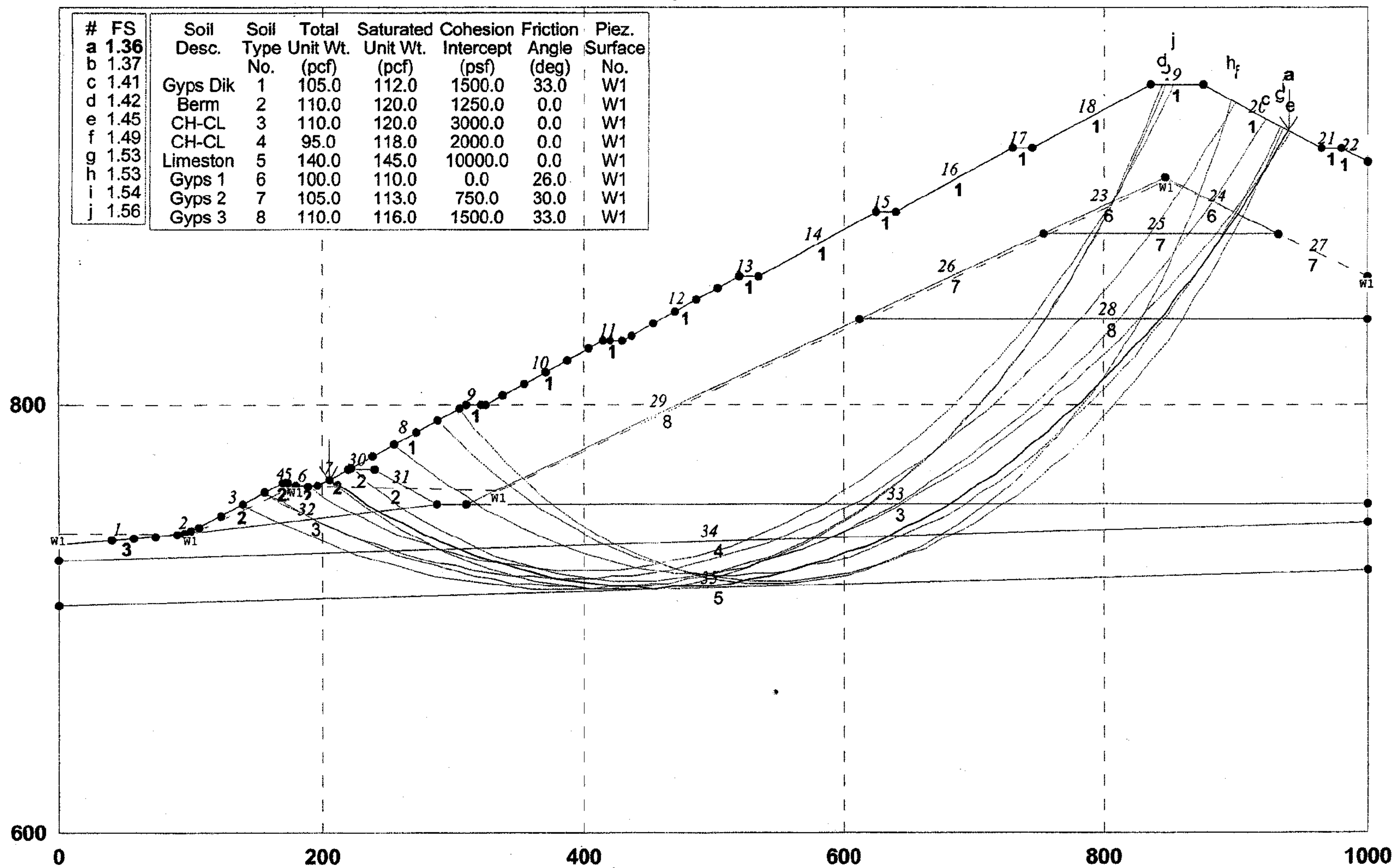
PCSTABL5M/si FSmin=1.01

Safety Factors Are Calculated By The Modified Bishop Method

STED

TVA Kingston - Option 1B - X_X Wet Stack - Static - Soil 4 Very Stiff

C:\SLOPE\KNG1WS1.PL2 Run By: Wade Anundson, PE&C 5/6/03 12:07PM



#	FS
a	**1.36**
b	1.37
c	1.41
d	1.42
e	1.45
f	1.49
g	1.53
h	1.53
i	1.54
j	1.56

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gyps Dik	1	105.0	112.0	1500.0	33.0	W1
Berm	2	110.0	120.0	1250.0	0.0	W1
CH-CL	3	110.0	120.0	3000.0	0.0	W1
CH-CL	4	95.0	118.0	2000.0	0.0	W1
Limeston	5	140.0	145.0	10000.0	0.0	W1
Gyps 1	6	100.0	110.0	0.0	26.0	W1
Gyps 2	7	105.0	113.0	750.0	30.0	W1
Gyps 3	8	110.0	116.0	1500.0	33.0	W1

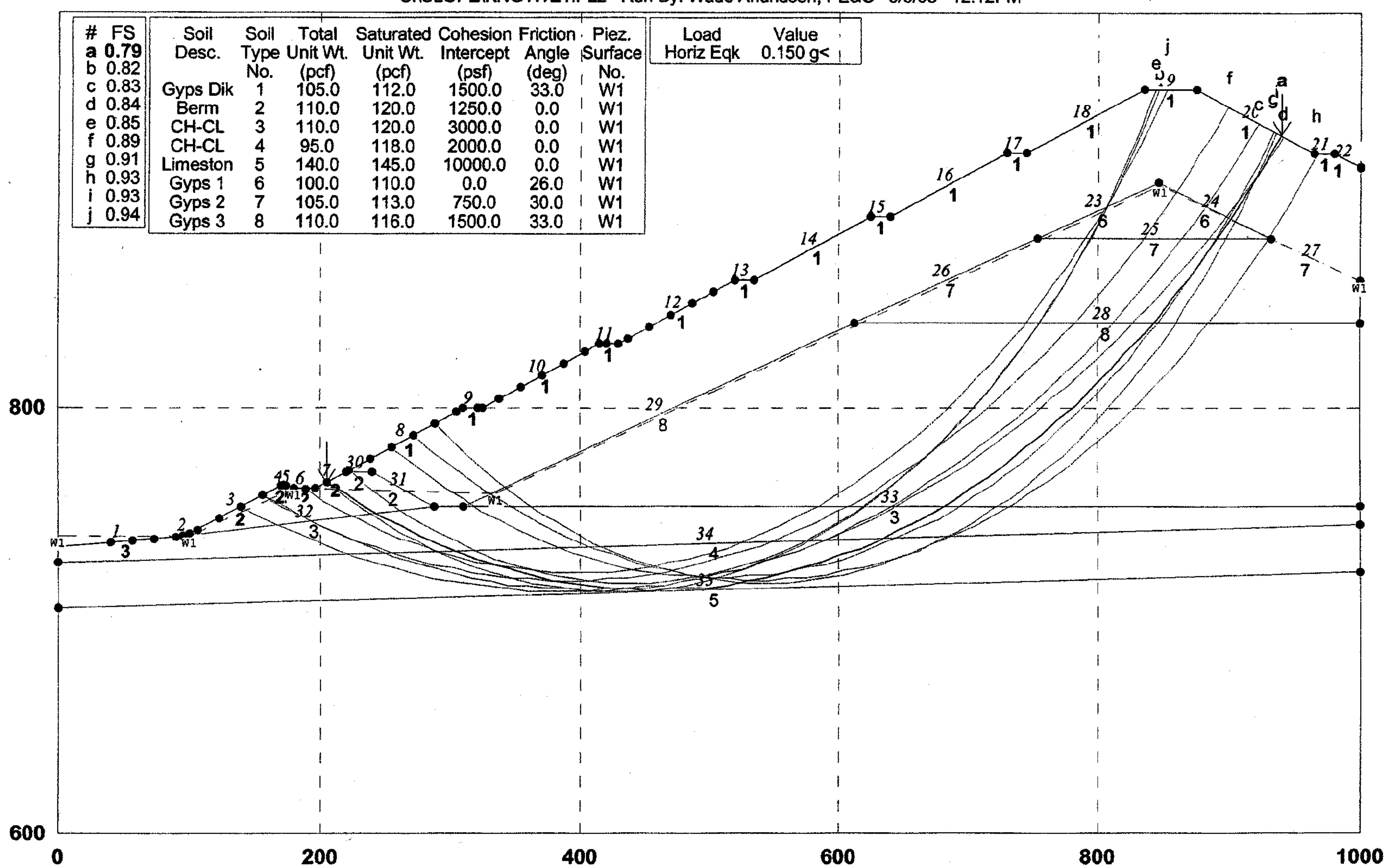
PCSTABL5M/si FSmin=1.36

Safety Factors Are Calculated By The Modified Bishop Method

STED

TVA Kingston - Option 1B - X_X Wet Stack - E'quake - Soil 4 Very Stiff

C:\SLOPE\KNG1WE1.PL2 Run By: Wade Anundson, PE&C 5/6/03 12:12PM



#	FS
a	**0.79**
b	0.82
c	0.83
d	0.84
e	0.85
f	0.89
g	0.91
h	0.93
i	0.93
j	0.94

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gyps Dik	1	105.0	112.0	1500.0	33.0	W1
Berm	2	110.0	120.0	1250.0	0.0	W1
CH-CL	3	110.0	120.0	3000.0	0.0	W1
CH-CL	4	95.0	118.0	2000.0	0.0	W1
Limeston	5	140.0	145.0	10000.0	0.0	W1
Gyps 1	6	100.0	110.0	0.0	26.0	W1
Gyps 2	7	105.0	113.0	750.0	30.0	W1
Gyps 3	8	110.0	116.0	1500.0	33.0	W1

Load	Value
Horiz Eqk	0.150 g<

PCSTABL5M/si FSmin=0.79

Safety Factors Are Calculated By The Modified Bishop Method

STED

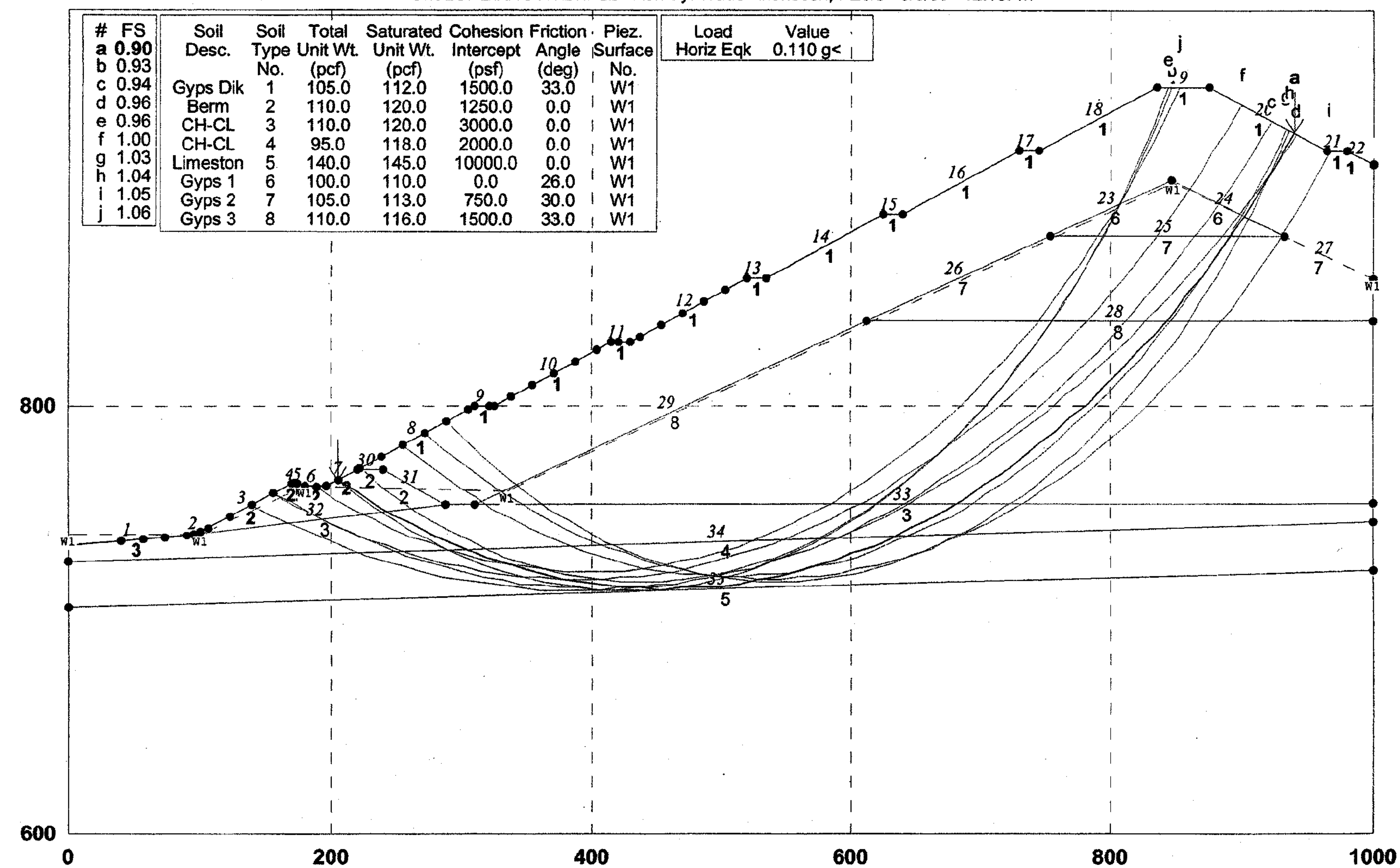
TVA Kingston - Option 1B - X_X Wet Stack - E'quake - Soil 4 Very Stiff

C:\SLOPE\KNG1WE1.PL2 Run By: Wade Anundson, PE&C 5/6/03 12:13PM

#	FS
a	**0.90**
b	0.93
c	0.94
d	0.96
e	0.96
f	1.00
g	1.03
h	1.04
i	1.05
j	1.06

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gyps Dik	1	105.0	112.0	1500.0	33.0	W1
Berm	2	110.0	120.0	1250.0	0.0	W1
CH-CL	3	110.0	120.0	3000.0	0.0	W1
CH-CL	4	95.0	118.0	2000.0	0.0	W1
Limeston	5	140.0	145.0	10000.0	0.0	W1
Gyps 1	6	100.0	110.0	0.0	26.0	W1
Gyps 2	7	105.0	113.0	750.0	30.0	W1
Gyps 3	8	110.0	116.0	1500.0	33.0	W1

Load	Value
Horiz Eqk	0.110 g<

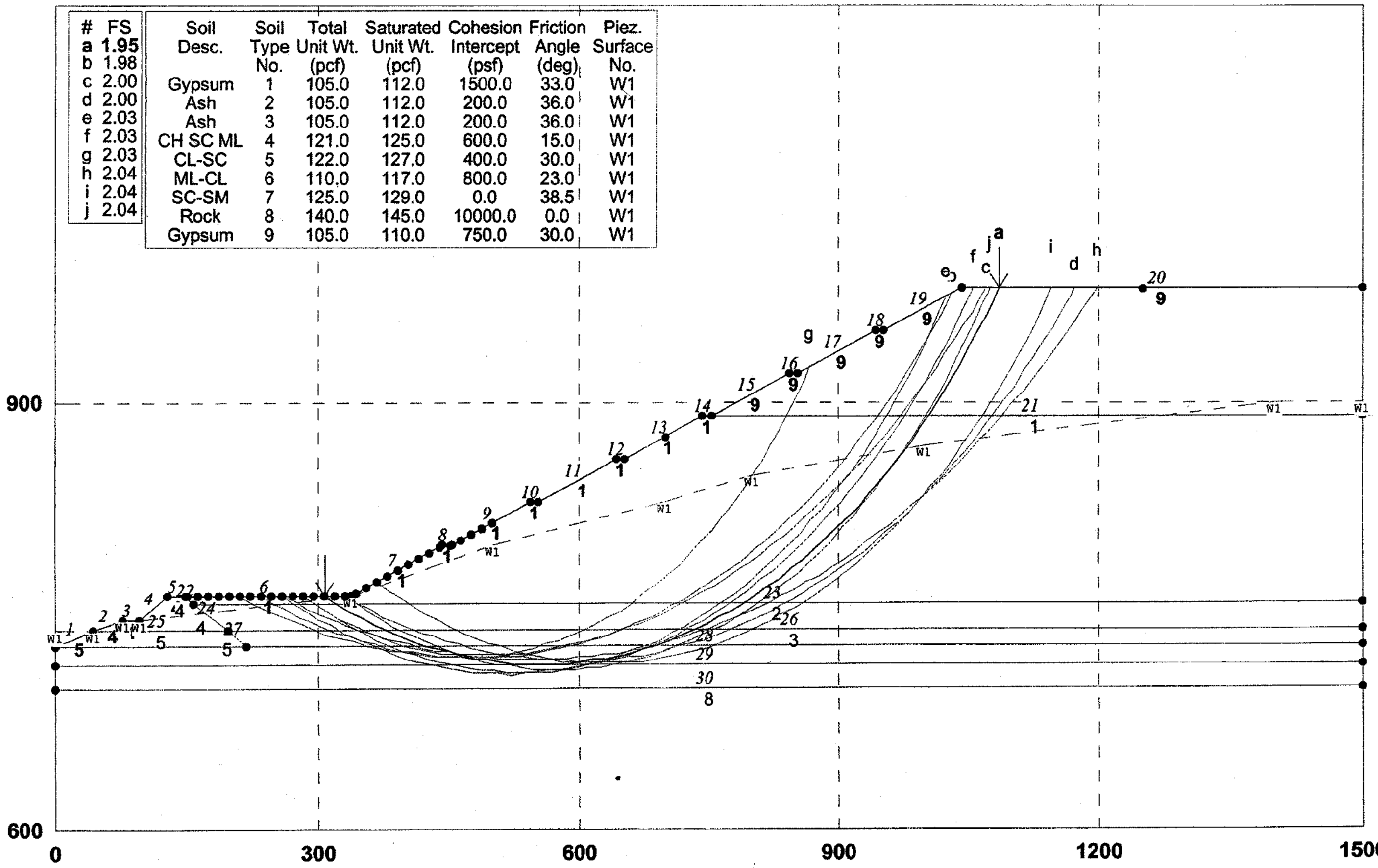


PCSTABL5M/si FSmin=0.90
Safety Factors Are Calculated By The Modified Bishop Method

STED

TVA Kingston - Option 2B Dry Stack - Static

C:\SLOPE\KING2DS1.PL2 Run By: Wade Anundson, PE&C 5/1/03 11:55AM



#	FS
a	**1.95**
b	1.98
c	2.00
d	2.00
e	2.03
f	2.03
g	2.03
h	2.04
i	2.04
j	2.04

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gypsum	1	105.0	112.0	1500.0	33.0	W1
Ash	2	105.0	112.0	200.0	36.0	W1
Ash	3	105.0	112.0	200.0	36.0	W1
CH SC ML	4	121.0	125.0	600.0	15.0	W1
CL-SC	5	122.0	127.0	400.0	30.0	W1
ML-CL	6	110.0	117.0	800.0	23.0	W1
SC-SM	7	125.0	129.0	0.0	38.5	W1
Rock	8	140.0	145.0	10000.0	0.0	W1
Gypsum	9	105.0	110.0	750.0	30.0	W1

PCSTABL5M/si FSmin=1.95

Safety Factors Are Calculated By The Modified Bishop Method

STED

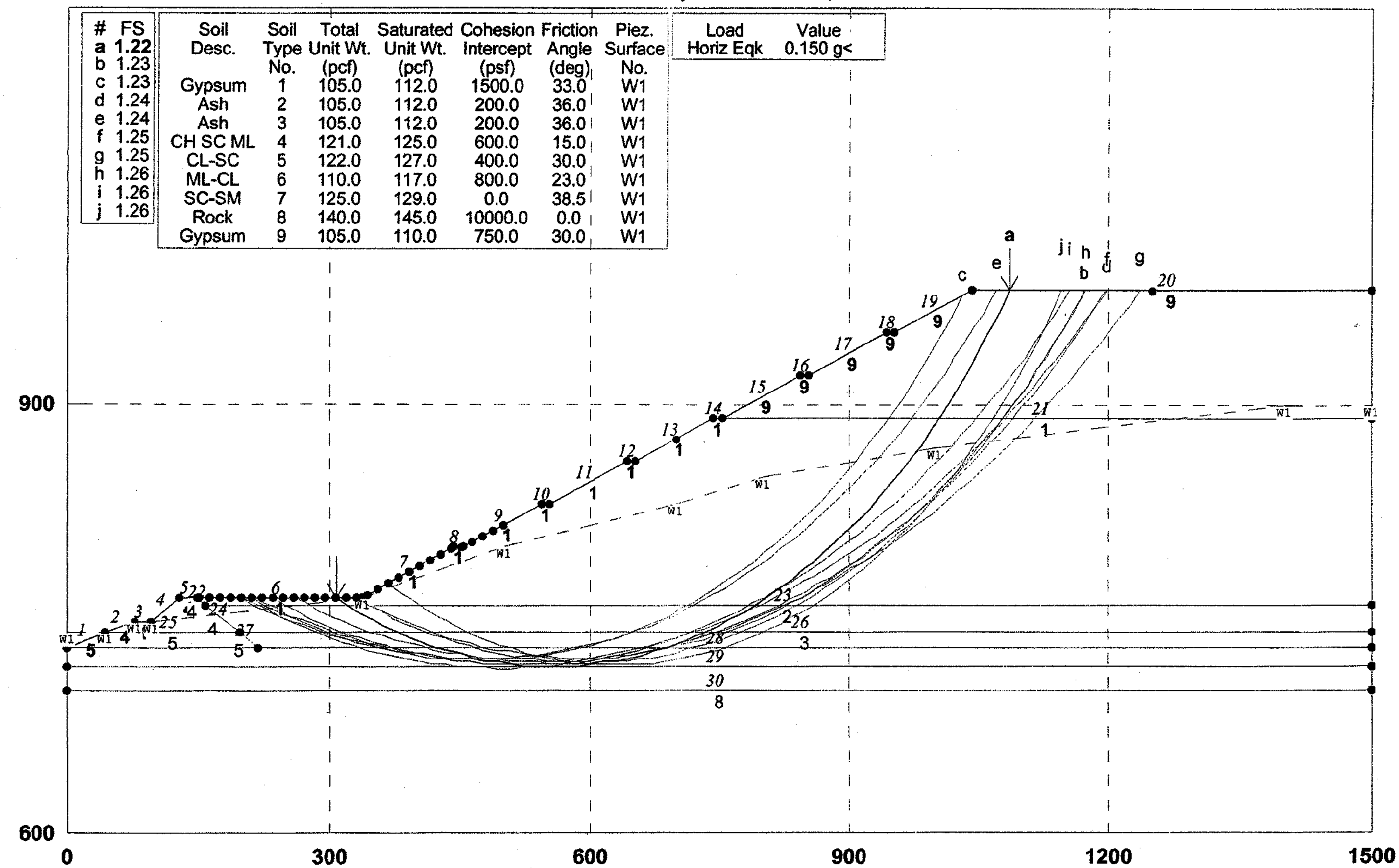
TVA Kingston - Option 2B Dry Stack - Seismic

C:\SLOPE\KING2DE1.PL2 Run By: Wade Anundson, PE&C 5/1/03 11:56AM

#	FS
a	**1.22**
b	1.23
c	1.23
d	1.24
e	1.24
f	1.25
g	1.25
h	1.26
i	1.26
j	1.26

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gypsum	1	105.0	112.0	1500.0	33.0	W1
Ash	2	105.0	112.0	200.0	36.0	W1
Ash	3	105.0	112.0	200.0	36.0	W1
CH SC ML	4	121.0	125.0	600.0	15.0	W1
CL-SC	5	122.0	127.0	400.0	30.0	W1
ML-CL	6	110.0	117.0	800.0	23.0	W1
SC-SM	7	125.0	129.0	0.0	38.5	W1
Rock	8	140.0	145.0	10000.0	0.0	W1
Gypsum	9	105.0	110.0	750.0	30.0	W1

Load	Value
Horiz Eqk	0.150 g<



PCSTABL5M/si FSmin=1.22
Safety Factors Are Calculated By The Modified Bishop Method

STED

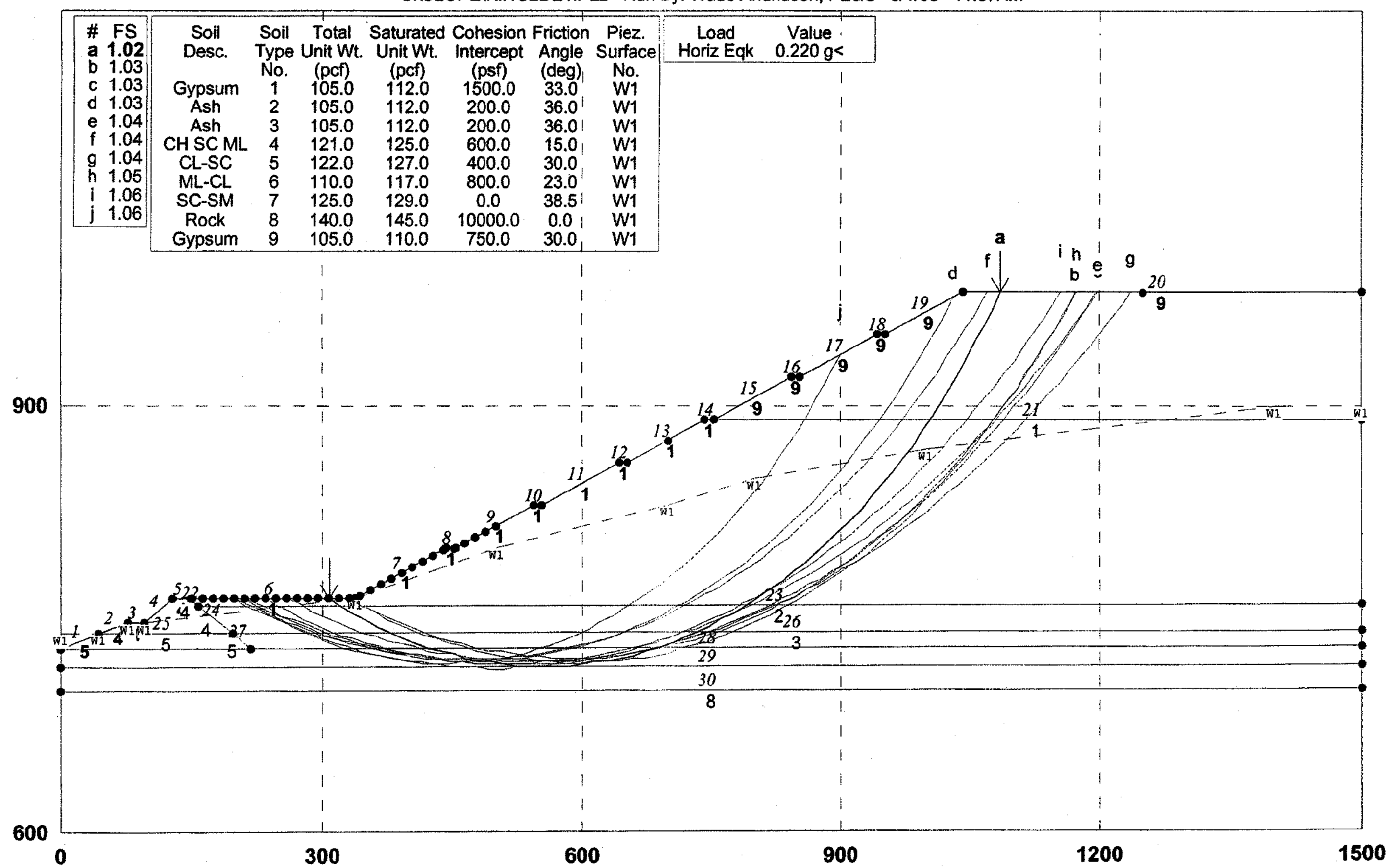
TVA Kingston - Option 2B Dry Stack - Seismic

C:\SLOPE\KING2DE1.PL2 Run By: Wade Anundson, PE&C 5/1/03 11:57AM

#	FS
a	**1.02**
b	1.03
c	1.03
d	1.03
e	1.04
f	1.04
g	1.04
h	1.05
i	1.06
j	1.06

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gypsum	1	105.0	112.0	1500.0	33.0	W1
Ash	2	105.0	112.0	200.0	36.0	W1
Ash	3	105.0	112.0	200.0	36.0	W1
CH SC ML	4	121.0	125.0	600.0	15.0	W1
CL-SC	5	122.0	127.0	400.0	30.0	W1
ML-CL	6	110.0	117.0	800.0	23.0	W1
SC-SM	7	125.0	129.0	0.0	38.5	W1
Rock	8	140.0	145.0	10000.0	0.0	W1
Gypsum	9	105.0	110.0	750.0	30.0	W1

Load	Value
Horiz Eqk	0.220 g<

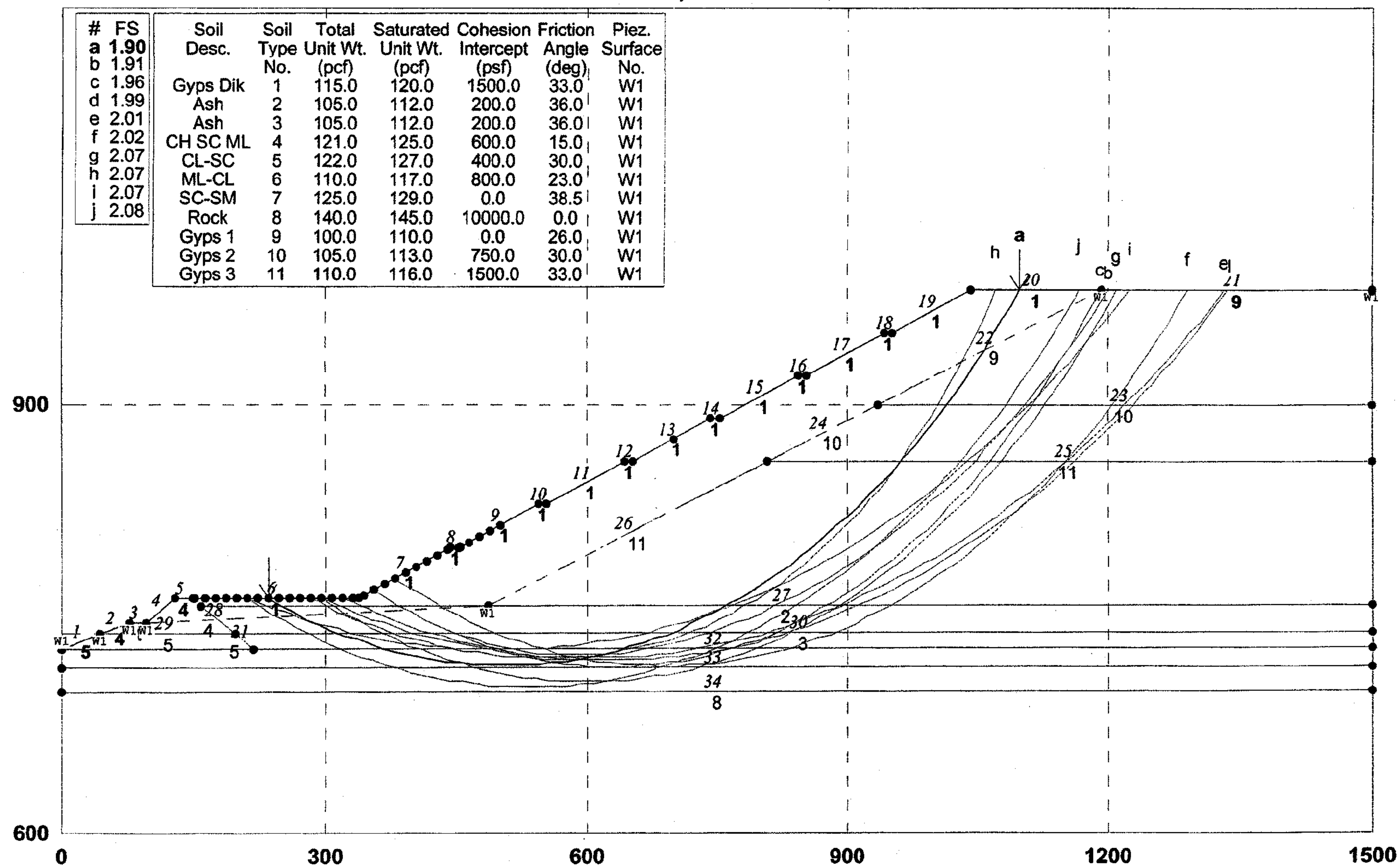


PCSTABL5M/si FSmin=1.02
Safety Factors Are Calculated By The Modified Bishop Method

STED

TVA Kingston - Option 2B Wet Stack - Static

C:\SLOPE\KING2WS2.PL2 Run By: Wade Anundson, PE&C 5/1/03 11:58AM



#	FS
a	**1.90**
b	1.91
c	1.96
d	1.99
e	2.01
f	2.02
g	2.07
h	2.07
i	2.07
j	2.08

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gyps Dik	1	115.0	120.0	1500.0	33.0	W1
Ash	2	105.0	112.0	200.0	36.0	W1
Ash	3	105.0	112.0	200.0	36.0	W1
CH SC ML	4	121.0	125.0	600.0	15.0	W1
CL-SC	5	122.0	127.0	400.0	30.0	W1
ML-CL	6	110.0	117.0	800.0	23.0	W1
SC-SM	7	125.0	129.0	0.0	38.5	W1
Rock	8	140.0	145.0	10000.0	0.0	W1
Gyps 1	9	100.0	110.0	0.0	26.0	W1
Gyps 2	10	105.0	113.0	750.0	30.0	W1
Gyps 3	11	110.0	116.0	1500.0	33.0	W1

PCSTABL5M/si FSmin=1.90

Safety Factors Are Calculated By The Modified Bishop Method

STED

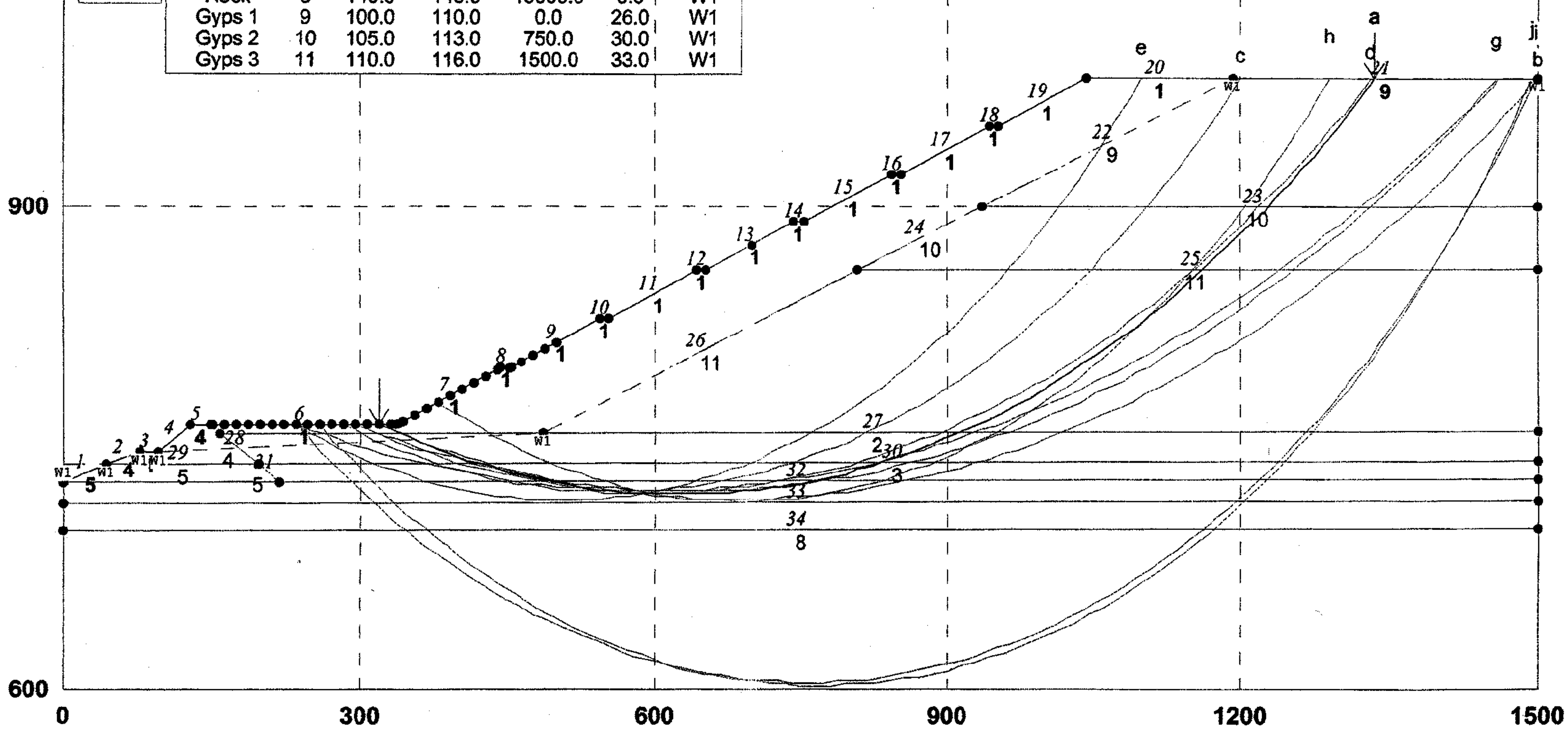
TVA Kingston - Option 2B Wet Stack - Seismic

C:\SLOPE\KING2WE3.PL2 Run By: Wade Anundson, PE&C 5/1/03 12:00PM

#	FS
a	**1.17**
b	1.17
c	1.18
d	1.18
e	1.20
f	1.20
g	1.20
h	1.21
i	1.22
j	1.22

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gyps Dik	1	115.0	120.0	1500.0	33.0	W1
Ash	2	105.0	112.0	200.0	36.0	W1
Ash	3	105.0	112.0	200.0	36.0	W1
CH SC ML	4	121.0	125.0	600.0	15.0	W1
CL-SC	5	122.0	127.0	400.0	30.0	W1
ML-CL	6	110.0	117.0	800.0	23.0	W1
SC-SM	7	125.0	129.0	0.0	38.5	W1
Rock	8	140.0	145.0	10000.0	0.0	W1
Gyps 1	9	100.0	110.0	0.0	26.0	W1
Gyps 2	10	105.0	113.0	750.0	30.0	W1
Gyps 3	11	110.0	116.0	1500.0	33.0	W1

Load	Value
Horiz Eqk	0.150 g<



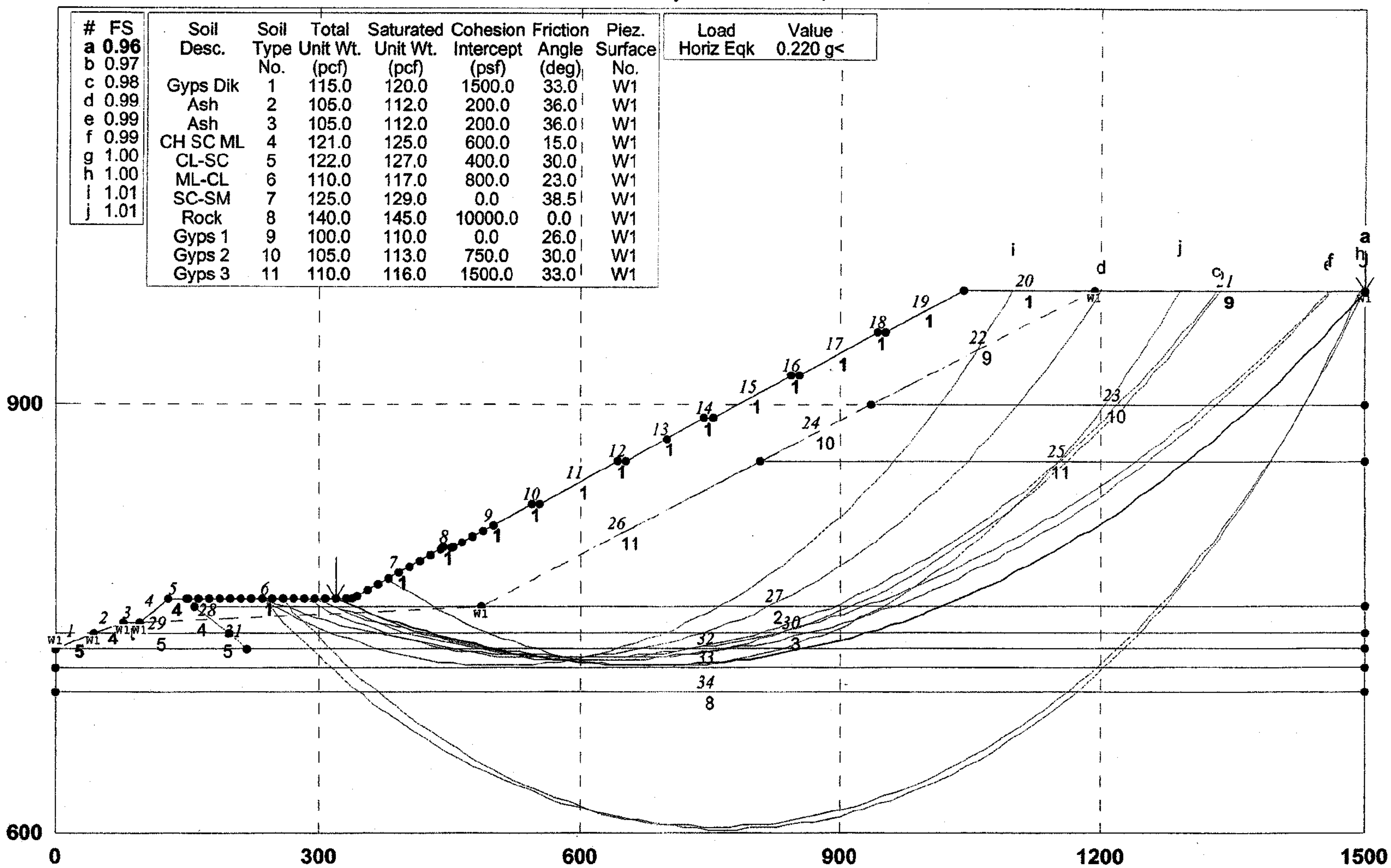
PCSTABL5M/si FSmin=1.17

Safety Factors Are Calculated By The Modified Bishop Method

STED

TVA Kingston - Option 2B Wet Stack - Seismic

C:\SLOPE\KING2WE4.PL2 Run By: Wade Anundson, PE&C 5/1/03 12:02PM



#	FS
a	**0.96**
b	0.97
c	0.98
d	0.99
e	0.99
f	0.99
g	1.00
h	1.00
i	1.01
j	1.01

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Gyps Dik	1	115.0	120.0	1500.0	33.0	W1
Ash	2	105.0	112.0	200.0	36.0	W1
Ash	3	105.0	112.0	200.0	36.0	W1
CH SC ML	4	121.0	125.0	600.0	15.0	W1
CL-SC	5	122.0	127.0	400.0	30.0	W1
ML-CL	6	110.0	117.0	800.0	23.0	W1
SC-SM	7	125.0	129.0	0.0	38.5	W1
Rock	8	140.0	145.0	10000.0	0.0	W1
Gyps 1	9	100.0	110.0	0.0	26.0	W1
Gyps 2	10	105.0	113.0	750.0	30.0	W1
Gyps 3	11	110.0	116.0	1500.0	33.0	W1

Load	Value
Horiz Eqk	0.220 g<

PCSTABL5M/si FSmin=0.96

Safety Factors Are Calculated By The Modified Bishop Method

STED

The permeability of untreated, raw wet-FGD sludges ranges from about 1.8×10^{-4} to 1.4×10^{-6} cm/s (19, 20). These values are equivalent to those for fine to very fine sand, with drainage characteristics rated as good to poor. For comparison purposes, the permeability designated by the EPA for impermeable liner materials for hazardous waste landfills is on the order of 1×10^{-7} cm/s (typical of clay bases).

Tests on fly ash stabilized sludges have resulted in both increases and decreases in the permeability. The literature reported a permeability coefficient range for fly ash stabilized sludge from 1×10^{-4} to 6.0×10^{-6} cm/sec. Fixed sludges, however, almost always exhibit permeability coefficients lower than the untreated sludge. Values are quite variable and difficult to reproduce. Most fixed sludges fall into the 10^{-5} to 10^{-6} range, but permeabilities lower than 10^{-7} have been recorded (7, 16). Table 3-9 consolidates permeability information for several conditioned sludges.

Strength. A knowledge of waste shear strength is a prerequisite for disposal facility design. Waste strength characteristics are used to assess landfill slope stability and the in-situ waste's load bearing capacity. The shear strength of soil and soil-like waste materials generally is expressed by two parameters: cohesion and angle of internal friction. The measurement of these parameters can be accomplished in the laboratory by one of the following test methods:

- Unconsolidated Undrained (UU) Triaxial Shear Test (ASTM D2850)
- Unconfined Compressive Strength Test (ASTM D2166)
- Consolidated Drained (CD) Direct Shear Test (ASTM D3080)
- Consolidated Undrained (CU) Triaxial Shear Test (ASTM D4767)

The unconfined compression test is a special case of the UU shear test with confining pressure equal to zero (shear strength is taken as one-half the compressive strength).

The primary difference between the tests listed above is the conditions under which the tests are performed. Test conditions can be modified to investigate variations in specimen drainage characteristics during shear (drained versus undrained) and consolidated or unconsolidated conditions prior to shearing. Typically, the unconsolidated undrained test conditions associated with the first two methods are representative of relatively rapid loading conditions (rapid with respect to the rate of consolidation or excess pore pressure dissipation). Test conditions of the direct shear and CU triaxial shear tests typically approximate longer-term soil shear strength conditions.

For stabilized or chemically fixed wastes, the compressive strength test for molded soil-cement cylinders (ASTM D1633) may be a suitable alternate testing procedure to those discussed above. This test procedure is similar to ASTM D2166 except ASTM D1633 assumes no sample deformation occurs during compression and uses the specimen's original dimensions to calculate unconfined compressive strength. As Table 3-10 indicates, stabilized and fixed sludges exhibit substantially greater strengths than raw sludges.

Summarized in Table 3-11 are effective stress parameters (typically developed from GC or CU shear tests) for conditioned wet-FGD sludge (16). Strength tests on unconditioned, raw wet-FGD sludge indicate an angle of internal friction of about 20°. For comparison, loose sands have friction angles of about 30°; saturated silts have friction angles of about 20° and behave in a manner similar to wet-FGD sludges. Testing of unconditioned wet-FGD sludges shows little or no cohesion. Having no cohesion, the material has no unconfined compressive strength.

Reported unconfined compressive strength data for dual-alkali sludges indicates values ranging from 1 to 11 psi. Available test data for sludge-fly ash mixtures indicates that the unconfined compressive strength of sludge/fly ash mixtures generally increases with increasing fly ash content up to 40 to 50 percent ash by dry weight. Strength values ranging from approximately 11 to 21 psi were reported for mixtures with 40 to 50 percent ash. As the fly ash to sludge ratio continues to increase, strength begins to decrease. This may be because fly ash is noncohesive or because pozzolanic reactions diminish due to lack of water (16). Cured sludge/fly ash/lime mixtures reportedly can achieve substantially higher unconfined strengths than those of sludge or sludge-fly ash mixtures.

Table 3-9

Permeabilities of Dewatered Only, Stabilized and Fixed Wet-FGD Sludges

Sludge Type (Fixative)	Permeability (cm/sec)	Reference
Dewatered Only		
Lime	1.0×10^{-5} - 1.8×10^{-4}	
Limestone	1.4×10^{-6} - 7.5×10^{-4}	
Dual-Alkali	8.1×10^{-5} - 9.8×10^{-4}	(15)
Stabilized		
1/1 Ash/Gypsum	1.7×10^{-5} - 4.0×10^{-5}	(13)
9/1 Ash/Gypsum	3.1×10^{-5}	
1/1 Ash/Coprecipitate[a]	6.0×10^{-6} - 1.0×10^{-4}	
9/1 Ash/Coprecipitate[a]	1.4×10^{-5} - 2.4×10^{-5}	
Fixed		
Limestone (Poz-O-Tec)	5.5×10^{-8}	
Limestone (Chemfix)	1.5×10^{-5} - 2.1×10^{-5}	
Limestone (Calcilox)	6.9×10^{-5}	
Limestone (TERRA-CRETE)	2.1×10^{-6} - 6.1×10^{-5}	(21)

[a] "Coprecipitate" is a $CaSO_3/CaSO_4$ mixture precipitated from saturated solution in the laboratory.

Source: Adapted from Summers, K. V. et al. Physical-Chemical Characteristics of Utility Solid Wastes. EPRI EA-3236, RP 1487-12, September 1983.

Table 3-10

Unconfined Compressive Strengths of Wet-FGD Sludges

Sludge Type (Fixative)	Sludge Moisture Content (%)		Unconfined Compressive Strength (psi)
Raw			
Lime, limestone, dual-alkali	@ 50%		0
Dewatered Only			
Lime sludge	0-14.4		12-29
Limestone sludge	0-10.3		11-33
Stabilized			
1/4/5 (lime)/fly ash/sludge	-	14 days	22-1060
1/1 fly ash/sludge	-		22-460
1/4/5 (lime/fly ash/sludge	-	56 days	28-1510
1/1 fly ash/sludge	-		17-669
1/4/5 (lime)/fly ash/sludge	-	500 days	29-5561[a]
1/1 fly ash/sludge	-		14.5-1600
1/1 fly ash/sludge	55		85
1/1 fly ash/sludge (1% lime)	-		250
1/1 fly ash/sludge (3% lime)	-		600
1/1 fly ash/sludge (5% lime)	-		950
Fixed			
Limestone (Chemifix)	51		100-133
Limestone (Calcilox)	58		26-33
Limestone (Poz-O-Tec)	37		410-510
Lime/limestone (TERRA-CRETE)	-		12-80

a Most of the experimental cylinders disintegrated.

Source: Adapted from Summers, K. V. et al. Physical-Chemical Characteristics of Utility Solid Wastes. Tetra Tech, Inc., EPRI EA-3236, RP 1487-12, September 1983.

Table 3-11

Effective Shear Strength Parameters for Sludges and Sludge/Fly Ash Mixtures

	Angle of Internal Friction (degrees)	Cohesion (psi)
Sludge	31 - 39	0 - 5
Sludge/Fly Ash[1]	28 - 37	2 - 15
Sludge/Fly Ash/Lime[2]	31 - 44	1 - 8

[1] Uncured samples with sludge:fly ash ratios of 2:1 and 1:1.
[2] Samples cured up to 14 days with a sludge:fly ash:lime ratio of 1:1:0.05.

Available data for sludge/fly ash/lime mixtures cured for 28 days and containing 60 to 80 percent sludge indicates that the strength ranges from 14 to almost 142 psi, with higher strengths corresponding to higher lime content. Strength gain is related to the number of fly ash particle/lime particle contacts and a uniformly graded lime with particle sizes around 0.2 mm apparently has a stronger effect on the strength gain than well graded distributions (16).

Other Qualitative Properties. These properties include corrosivity, abrasiveness, and temperature. Limestone sludges, once formed, are highly corrosive, ranging in pH from as low as 4.5 up to as high as 6.5. Under these conditions special consideration must be given to materials of construction that will be compatible in such an acidic atmosphere. Sludges also may contain varying amounts of fly ash, calcium sulfites, and calcium sulfates. These solid particulates are highly abrasive as demonstrated by the frequent replacement of piping and valves under such service in the industry (22). Since it is well known that fly ash is abrasive, it can be inferred that the higher the fly ash content in the sludge the more abrasive the slurry. The temperatures of the sludge are determined initially by the operating temperatures of the scrubber. In most instances the temperature of the sludge from the bleed stream is 125°F with occasional excursions up to 150°F. This temperature is reduced from the flue gas temperature due to the introduction and mixing of the flue gases with ambient temperature lime slurry and radiant cooling effects that occur in the reaction tank at the bottom of the scrubber. The further down the process train that the sludge progresses, the lower the average temperature of the sludge becomes. For instance, the thickener underflow from one installation was reported to have a temperature of 100°F after entering the thickener at 125°F (22).

Predicting Properties of Wet-FGD Sludges

Because of the large number of system operating variables which influence scrubber sludge characteristics, it is difficult to accurately predict the chemical composition and physical properties of sludge prior to actual operation of a new scrubber. Ideally, a scrubber could be installed with no long-term provision for sludge disposal. A small, lined basin could be designed to retain the sludge for an interim period during which time a normal operating mode could be established for the scrubber. Then the sludge could be tested to determine its physical and chemical properties and a sludge disposal system could be designed and implemented based on actual operating data.

While such a system is ideal, it is not usually practical. Typically, utilities must know how they will handle the sludge from a new facility and win approval from the regulatory agencies long before the sludge is generated. They must, therefore, use other methods of estimating what the sludge composition and physical properties will be. There are several alternatives:

- Use data from a pilot plant operated similarly to the planned facility
- Use data from actual operating installations which have system components similar to those at the planned facility
- Use data, such as that reported herein, which is gained from general operating experience at a number of installations
- Combination of the methods given above

Predicting Composition/Chemical Properties

Raw scrubber sludge composition is influenced by the influent streams to the scrubber as well as the reaction kinetics. Information pertaining to coal characteristics, upstream particulate removal, reagent specifications, make-up water composition, sludge SO_3/SO_4 ratio, and other factors can help in predetermining sludge composition. These aspects are discussed in the following paragraphs.

Research the characteristics of the coal to be used. A knowledge of coal characteristics and composition, as determined on samples from existing mines or on cores from new mines can provide valuable information: (a) the quantity of ash helps to predict the quantity of fly ash found in the scrubber influent, either with or without upstream particulate removal; (b) a knowledge of heating value and sulfur content are necessary to determine coal and reagent usage; (c) trace metals are of interest, but a correlation of the extremely small quantities normally present in

ATTACHMENT 5

Ash Pond Settling Characteristics Based on Simplified Modeling

ATTACHMENT 5
KIF FGD – ASH & GYPSUM DISPOSAL
ASH SETTLING

Introduction

In order to provide for on-site disposal volume for the future FGD gypsum in addition to the normal ash, one option is to use the existing ash pond for wet disposal of both ash and gypsum. This would involve reclaiming the wet ash from the existing ash pond to allow for gypsum disposal (wet stacking) in the existing pond area. However, the elimination of the ash pond also eliminates the settling volume for meeting the NPDES limit for total suspended solids (TSS) from the ash sluice water – 29 mg/l at the Stilling Basin discharge.

Parsons originally proposed two (2) options to replace the existing ash pond settling volume:

Long channel (along the divider dike with the Stilling Basin) to provide the 2 functions of the present pond:
Provide dredge zone for ash deposition & hydraulic dredging
Provide settling volume for meeting the TSS limit

Separate (smaller) dredging & settling ponds

The minimum size of the channel & ponds to meet the NPDES for TSS to the Stilling Basin needs to be determined to evaluate the feasibility of this approach.

Ash Pond Flows

The ash pond water flow (gpm, Mgpd, cfs) determines the residence time/velocity of the sluice water in the ash pond and, therefore, the ability of the ash pond to meet the TSS limit. There are several ash pond flows available:

Calculated
Email response from the plant on the capacity & operation of the ash sluice pumps (bottom & fly ash) shows a normal operation of 32 to 36 Mgpd (22,500 to 25,000 gpm), depending on the number of ash sluice pumps in operation. The plant stated that they run a minimum # of pumps to maintain sluice pressure
Ash sluice % Solids – for a 8% ash coal & for 1% solids in the ash sluice water (typical), the continuous ash pond flow would be ~22 Mgpd (15,000 gpm)

NPDES Permit – The NPDES permit flow is 33 Mgpd (22,912 gpm, 51.05 cfs)

Observed – Observations of the weir range at the stilling pond discharge range from 18 to 53 Mgpd, with 32 Mgpd average (recent '03 & '04 data)

This range of ash pond flows is large but the average range appears to be fairly consistent – from a review of the almost weekly data for '03 & '04. Therefore, the NPDES permit limit will be used to evaluate the ash pond settling – 33 Mgpd.

Technical

Particulate Size

The 1995 "Grain Size Distribution Test Report" for KIF has the last point on the curve at ~5% finer & ~0.0016 mm. The test was re-run for a longer termination time (96 hours) – the results were basically the same with the last point ~2% finer & ~0.0015 mm. Therefore, the smallest particle will be assumed at ~0.0015 mm.

The problem is that for the average 14 mg/l TSS the amount of fly ash discharged is ~0.5 lb/hr. Therefore, the smallest particle needs to be removed, ~0.0015 mm. The '95 analyzed ash material was taken from the existing cells, where the dredged ash has been stacked, while the '03 sample was taken from the near the ash pond discharge (to the Stilling Basin). The question is – are these size distributions representative of the fine particle size in the sluice water to be removed to achieve the NPDES discharge limit for TSS.

Settling Velocity

Equations for discrete particle settling (Stoke's Law) were used to estimate the size of a channel or pond (after dredging zone) for the smallest particle to settle [Ref 1, 2]. The procedure for determining the channel or pond dimensions involved the following calculations – see attached spreadsheet:

Determining the amount of sluice water – see Ash Pond Flows
Assuming dimensions for a channel or pond – establishes the velocity of the water
Determining the critical settling velocity of particles (in "undisturbed" water)
Determine the time for particle to settle (to depth of channel or pond)
Use settling time to determine the channel or pond size (no contingency)

This settling channel or pond has to be after any heavy solids deposition & ash dredging so that there is "quiescent" water to settle the smallest particle size.

For the pond size, the settling area was the flow divided by the critical settling velocity – same as for the channel size.

Equations

Settling Velocity (Vs) = 1/18 [(d^2g/viscosity)(SG-1)]

d = particle diameter
SG = particle specific gravity (given in the TVA "grain Size Distribution Test report")
Viscosity (at 68 F) = 0.01003 cm^2/sec

Pond/Channel Size (A) = Q/ Vs

Water Temperature – the viscosity is a function of water temperature:
Increase from 68 F to 86 F results in a 20% reduction in acreage
Decrease from 68 F to 50 F results in a 37% increase in acreage

Since the condenser discharge is used for ash sluice water, there should not be a "cold" condition where the viscosity increases significantly.

It should be noted that use of Stokes Law is a simplified method, and does not account for complexities in particle settling characteristics. A more detailed modeling effort would be required to definitively estimate settlement of ash particles. These methods utilize computer programs; however, settling test data would be required to develop the data necessary to execute the computer modeling.

Results

The assumption of the smallest size is critical. The existing ash pond was checked for the capacity to settle small particles:

PARTICLE SIZE	0.0015 mm	0.002 mm	0.003 mm	
MGPD	33	33	33	
ACRES	220	120	55	

Using Stokes' Law, it is apparent that the present ash pond (~75 acres) & Stilling Basin (~25 acres) cannot theoretically settle the smallest particle (0.0015 mm). The apparent smallest particle that can be theoretically be settled is ~0.0022 mm at the NPDES permitted flow (~ 33 Mgpd). Since the NPDES limit for TSS is achieved (< 1 lb/hr = >99% removal), the "2% finer" may not be accurate – may just be a function of the way the test data is recorded.

Conclusion

Based on recent settling tests (hydrometer) with a longer termination time, the smallest particle size to be removed has been determined. Theoretically, the present ash pond + Stilling Basin cannot settle this smallest particle. However, the pond seems to be meeting the TSS requirement using the existing pond area. Therefore, the smallest theoretical particle settled is between 0.002 & 0.003 mm.

Parsons has established that for planning purposes the present pond size cannot be reduced and still maintain the NPDES TSS requirement. Therefore, continue wet sluicing of ash to the existing ash disposal is not feasible if gypsum is stacked in the existing ash disposal area in a configuration that would provide less than a particle size of about 0.003 mm (55 acres). This is simply an estimate based on simplified modeling. TVA should continue to monitor TSS levels if less pond area is utilized for particle settling, and may have to utilize administrative procedures to prevent violations.

Recommendation

Dry fly ash disposal is the only option if gypsum is stacked in the existing ash disposal area

References

1. Coal Ash Pond Manual, EPRI CS-2409, October 1981 (Chapter 8)

2. Erosion & Sediment Control – Surface Mining in the Eastern U.S., Volume 2: Design, EPA/625/3-76/006b, October 1975

ATTACHMENT 6

Projected Volumes of Gypsum for Varying Sulfur Content for Peninsula Site and Ash/Gypsum Volume Projections for Ash Pond Site

KIF Gypsum and Ash Disposal Volumes for Sizing Disposal Facility - Ash Pond Site KIF Gypsum Only										
	0.9% Sulfur		1.1% Sulfur (Base) (2)		1.25% Sulfur (4)		1.5% Sulfur		2.0% Sulfur	
Year	Gypsum	Total (cy)	Gypsum	Total (cy)	Gypsum	Total (cy)	Gypsum	Total (cy)	Gypsum	Total (cy)
2008	224156	224156	273428	273428	335832	335832	372763	372763	496844	496844
2009	224156	448312	273428	546857	335832	671664	372763	745525	496844	993687
2010	224156	672469	273428	820285	335832	1007496	372763	1118288	496844	1490531
2011	224156	896625	273428	1093713	335832	1343328	372763	1491051	496844	1987374
2012	224156	1120781	273428	1367142	335832	1679160	372763	1863814	496844	2484218
2013	224156	1344937	273428	1640570	335832	2014992	372763	2236576	496844	2981062
2014	224156	1569094	273428	1913998	335832	2350824	372763	2609339	496844	3477905
2015	224156	1793250	273428	2187427	335832	2686656	372763	2982102	496844	3974749
2016	224156	2017406	273428	2460855	335832	3022488	372763	3354864	496844	4471592
2017	224156	2241562	273428	2734283	335832	3358320	372763	3727627	496844	4968436
2018	224156	2465719	273428	3007712	335832	3694152	372763	4100390	496844	5465280
2019	224156	2689875	273428	3281140	335832	4029984	372763	4473153	496844	5962123
2020	224156	2914031	273428	3554568	335832	4365816	372763	4845915	496844	6458967
2021	224156	3138187	273428	3827996	335832	4701648	372763	5218678	496844	6955810
2022	224156	3362344	273428	4101425	335832	5037480	372763	5591441	496844	7452654
2023	224156	3586500	273428	4374853	335832	5373312	372763	5964204	496844	7949498
2024	224156	3810656	273428	4648281	335832	5709144	372763	6336966	496844	8446341
2025	224156	4034812	273428	4921710	335832	6044976	372763	6709729	496844	8943185
2026	224156	4258969	273428	5195138	335832	6380808	372763	7082492	496844	9440028
2027	224156	4483125	273428	5468566	335832	6716640	372763	7455254		
2028	224156	4707281	273428	5741995	335832	7052472	372763	7828017		
2029	224156	4931437	273428	6015423	335832	7388304	372763	8200780		
2030	224156	5155594	273428	6288851	335832	7724136	372763	8573543		
2031	224156	5379750	273428	6562280	335832	8059968	372763	8946305		
2032	224156	5603906	273428	6835708	335832	8395800	372763	9319068		
2033	224156	5828062	273428	7109136	335832	8731632				
2034	224156	6052218	273428	7382565	335832	9067464				
2035	224156	6276375	273428	7655993	335832	9403296				
2036	224156	6500531	273428	7929421						
2037	224156	6724687	273428	8202850						
2038	224156	6948843	273428	8476278						
2039	224156	7173000	273428	8749706						
2040	224156	7397156	273428	9023135						
2041	224156	7621312	273428	9296563						
2042	224156	7845468								
2043	224156	8069625								
2044	224156	8293781								
2045	224156	8517937								
2046	224156	8742093								
2047	224156	8966250								
2048	224156	9190406								
2049	224156	9414562								
2050										
2051										
Subtotal	**9414562**		**9296563**		**9403296**		**9319068**		**9440028**	
NOTES										
1. Quantities in CY. % Sulfur for KIF (Base) is 1.1% and BRF (Base) is 1.3%. Quantities estimated by PE&C unless noted otherwise.										
2. Density of gypsum		0.88								
3. Disposal Capacity is 9.4 million cy										
4. Quantities provided by TVA.										

KIF Gypsum and Ash Disposal Volumes for Sizing Disposal Facility - Peninsula Site KIF + BRF Gypsum										
	0.9% Sulfur		1.1% Sulfur (Base) (1)		1.25% Sulfur (6)		1.5% Sulfur		2.0% Sulfur	
Year	Gypsum	Total (cy)	Gypsum	Total (cy)	Gypsum	Total (cy)	Gypsum	Total (cy)	Gypsum	Total (cy)
2008	337418	337418	437538	437538	524270	524270	562098	562098	749333	749333
2009	337418	674835	437538	875076	524270	1048540	562098	1124196	749333	1498666
2010	337418	1012253	437538	1312613	524270	1572810	562098	1686294	749333	2248000
2011	337418	1349671	437538	1750151	524270	2097080	562098	2248392	749333	2997333
2012	337418	1687089	437538	2187689	524270	2621350	562098	2810490	749333	3746666
2013	337418	2024507	437538	2625227	524270	3145620	562098	3372588	749333	4495999
2014	337418	2361925	437538	3062764	524270	3669890	562098	3934686	749333	5245332
2015	337418	2699343	437538	3500302	524270	4194160	562098	4496784	749333	5994666
2016	337418	3036761	437538	3937840	524270	4718430	562098	5058882	749333	6743999
2017	337418	3374179	437538	4375378	524270	5242700	562098	5620980	749333	7493332
2018	337418	3711597	437538	4812915	524270	5766970	562098	6183078	749333	8242665
2019	337418	4049015	437538	5250453	524270	6291240	562098	6745176	749333	8991998
2020	337418	4386433	437538	5687991	524270	6815510	562098	7307274	749333	9741332
2021	337418	4723851	437538	6125529	524270	7339780	562098	7869372		
2022	337418	5061269	437538	6563066	524270	7864050	562098	8431470		
2023	337418	5398687	437538	7000604	524270	8388320	562098	8993568		
2024	337418	5736105	437538	7438142	524270	8912590	562098	9555666		
2025	337418	6073523	437538	7875680	524270	9436860				
2026	337418	6410941	437538	8313217						
2027	337418	6748359	437538	8750755						
2028	337418	7085777	437538	9188293						
2029	337418	7423195	437538	9625831						
2030	337418	7760613								
2031	337418	8098031								
2032	337418	8435449								
2033	337418	8772867								
2034	337418	9110285								
2035	337418	9447703								
2036										
2037										
2038										
2039										
2040										
Subtotal	**9447704**		**9625831**		**9436860**		**9555666**		**9741332**	
NOTES										
1. % Sulfur for KIF (Base) is 1.1% and BRF (Base) is 1.3%. Quantities estimated by PE&C unless noted otherwise.										
2. Density of gypsum	0.88									
3. Disposal Capacity is 9.4 million cy										
4. Quantities provided by TVA.										

KIF Gypsum and Ash Disposal Volumes for Sizing Disposal Facility - Ash Pond Site KIF Gypsum Only																
	0.9% Sulfur			1.1% Sulfur (Base) (2)			1.25% Sulfur (6)			1.5% Sulfur			2.0% Sulfur(7)			Ash
Year	Gypsum	Ash (2)	Total (cy)	Gypsum	Ash	Total (cy)	Gypsum	Ash (2)	Total (cy)	Gypsum	Ash	Total (cy)	Gypsum	Ash	Total (cy)	Only
2008	224156		224156	273428		273428	335832		335832	372763		372763	496844		496844	
2009	224156		448312	273428		546857	335832		671664	372763		745525	496844		993687	
2010	224156		672469	273428		820285	335832		1007496	372763		1118288	496844		1490531	
2011	224156		896625	273428		1093713	335832		1343328	372763		1491051	496844		1987374	
2012	224156		1120781	273428		1367142	335832		1679160	372763		1863814	496844		2484218	
2013	224156		1344937	273428		1640570	335832		2014992	372763		2236576	496844		2981062	
2014	224156		1569094	273428		1913998	335832		2350824	372763		2609339	496844		3477905	
2015	224156		1793250	273428		2187427	335832		2686656	372763		2982102	496844		3974749	
2016	224156	393434	2410840	273428	479831	2940686	335832	393434	3415922	372763	479798	3834663	496844	479798	4951391	393434
2017	224156	393434	3028431	273428	479831	3693946	335832	393434	4145188	372763	479798	4687224	496844	479798	5928033	786868
2018	224156	393434	3646021	273428	479831	4447206	335832	393434	4874454	372763	479798	5539785	496844	479798	6904674	1180302
2019	224156	393434	4263611	273428	479831	5200466	335832	393434	5603720	372763	479798	6392346	496844	479798	7881316	1573736
2020	224156	393434	4881201	273428	479831	5953725	335832	393434	6332986	372763	479798	7244907	496844	479798	8857958	1967170
2021	224156	393434	5498792	273428	479831	6706985	335832	393434	7062252	372763	479798	8097468	496844	479798	9834600	2360604
2022	224156	393434	6116382	273428	479831	7460245	335832	393434	7791518	372763	479798	8950029	496844	479798	10811242	2754038
2023	224156	393434	6733972	273428	479831	8213505	335832	393434	8520784	372763	479798	9802590	496844	479798	11787884	3147472
2024	224156	393434	7351563	273428	479831	8966765	335832	393434	9250050	372763	479798	10655151	496844	479798	12764526	3540907
2025	224156	393434	7969153	273428	479831	9720024	335832	393434	9979316	372763	479798	11507712	496844	479798	13741168	3934341
2026	224156	393434	8586743	273428	479831	10473284	335832	393434	10708582	372763	479798	12360273	496844	479798	14717810	4327775
2027	224156	393434	9204334	273428	479831	11226544	335832	393434	11437848	372763	479798	13212834	496844	479798	15694451	4721209
2028	224156	393434	9821924	273428	479831	11979804	335832	393434	12167114	372763	479798	14065395	496844	479798	16671093	5114643
2029	224156	393434	10439514	273428	479831	12733064	335832	393434	12896380	372763	479798	14917956	496844	479798	17647735	5508077
2030	224156	393434	11057104	273428	479831	13486323	335832	393434	13625646	372763	479798	15770517	496844	479798	18624377	5901511
2031	224156	393434	11674695	273428	479831	14239583	335832	393434	14354912	372763	479798	16623078	496844	479798	19601019	6294945
2032	224156	393434	12292285	273428	479831	14992843	335832	393434	15084178	372763	479798	17475639	496844	479798	20577661	6688379
2033	224156	393434	12909875	273428	479831	15746103	335832	393434	15813444	372763	479798	18328200	496844	479798	21554303	7081813
2034	224156	393434	13527466	273428	479831	16499362	335832	393434	16542710			0	496844	479798	22530945	7475247
2035	224156	393434	14145056	273428	479831	17252622	335832	393434	17271976			0	496844	479798	23507586	7868681
2036	224156	393434	14762646	273428	479831	18005882	335832	393434	18001242			0	496844	479798	24484228	8262115
2037	224156	393434	15380237	273428	479831	18759142	335832	393434	18730508			0	496844	479798	25460870	8655549
2038	224156	393434	15997827			0			0				496844	479798	26437512	9048983
2039	224156	393434	16615417			0			0				496844	479798	27414154	9442417
2040	224156	393434	17233007			0			0				496844	479798	28390796	9835852
2041	224156	393434	17850598			0									0	10229286
2042	224156	393434	18468188													10622720
2043			0													
Subtotal	7845468	10622720	**18468188**	8202850	10556292	**18759142**	10074960	8655548	**18730508**	9691831	8636369	**18328200**	16395839	11994957	**28390796**	**10622720**

NOTES

1. % Sulfur for KIF (Base) is 1.1% and BRF (Base) is 1.3%. Quantities estimated by PE&C unless noted otherwise.
2. Forcast for Ash annual volume for Base case is 433814 tons, greater than volume provided by TVA (360,000 ton).
   Forcast for Ash annual volume (0.9% sulfur) is 355,727 tons per year (agrees w/published results), which is equivalent to 393,434 cy/yr.
   Assuming 360,000 cy/yr for ash (base case).
3. Density of ash = 1.106 cy/ton
4. Density of gypsu 0.88 cy/ton
5. Disposal Capacity is 18.7 million cy. Volume Increase due to densificaiton over time is not factored in.
6. Quantities provided by TVA.
7. 2% Volumes projected to predict year of capicity for both Options 1A and 3B.

KIF Gypsum and Ash Disposal Volumes for Sizing Disposal Facility - Ash Pond Site KIF + BRF Gypsum

	0.9% Sulfur			1.1% Sulfur (Base) (1)			1.25% Sulfur (6)			1.5% Sulfur			2.0% Sulfur(7)		
Year	Gypsum	Ash	Total (cy)	Gypsum	Ash (2)	Total (cy)	Gypsum	Ash	Total (cy)	Gypsum	Ash	Total (cy)	Gypsum	Ash	Total (cy)
2008	337418		337418	437538		437538	524270		524270	562098		562098	749333		749333
2009	337418		674836	437538		875076	524270		1048540	562098		1124196	749333		1498666
2010	337418		1012254	437538		1312613	524270		1572810	562098		1686294	749333		2248000
2011	337418		1349672	437538		1750151	524270		2097080	562098		2248392	749333		2997333
2012	337418		1687090	437538		2187689	524270		2621350	562098		2810490	749333		3746666
2013	337418		2024508	437538		2625227	524270		3145620	562098		3372588	749333		4495999
2014	337418		2361926	437538		3062764	524270		3669890	562098		3934686	749333		5245332
2015	337418		2699344	437538		3500302	524270		4194160	562098		4496784	749333		5994666
2016	337418	393434	3430196	437538	479831	4417671	524270	393434	5111864	562098	479798	5538681	749333	479798	7223797
2017	337418	393434	4161048	437538	479831	5335041	524270	393434	6029568	562098	479798	6580577	749333	479798	8452929
2018	337418	393434	4891900	437538	479831	6252410	524270	393434	6947272	562098	479798	7622473	749333	479798	9682060
2019	337418	393434	5622752	437538	479831	7169779	524270	393434	7864976	562098	479798	8664369	749333	479798	10911192
2020	337418	393434	6353604	437538	479831	8087148	524270	393434	8782680	562098	479798	9706266	749333	479798	12140323
2021	337418	393434	7084456	437538	479831	9004517	524270	393434	9700384	562098	479798	10748162	749333	479798	13369455
2022	337418	393434	7815308	437538	479831	9921887	524270	393434	10618088	562098	479798	11790058	749333	479798	14598586
2023	337418	393434	8546160	437538	479831	10839256	524270	393434	11535792	562098	479798	12831955	749333	479798	15827717
2024	337418	393434	9277012	437538	479831	11756625	524270	393434	12453496	562098	479798	13873851	749333	479798	17056849
2025	337418	393434	10007864	437538	479831	12673994	524270	393434	13371200	562098	479798	14915747	749333	479798	18285980
2026	337418	393434	10738716	437538	479831	13591364	524270	393434	14288904	562098	479798	15957643	749333	479798	19515112
2027	337418	393434	11469568	437538	479831	14508733	524270	393434	15206608	562098	479798	16999540	749333	479798	20744243
2028	337418	393434	12200420	437538	479831	15426102	524270	393434	16124312	562098	479798	18041436	749333	479798	21973375
2029	337418	393434	12931272	437538	479831	16343471	524270	393434	17042016			0	749333	479798	23202506
2030	337418	393434	13662124	437538	479831	17260840	524270	393434	17959720			0	749333	479798	24431638
2031	337418	393434	14392977	437538	479831	18178210	524270	393434	18877424			0	749333	479798	25660769
2032	337418	393434	15123829			0			0			0	749333	479798	26889901
2033	337418	393434	15854681			0			0			0	749333	479798	28119032
2034	337418	393434	16585533			0			0			0			
2035	337418	393434	17316385			0			0			0			
2036	337418	393434	18047237			0			0			0			
2037	337418	393434	18778089			0			0			0			
2038			0												
2039			0												
2040			0												
Subtotal	10122540	8655549	**18778089**	10500906	7677303	**18178210**	12582480	6294944	**18877424**	11804058	6237378	**18041436**	19482663	8636369	**28119032**

NOTES

1. % Sulfur for KIF (Base) is 1.1% and BRF (Base) is 1.3%. Quantities estimated by PE&C unless noted otherwise.
2. Forcast for Ash annual volume for Base case is 433814 tons, greater than volume provided by TVA (360,000 cy).
   Forcast for Ash annual volume (0.9% sulfur) is 355,727 tons per year (agrees w/published results), which is equivalent to 393,434 cy/yr.
   Assuming 360,000 cy/yr for ash (base case).
3. Density of ash = 1.106 cy/ton
4. Density of gypsum 0.88 cy/ton
5. Disposal Capacity is 18.7 million cy. Volume increase due to densification over time is not factored in.
6. Quantities provided by TVA.
7. 2% Volumes projected to predict year of capicity for both Options 1A and 3B.

PEC ESTIMATS FOR ANNUAL GYPSUM AND ASH PRODUCTION FOR % SULFUR IN COAL									
PLANT	KIF	KIF	KIF	KIF		BRF	BRF	BRF	BRF
CAPACITY,	75	75	75	75		80	80	80	80
		BASE					BASE		
SULFUR, %	0.9	1.1	1.5	2.0		0.9	1.3	1.5	2.0
GYPSUM, T	254273	310,714	423,594	564,695		129,156	186,488	215,154	286,820
ASH, TPY	355,727	433,814	433,814	433,814		180,765	220,445	220,445	220,445
	(8.2%)	(10.0%)	(10.0%)	(10.0%)		(8.2%)	(10.0%)	(10.0%)	(10.0%)
TOTAL, TPY	610,000	744,528	857,408	998,509	0	309,921	406,933	435,599	507,265
NOTES	Sulfur	KIF SCR has 2.0% sulfur as design coal - assume this is future coal with FGD							
		BRF SCR has 0.9% sulfur as design coal - assume this is present coal							
	Ash	KIF SCR has 10.2% ash as design coal - assume this is future coal with FGD							
		BRF SCR has 8.2% ash as design coal - assume this is present coal							

KIF Gypsum and Ash Disposal Volumes for Sizing Disposal Facility

Year	Gypsum	Ash	Total Ash + Gypsum
2008	524270		524270
2009	524270		524270
2010	524270		524270
2011	524270		524270
2012	524270		524270
2013	524270		524270
2014	524270		524270
2015	524270		524270
2016	524270	393434	917704
2017	524270	393434	917704
2018	524270	393434	917704
2019	524270	393434	917704
2020	524270	393434	917704
2021	524270	393434	917704
2022	524270	393434	917704
2023	524270	393434	917704
2024	524270	393434	917704
2025	524270	393434	917704
2026	524270	393434	917704
2027	524270	393434	917704
2028	524270	393434	917704
2029	524270	393434	917704
2030	524270	393434	917704
2031	524270	393434	917704
2032	524270	393434	917704
2033			0
2034			0
2035			0
2036			0
2037			0
Subtotal	13106750	6688378	19795128

Notes:

1. 1.25% sulfur assumed, 0.88 tons/cy assumed
2. Bottom ash is not disposed in this facility
3. 335,832 cy (KIF) + 188,438 cy (BRF) annually
4. Combined capacity of Option 3B is 18.7 million cy

ATTACHMENT 7

Selected Correspondence with TVA

Smith, Daniel R

From: Petty, Harold L. [hlpetty@tva.gov]
Sent: Tuesday, October 14, 2003 7:38 AM
To: Stammler, Theodor B; Bowers, Larry C
Cc: Smith, Daniel R.
Subject: FW: Assumptions used for the KIF Gypsum and Ash Disposal Option 3B (wet ash and gypsum co-disposed in ash pond) PR-0637

Dan Smith tried to send this to you and got an automatic message that you did not receive it. He asked me to resend this to you.

Thanks,
Lynn

-----Original Message-----
From: Smith, Daniel R.
Sent: Friday, October 10, 2003 3:03 PM
To: 'Bowers, Larry C'
Cc: Petty, Harold L.; 'Stammler, Ted'; 'Hedgecoth, Missy'; Wright, Thomas
Subject: Assumptions used for the KIF Gypsum and Ash Disposal Option 3B (wet ash and gypsum co-disposed in ash pond) PR-0637

We're starting concept drawings, and here are the assumptions I'm starting with.

- Annual gypsum generated at KIF for disposal at KIF - 300,000 cy
- Annual gypsum generated at BRF for disposal at KIF - 185,000 cy (485,000 combined). Start gypsum disposal in 2008.
- Annual fly ash disposal volume = 360,000 cy (start disposing of ash in ash pond in 2016). Dispose of ash in 3 existing cells until then.
- 14.9 million cy disposal volume available

Based on our assumptions, these gypsum volumes represent the following:

- BRF - 185,000 tpy gypsum for disposal = ~1.3% sulfur (at 80% Capacity factor)
- KIF = 300,000 tpy = ~1.1% (at 75% capacity factor)

If the sulfur % in the coal is raised after the scrubber goes on-line, the gypsum volumes will increase. We are going to attempt to define this better, but will need some information from TVA to refine these estimates, unless you want to go with these numbers.

Please advise if or how I need to revise these assumptions.

PS, Missy, I found some meeting minutes where TVA provided 360,000 cy per year of fly ash for disposal at KIF. I will use this unless you want me to assume what was in my email yesterday.

Thanks

Daniel R. (Dan) Smith, P.E.
Parsons E & C Phone: (423) 757-8088

Smith, Daniel R

From: Bowers, Larry C [lcbowers@tva.gov]
Sent: Tuesday, October 14, 2003 1:40 PM
To: Smith, Daniel R.; Smith, Amos L; Petty, Harold L.
Subject: FW: Gypsum calcs

As requested.
-----Original Message-----
From: Carter, Roy V.
Sent: Tuesday, October 14, 2003 1:32 PM
To: Bowers, Larry C
Cc: Hedgecoth, Melissa A.
Subject: Gypsum calcs

Larry,

as you requrested here is latest and greatest for BRF and KIF. I included COF 5 and 1-4 also.

The spreadsheet has been revised to reflect the fact that nearly all of the gypsum is sulfate. The Advatech Mass Balance indicates that there is only a very small amount of sulfite in the product, and this affects the mass calculations. It also affects the volume calcs. The conversion factor from tons/yr to yd3/yr I used earlier (1.16) was from Missy's ash projections for PAF. While 1.16 is probably good for PAF1-2, which has ~80% sulfite and si mixed with flyash, it is not appropriate for the new Advatech scrubber gypsum (which because of the forced oxidation produces nearly all sulfate). The EPRI document suggests a bulk density for gypsum that is predomantly sulfate of 84 lb/ft3. This translates to a conversion factor of 0.88.

Consequently, I have put both estimates in the attached spreadsheet. I suggest using the lower estimate since this is definitely different from the PAF 1-2 stuff.

Missy, what do you think?

The pages for BRF and KIF are based on the 2.5 # coal and 10,000 Btu/lb (and ash numbers we had before). I'll be back on thursday, please call me then with any questions.

Roy

Roy V. Carter
Tennessee Valley Authority
CEB 4C
P.O. Box 1010
Muscle Shoals, AL 35662-1010
Phone: 256-386-2832, Fax 256-386-3799

For KIF1-9 on 2.5# coal with capacity factor of 75%

Parameter	Input Data	Case Input	TVA Assumption
Unit rating	Unit rating (MW)	1700	Site specific
Capacity factor	Capacity factor (decimal %)	0.75	75 percent of time
Heat rate	Heat rate of boiler (Btu/kWh)	9300	Unit specific
Fuel heating value	Fuel heating value (Btu/lb)	10000	Site specific
Ash	Coal ash content (decimal %)	0.1	Site specific
Fly ash	Total ash to fly ash (decimal %)	0.9	Boiler type specific. See Note 2
Precipitator efficiency	Fly ash removed in ESP or baghouse (decimal %)	0.98	Unit specific
Scrubber efficiency	Fly ash removed in the scrubber (decimal %)	0.7	Site specific
Sulfur content	Sulfur content of coal (decimal %)	0.0125	Site specific; See Note 1
Sulfur removal	Sulfur removed by scrubber (decimal %)	0.98	Site specific
Reagent ratio	Reagent ratio	1.05	Unit specific
Limestone inerts	Limestone inerts (decimal %)	0.1	Spec lists 10% inerts
Limestone purity	limestone purity (decimal %)	0.9	Spec lists 90% limestone purity
PAF Conversion from tons/yr to yd3/yr		1.16	
EPRI Conversion from tons/yr to yd3/yr		0.88	

Note 1: to calc % S from lb SO2/Mbtu: % S = (____lb SO2/MBtu x ____Btu/lb of coal) / 20000
eg, for 10,000 Btu/lb coal, %S is half the lbs/MBtu heat input rate

Note 2: % of ash that goes to flyash is 25 % for cyclones, 80 % for PCs (rest is bottom ash)

Coal Consumption	5,193,585	tons/yr
Fly Ash	467,423	tons/yr
Precip Fly Ash	458,074	tons/yr
Scrubber Fly Ash	6,544	tons/yr
Sulfur Captured	1,988	ton-moles S/yr
Calcium Sulfate Dihydrate (99.97%)	341,863	tons/yr
Calcium Sulfate Hemihydrate (0%)	0	tons/yr
Calcium Sulfite Hemihydrate (0.03%)	85	tons/yr
Total Calcium	2,088	ton-moles S/yr
Total Limestone	231,953	tons/yr
Unreacted Reagent	9,941	tons/yr
Limestone Inerts	23,195	tons/yr
Total Gypsum, Weight Basis	**381,627**	**tons/yr**
Total Gypsum (a), Volume Basis	**442,688**	**cubic yards/yr**
Total Gypsum (b), Volume Basis	**335,832**	**cubic yards/yr**

a - is based on PAF conversion factor of 1.16, for mostly sulfite
b - is based on EPRI conversion factor of 0.88, for mostly sulfate

For BRF on 2.5# coal with a capacity factor of 75%

Parameter	Input Data	Case Input	TVA Assumption
Unit rating	Unit rating (MW)	950	Site specific
Capacity factor	Capacity factor (decimal %)	0.75	75 percent of time
Heat rate	Heat rate of boiler (Btu/kWh)	9338	Unit specific
Fuel heating value	Fuel heating value (Btu/lb)	10000	Site specific
Ash	Coal ash content (decimal %)	0.1	Site specific
Fly ash	Total ash to fly ash (decimal %)	0.9	Boiler type specific. See Note 2
Precipitator efficiency	Fly ash removed in ESP or baghouse (decimal %)	0.98	Unit specific
Scrubber efficiency	Fly ash removed in the scrubber (decimal %)	0.7	Site specific
Sulfur content	Sulfur content of coal (decimal %)	0.0125	Site specific; See Note 1
Sulfur removal	Sulfur removed by scrubber (decimal %)	0.98	Site specific
Reagent ratio	Reagent ratio	1.05	Unit specific
Limestone inerts	Limestone inerts (decimal %)	0.1	Spec lists 10% inerts
Limestone purity	limestone purity (decimal %)	0.9	Spec lists 90% limestone purity
PAF Conversion from tons/yr to yd3/yr		1.16	
EPRI Conversion from tons/yr to yd3/yr		0.88	

Note 1: to calc % S from lb SO2/Mbtu: % S = (____lb SO2/MBtu x ____Btu/lb of coal) / 20000
eg, for 10,000 Btu/lb coal, %S is half the lbs/MBtu heat input rate

Note 2: % of ash that goes to flyash is 25 % for cyclones, 80 % for PCs (rest is bottom ash)

Coal Consumption	2,914,156	tons/yr
Fly Ash	262,274	tons/yr
Precip Fly Ash	257,029	tons/yr
Scrubber Fly Ash	3,672	tons/yr
Sulfur Captured	1,116	ton-moles S/yr
Calcium Sulfate Dihydrate (99.97%)	191,821	tons/yr
Calcium Sulfate Hemihydrate (0%)	0	tons/yr
Calcium Sulfite Hemihydrate (0.03%)	47	tons/yr
Total Calcium	1,171	ton-moles S/yr
Total Limestone	130,150	tons/yr
Unreacted Reagent	5,578	tons/yr
Limestone Inerts	13,015	tons/yr
Total Gypsum, Weight Basis	**214,134**	**tons/yr**
Total Gypsum (a), Volume Basis	**248,395**	**cubic yards/yr**
Total Gypsum (b), Volume Basis	**188,438**	**cubic yards/yr**

a - Is based on PAF conversion factor of 1.16, for mostly sulfite
b - Is based on EPRI conversion factor of 0.88, for mostly sulfate

Smith, Daniel R

From: Smith, Daniel R
Sent: Thursday, February 05, 2004 5:37 PM
To: 'Petty, H. L.'; 'Bowers, Larry C'; 'Johnson, Lindy'; 'Smith, Amos'
Subject: KIF Ash Pond Location - combined ash/gypsum disposal in main ash pond PR-0637

A meeting was held on January 29, 2004 to further address disposal concepts for combined ash/gypsum disposal. This came about as a result of TVA's decision to permit additional space in the pond for ash disposal. Gypsum disposal may also be included. Parsons most recent task for the Phase 1 Study from TVA was to investigate potential airspace in the pond, while providing enough volume in the combined main pond/stilling basin to meet free water volume (FWV) requirements plus one year's ash volume (360,000 tons at a density of 67 lb/cf). This concept (to become Option 4 in the Phase 1 Study) was developed to further scope out work for a potential Phase 2 task to permit the ash pond for additional ash/gysum disposal.

Parsons presented a sketch that includes: the most recent pond survey (Nov 2003), and the design that TVA has developed for additional ash disposal (to provide capacity in lieu of dredging to existing dredge cells) in the pond area. The sketch is based on the following assumptions:

- raise the weirs in the stilling pond (currently at el 754.3) to el 759; raise the weirs in the main ash pond to el 759 (currently at 757.9). This will increase the FWV in the stilling basin;
- FWV is based only on current requirements (ash slucing). FWV will change for wet gypsum disposal, and if wet gypsum disposal is combined with wet ash disposal, the FWV requirements will be higher than current requirements.

FWV as computed by the state is a function of the inflow rate from all sources of water. Sources of water to the pond include, but are not limited to, ash slucing water, and runoff from the coal yard pond. Additional future flow due to gypsum slucing will increase the FWV requirements.

The latest concept sketch (Option 4) developed by Parsons has an approximate capacity (airspace) of 8.75 million cy. Parsons has studied ash settling using a simplified approach (Stoke's Law). Through literature searches, Parsons has found an EPA document prepared for the coal mining industry that provides guidelines for sizing wet ponds for settling solids. This approach was used for the current concept. Providing FWV capacity that includes the minimum volume required by the state (312.8 ac-ft), and 1 year ash disposal volume (246.7 ac-ft), results in a pond area approximately 50-55 ac. To achieve this, the pond size in the ash pond is 25 ac and 12 ft deep. The 12 ft depth is achievable based on a phone call between Dan Smith and Jim Settles, TVA KIF. Jim had reported that they can dredge to 12 ft depth, and up to 16 ft if necessary, but dredging deeper than 12 ft is not as efficient and productivity is affected. The 12 ft depth measured from el 759 is approximately equal to the el 748 elevation of the top of the original dike elevation (10N400), and seems to be higher than the preconstruction top shown on the same drawing. This would eliminate any concerns from the state about buffer erosion. The EPA approach is being used as the basis for pond size, and correlates with the 50-55 ac area determined to meet FWV plus one year of ash production. The simplified approach is only approximate, and Parsons stated that absolute guarantees cannot be made that a 50 ac pond will meet TSS requirements for the NPDES permit (based on this analysis), and that additional engineering or administrative controls may be necessary in the future should exceedances occur. It was agreed that at some point, dry ash conversion would be needed to maximize the airspace. It also became apparent that Option 4 represents the maximum limit for build out in the pond for combined wet ash/wet gypsum disposal. Switching to dry fly ash disposal would allow disposal to continue until the contours are achieved as shown in Option 3B (developed earlier in the study).

Other more rigorous approaches are available for sizing the pond. The Army Corps of Engineers has developed models for sediment detention. These models require settling tests be performed with the ash (and/or gypsum) material. Additional time and dollars would be needed to perform these tests and run the model. It was agreed that the simplified analysis is sufficient for the study, and is sufficient for determining the limits of ash/gypsum placement within the pond.

Additional discussion took place and is summarized as follows:

- The volume shown in Option 3B is only viable if the existing dredge cells are built out to the final contours shown in the current solid waste permit (el 866).
- The dredge cells will likely need to continue operation in order to allow time for gypsum production to commence, although additional study will be needed to determine where ash could be placed in the pond if this is not the case. The outer shell of the facility (Option 3B) could be built using we gypsum, but gypsum production would likely start in 2009-2010 (as currently scheduled).
- Parsons needs to address stability of the existing dredge cell/new ash/gypsum concept in order for Option 3B to work. The analysis will determine whether this could become a limiting factor (if no further actions are taken for the dredge

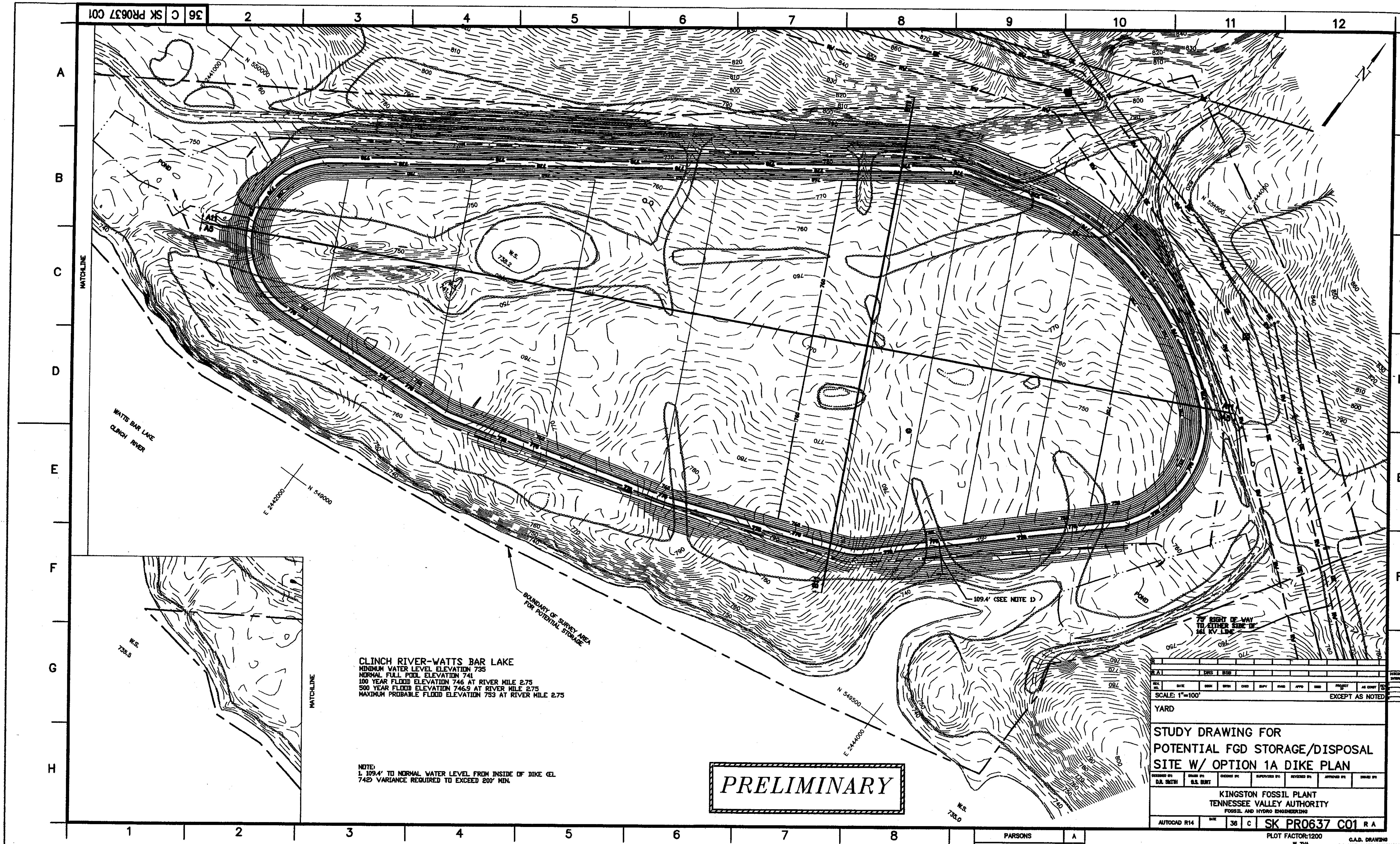
cells), or whether other options (cutoff wall) would enable dredge cells to continue operation.

<u>Actions</u>

TVA (Larry Bowers) will provide Parsons with an estimate of FWV for combined wet ash/wet gypsum disposal.

If anyone has any amendments, corrections, or comments, please contact the undersigned.

Daniel R. (Dan) Smith, P.E.
Parsons E & C Phone: (423) 757-8088
633 Chestnut St, Suite 400 Fax: (423) 266-0922
Chattanooga, TN 37932 Cell: (423) 364-1679 Email: Daniel.R.Smith@parsons.com



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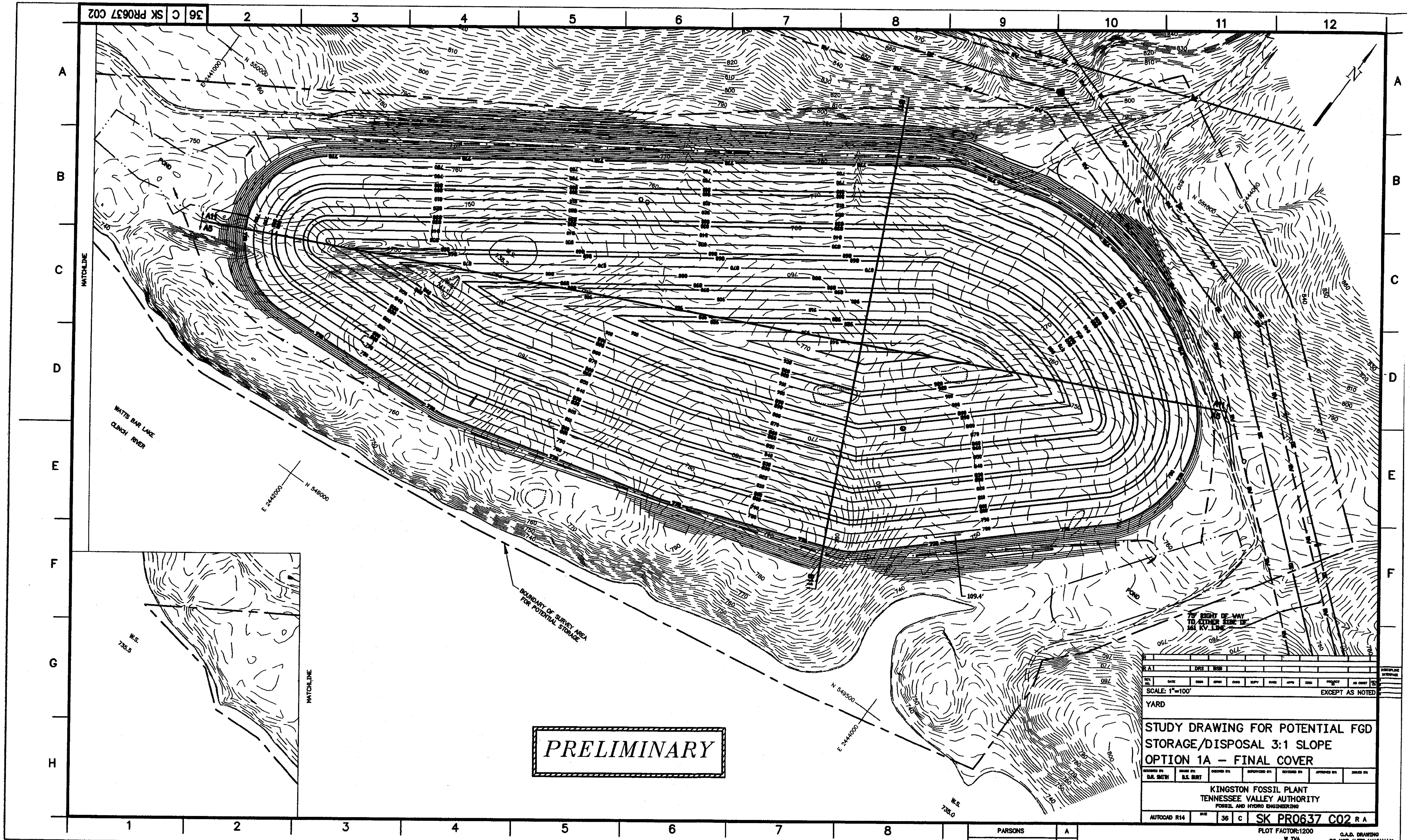

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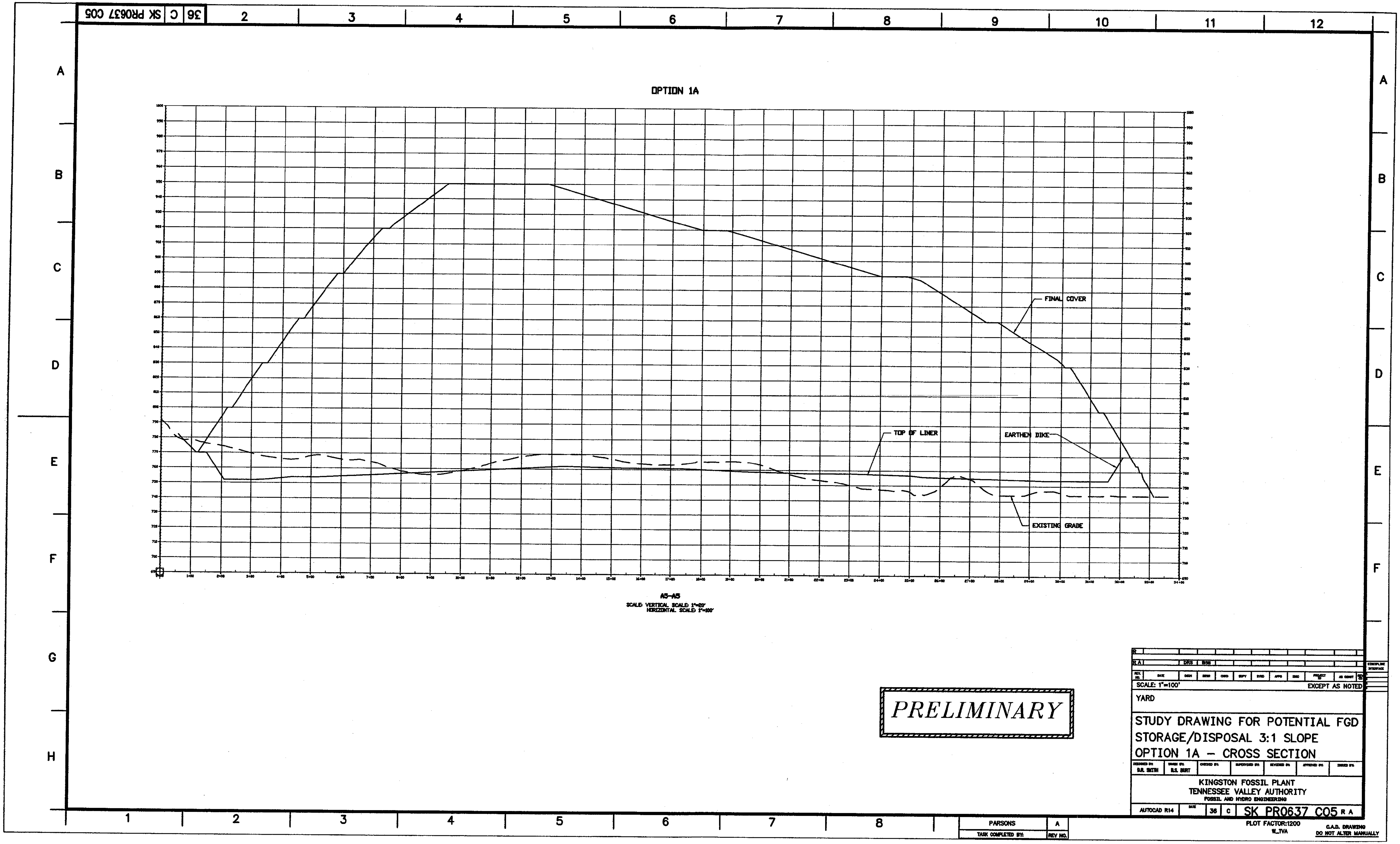

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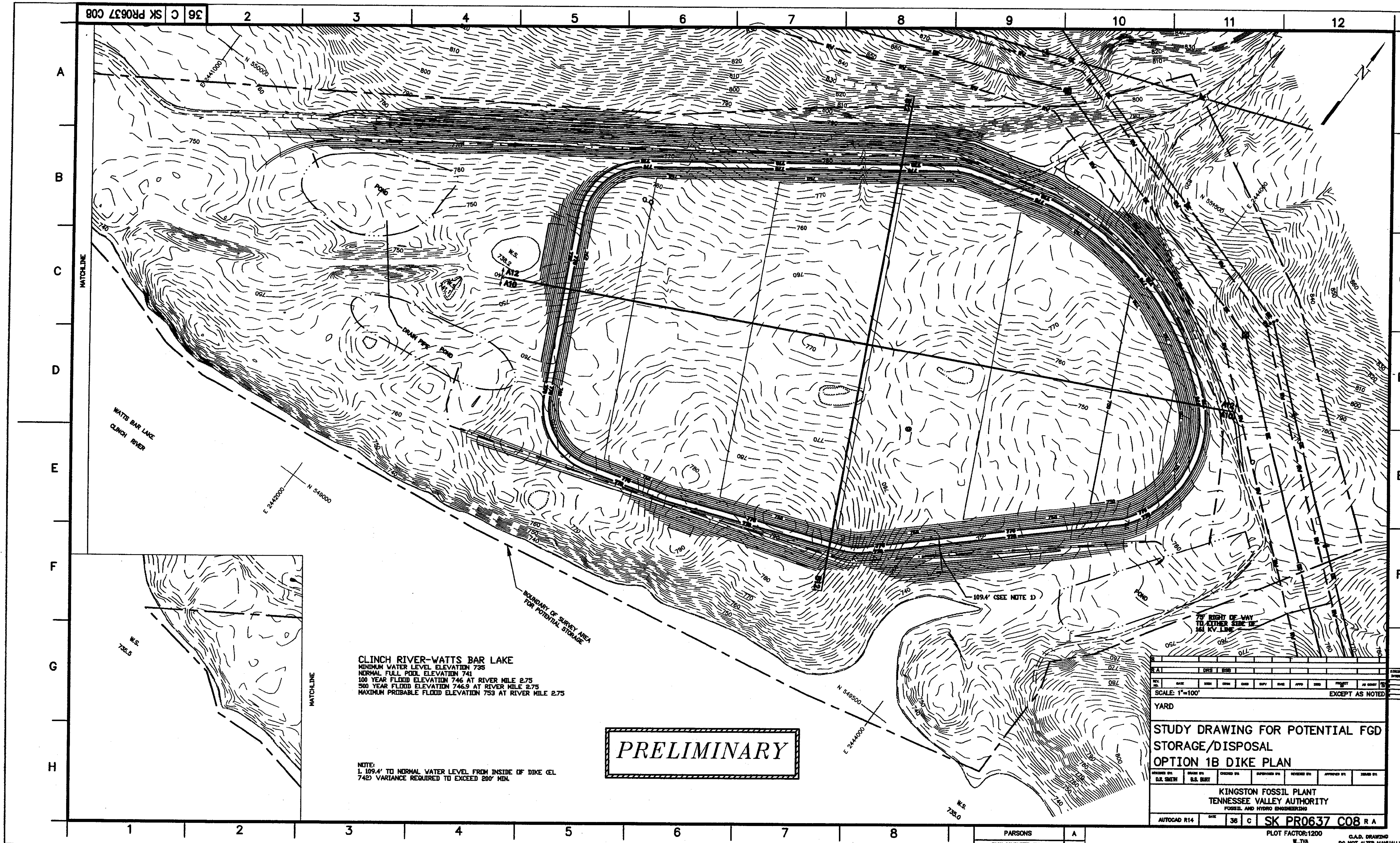

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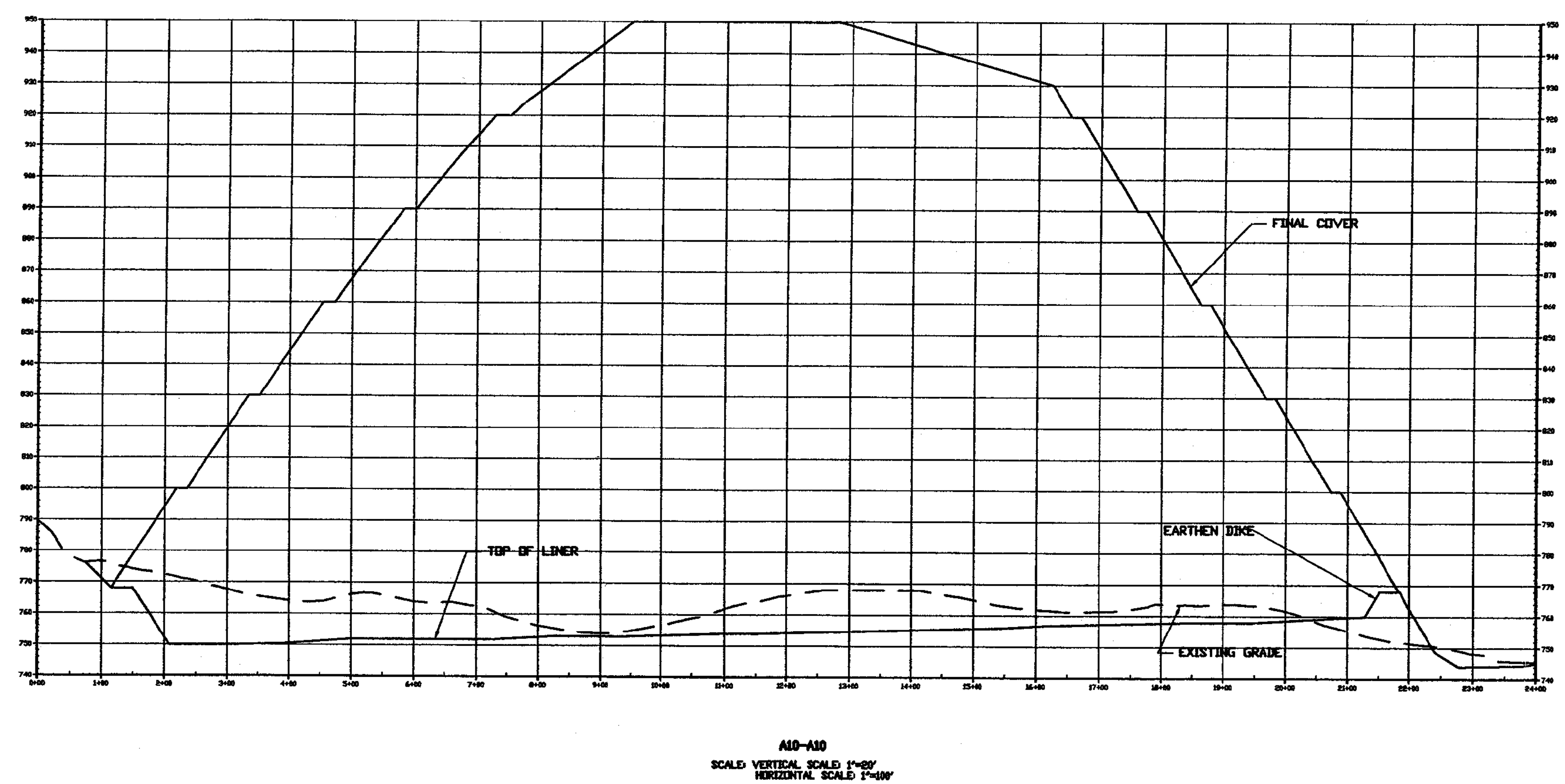

PRELIMINARY

SCALE: 1"=100' EXCEPT AS NOTED

YARD

STUDY DRAWING FOR
POTENTIAL FGD STORAGE/DISPOSAL
3:1 SLOPE OPT 1B – CROSS SECTION

D.R. SMITH | B.S. BURT

KINGSTON FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14 | 36 | C | SK PR0637 C10 | R A

PLOT FACTOR:1200
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

PARSONS | A
TASK COMPLETED BY: | REV NO.

36 | C | SK PR0637 C10

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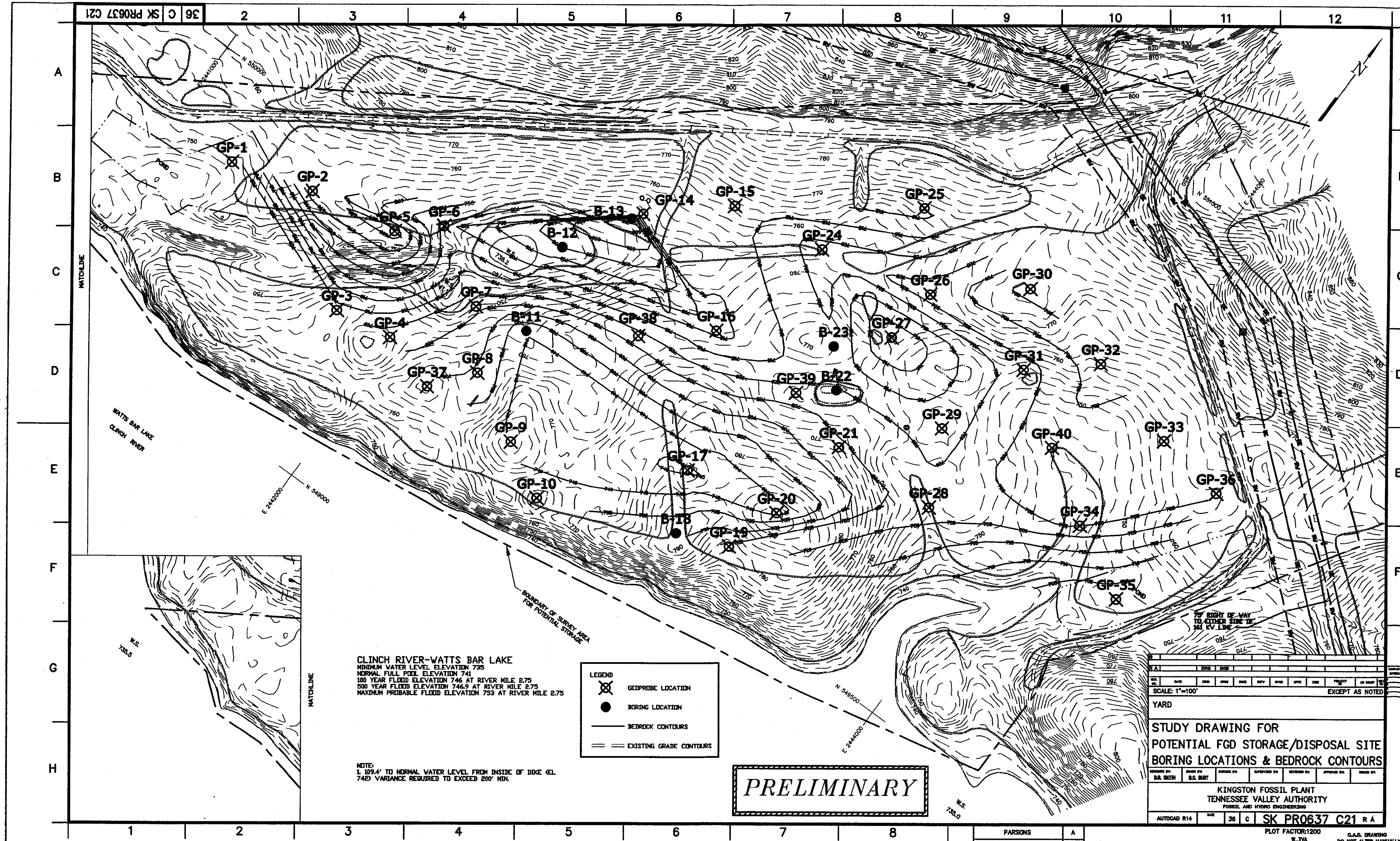
TVA-00004825



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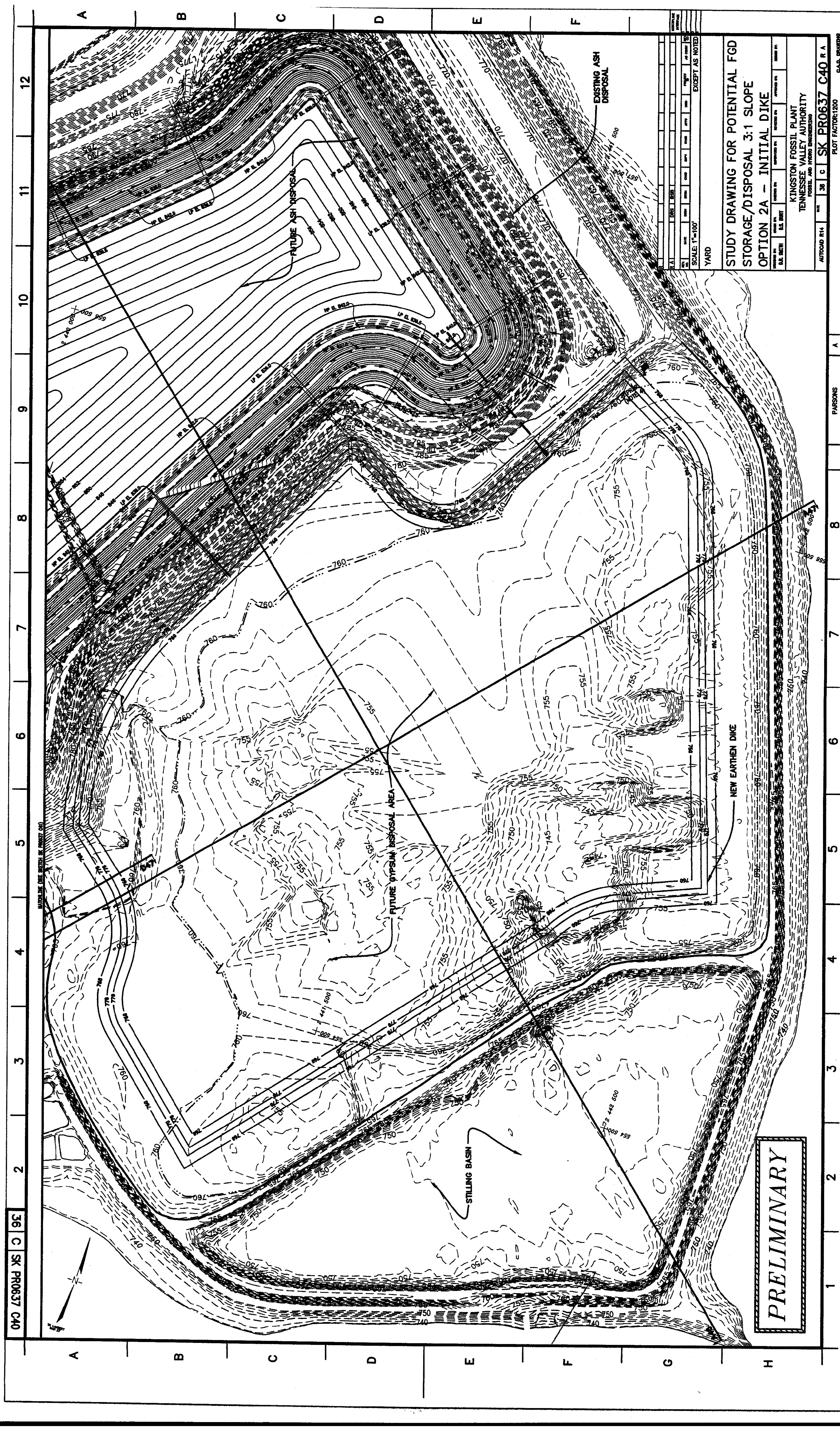

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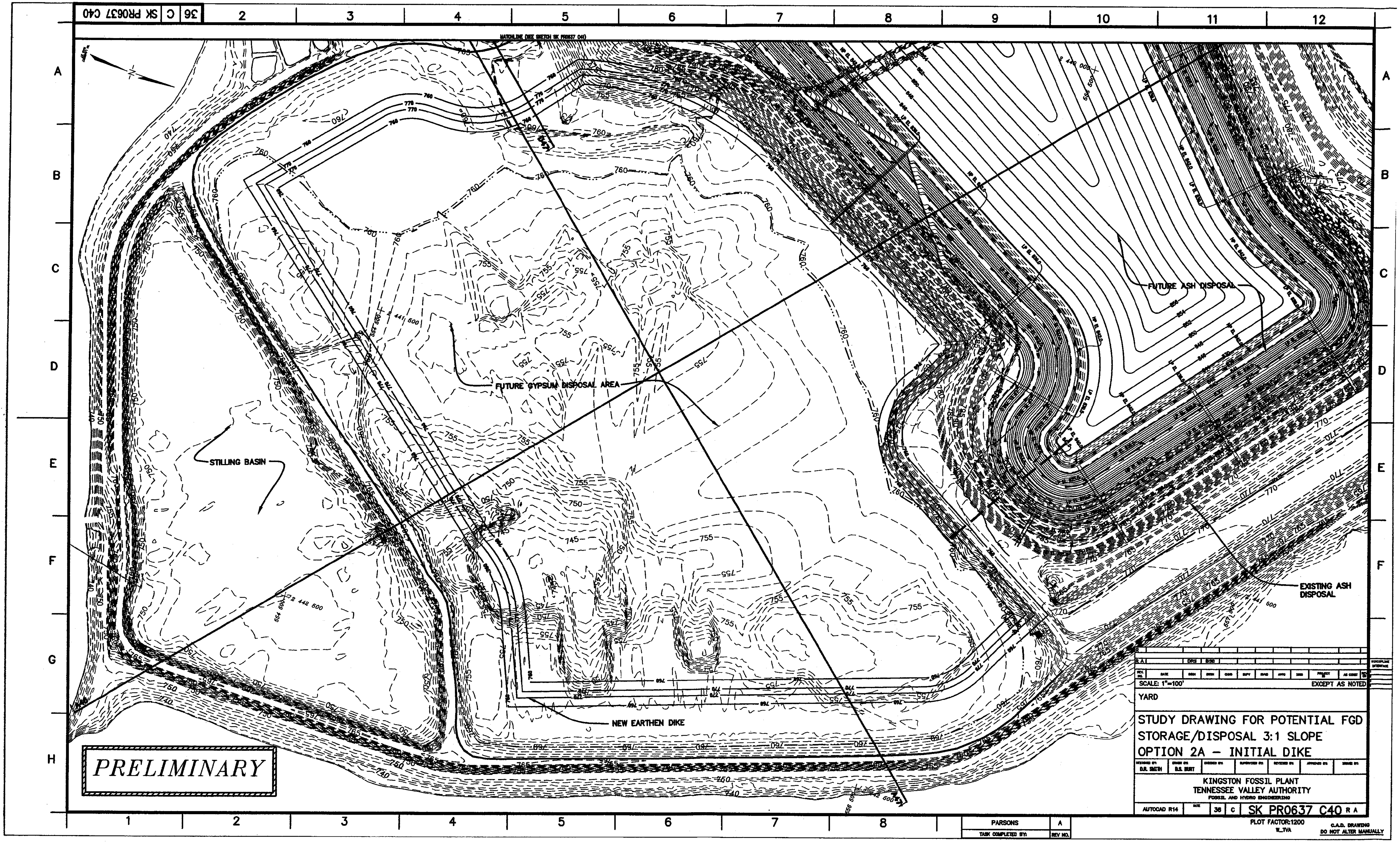

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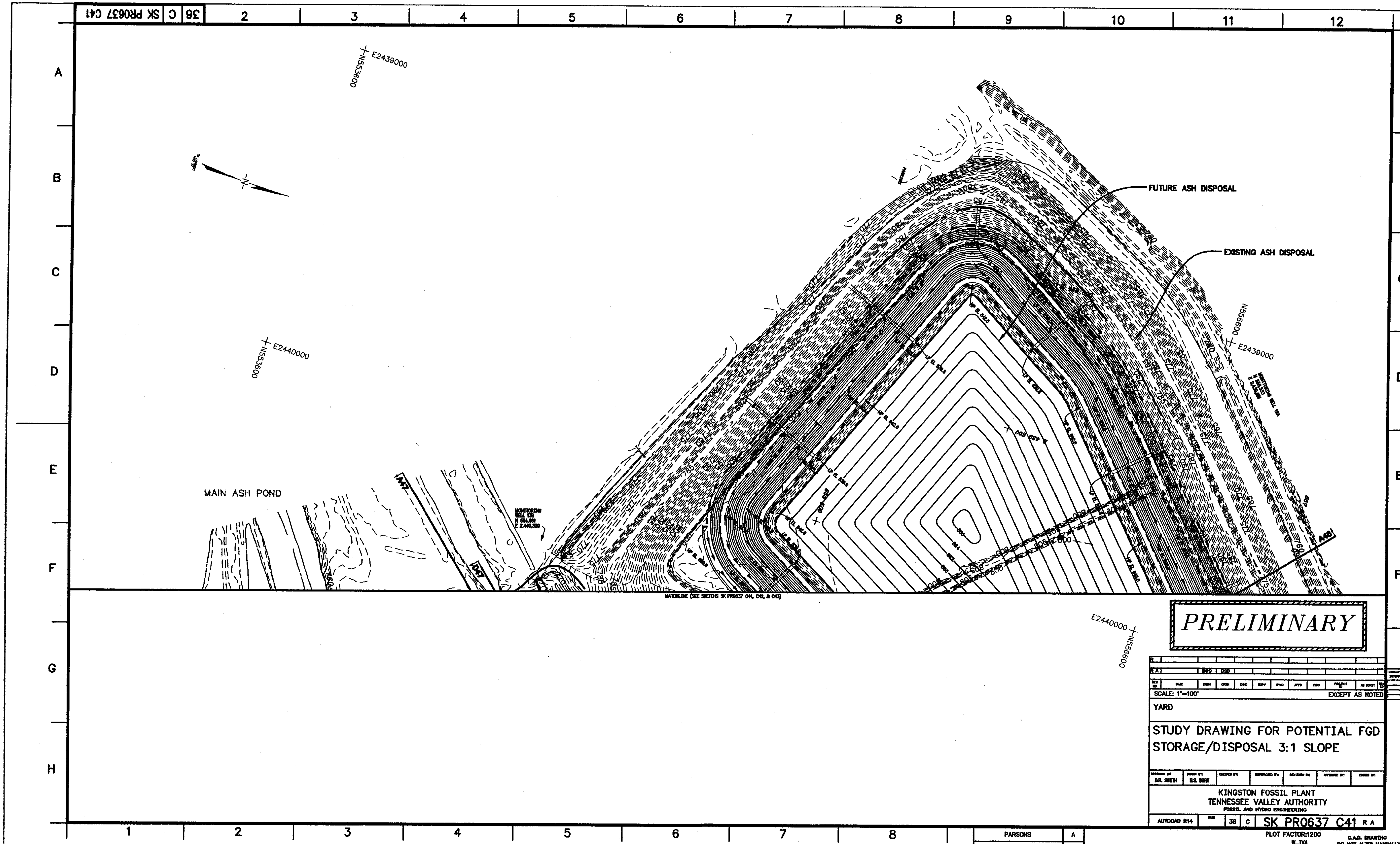

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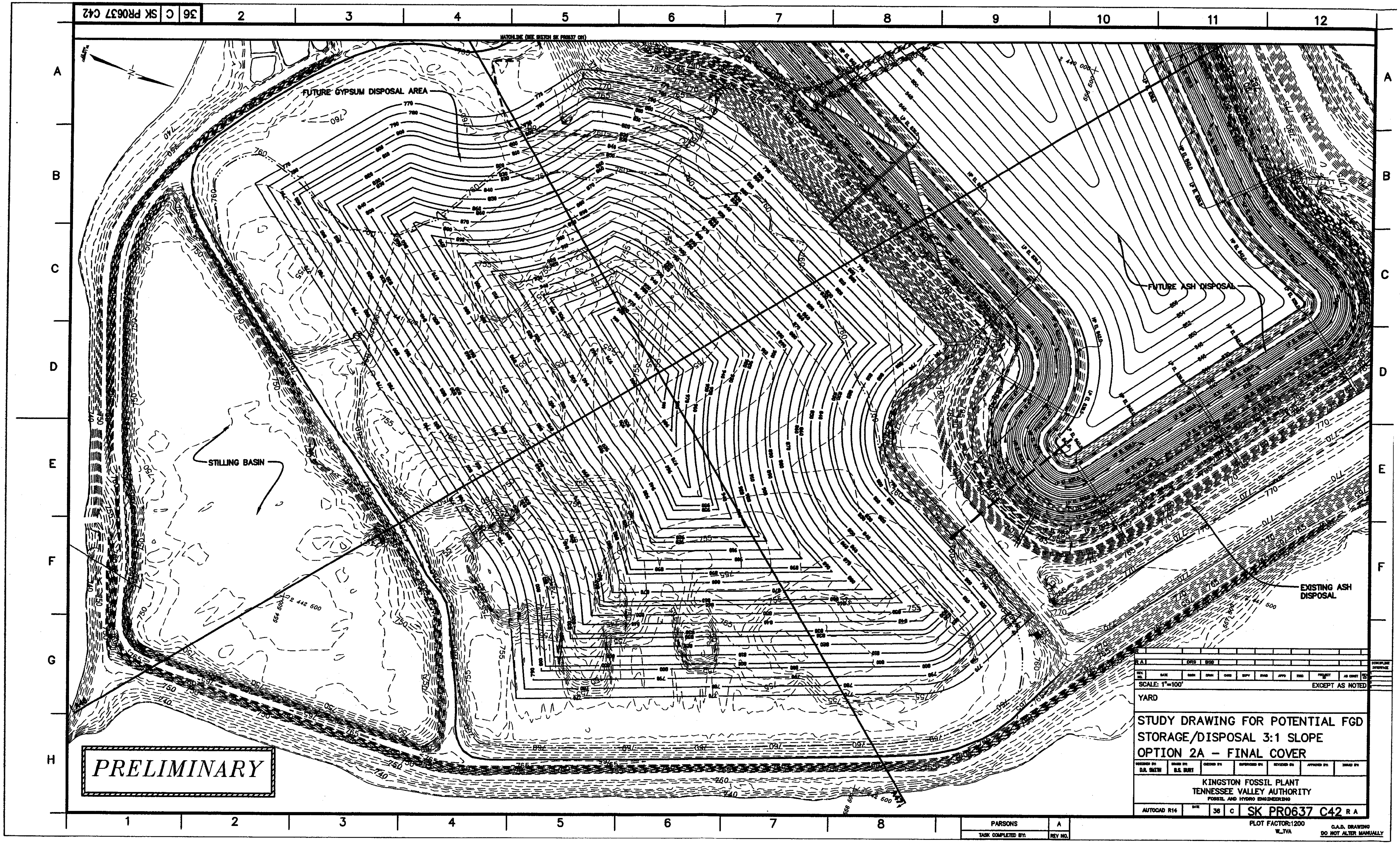

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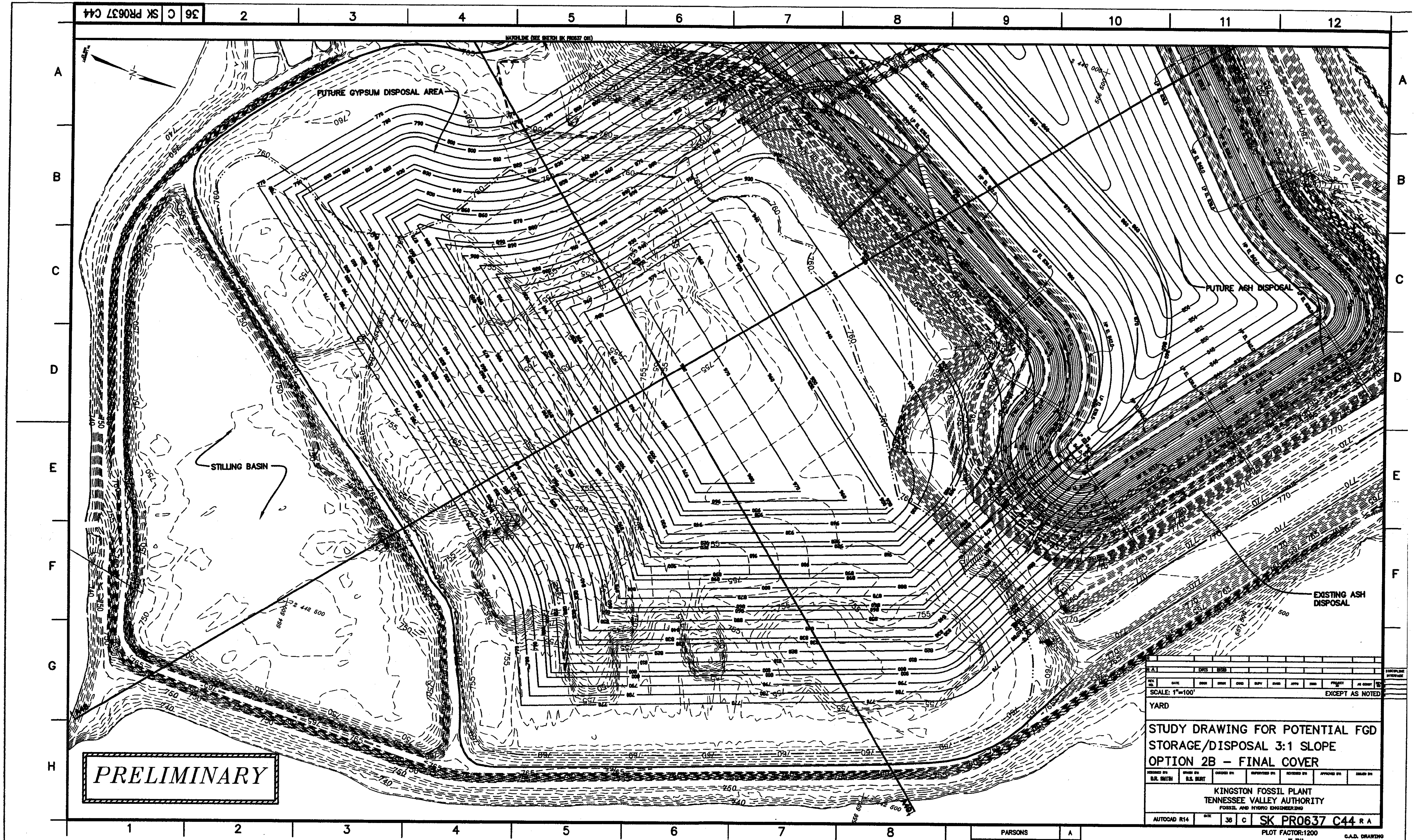

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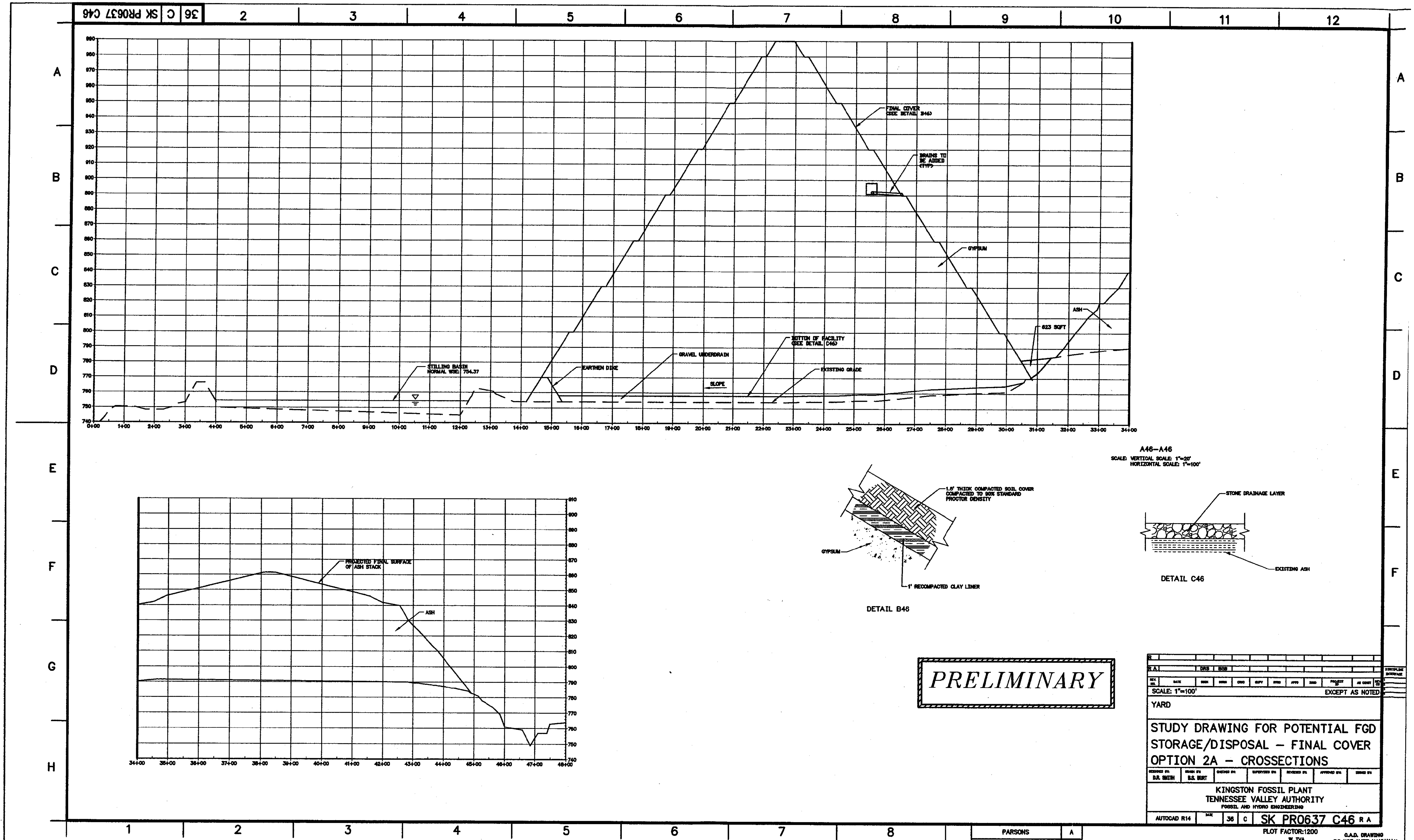

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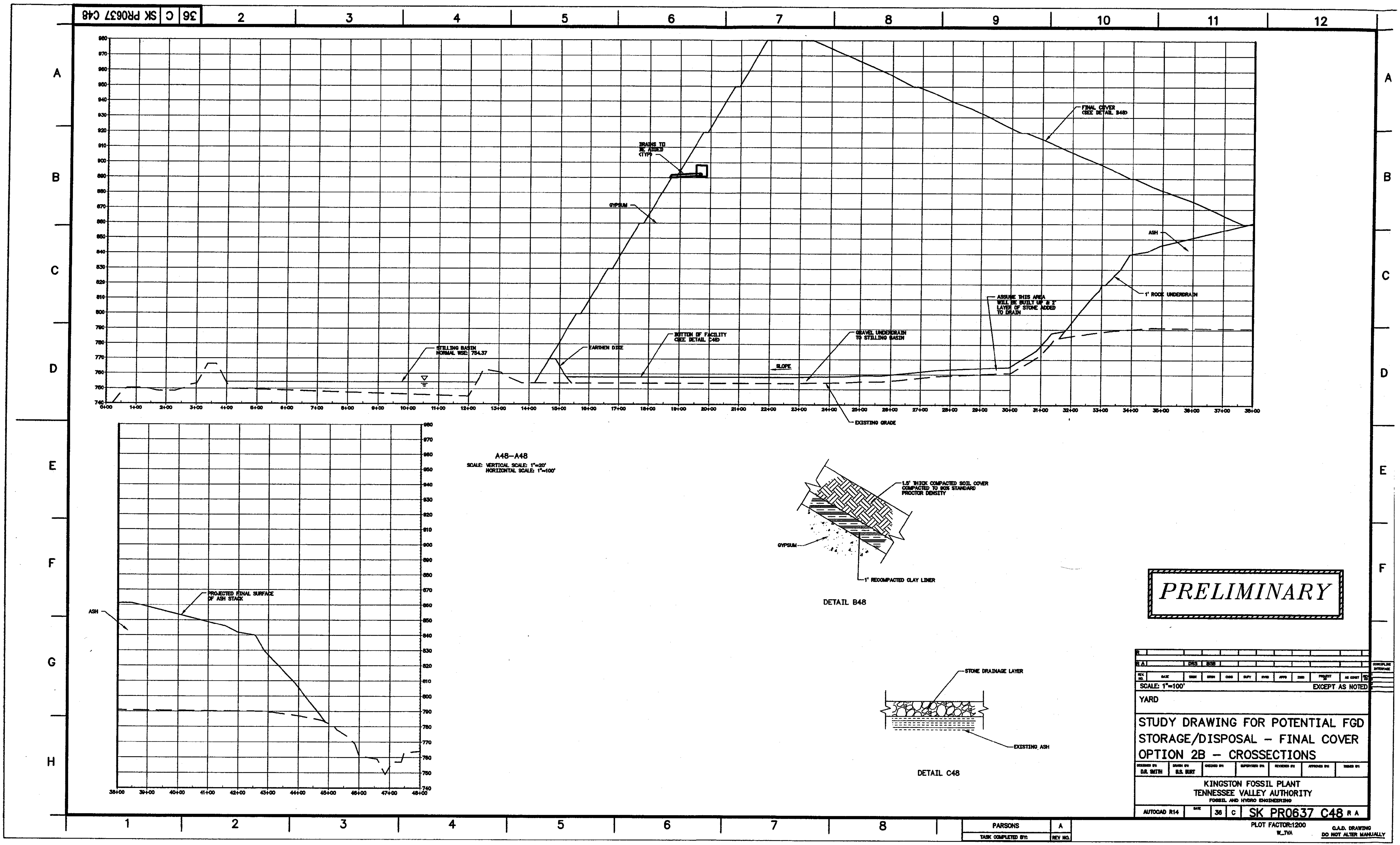

SCALE: 1"=100' EXCEPT AS NOTED

YARD

STUDY DRAWING FOR POTENTIAL FGD STORAGE/DISPOSAL – FINAL COVER OPTION 2B – CROSSECTIONS

D.R. SMITH B.S. BURT

KINGSTON FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14 | 36 | C | SK PR0637 C48 | R A

PLOT FACTOR:1200
W_TVA

C.A.D. DRAWING DO NOT ALTER MANUALLY

PARSONS | A
TASK COMPLETED BY: | REV NO.

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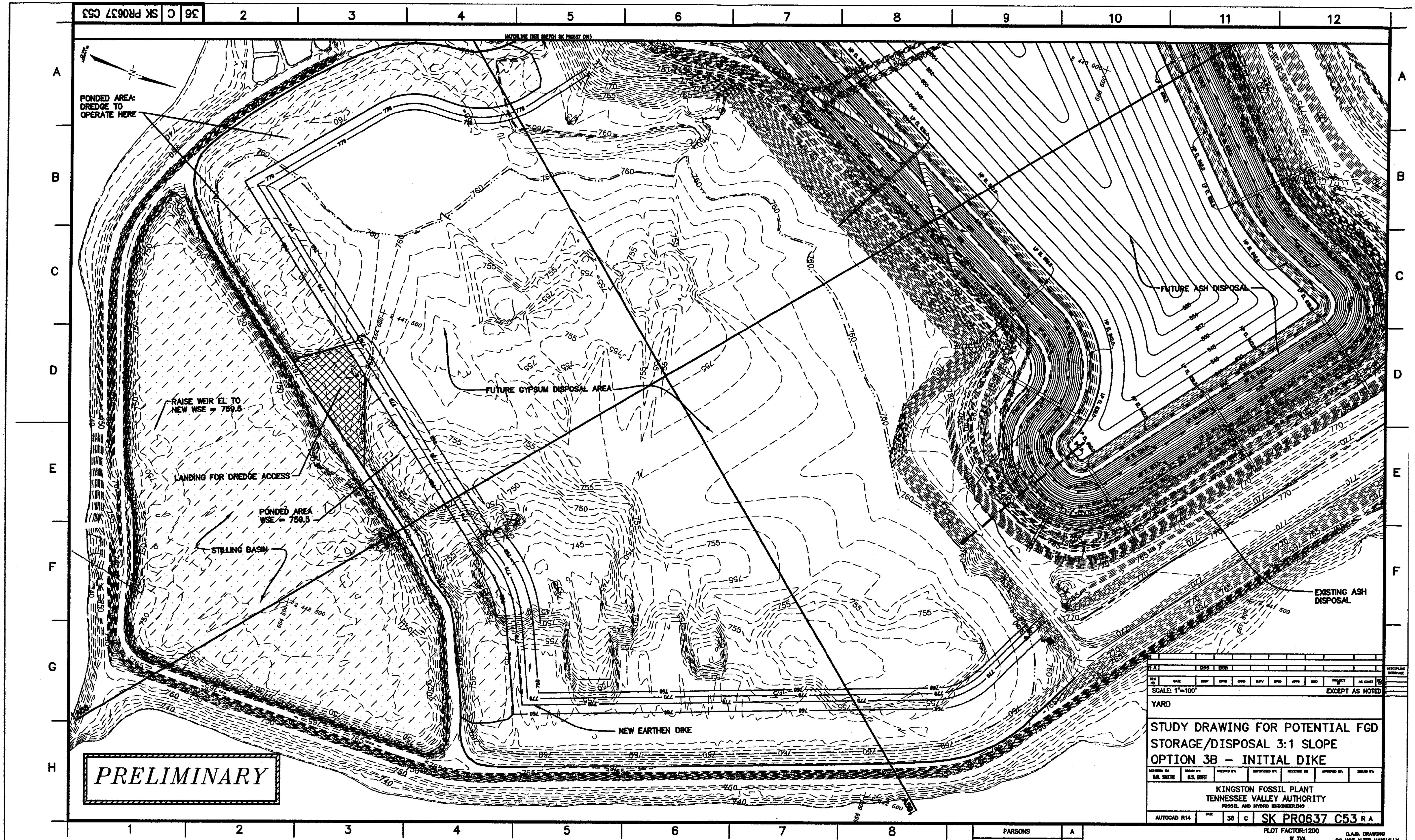

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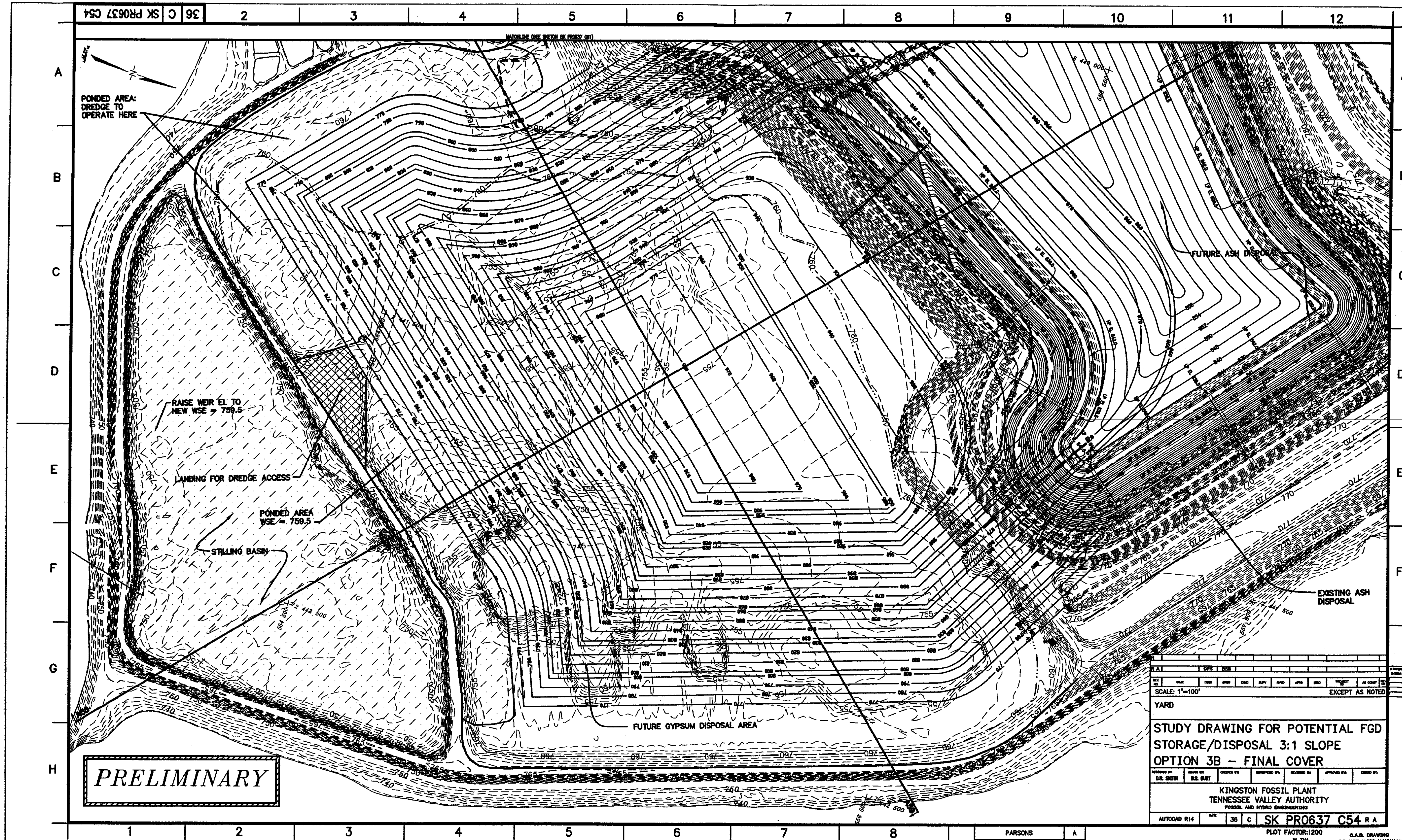

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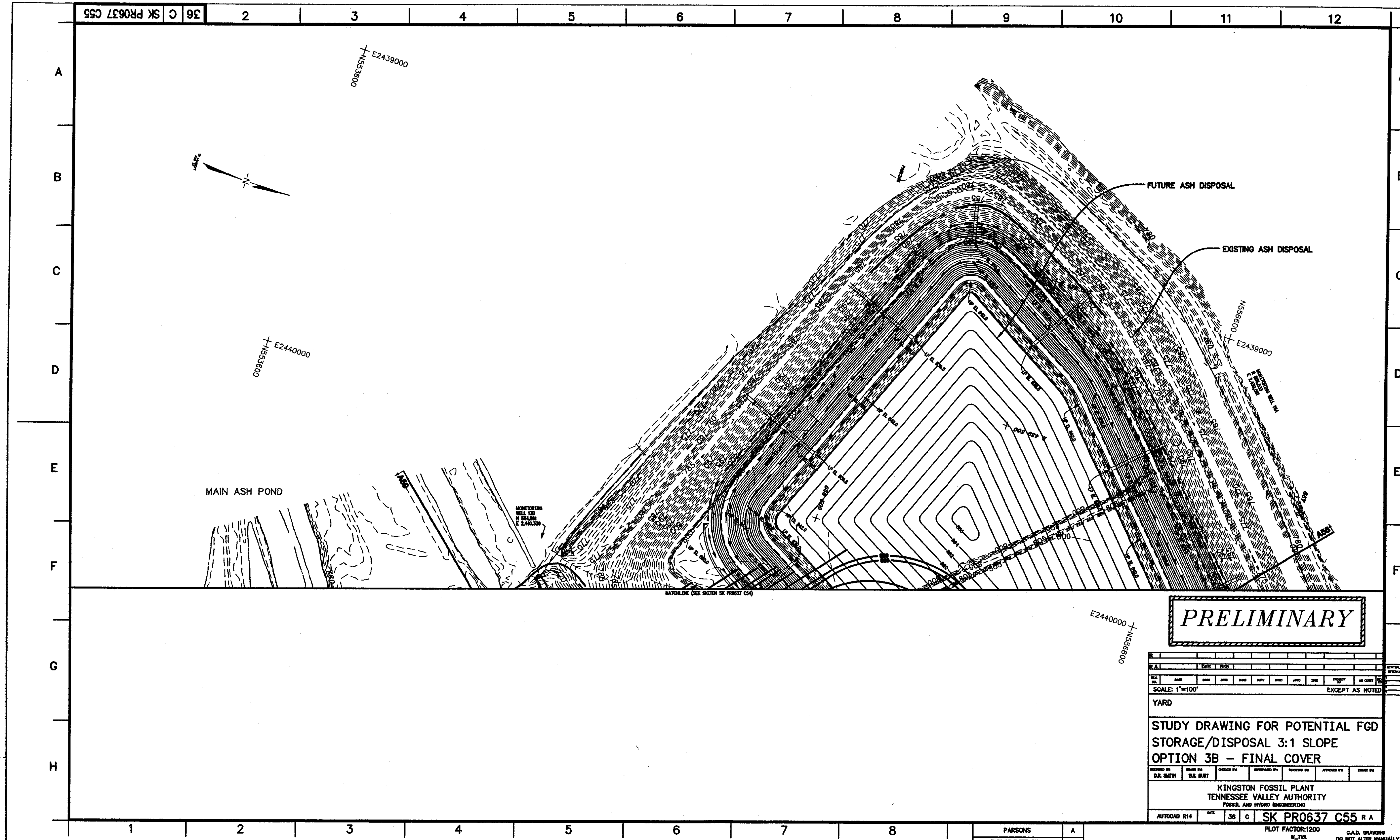

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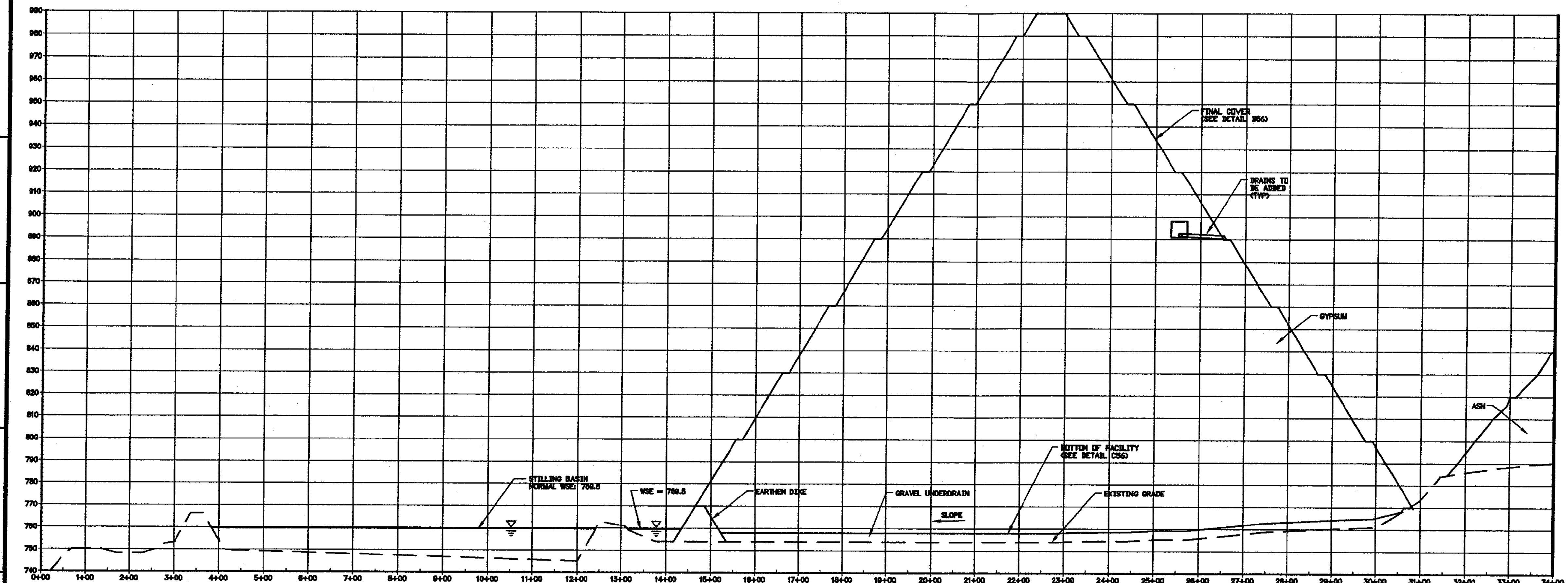
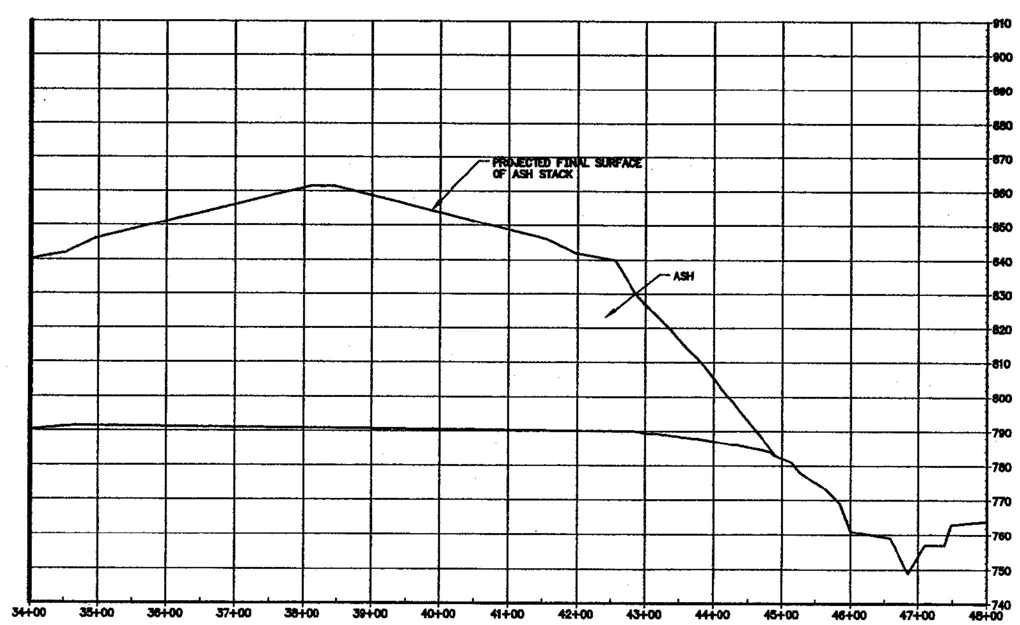
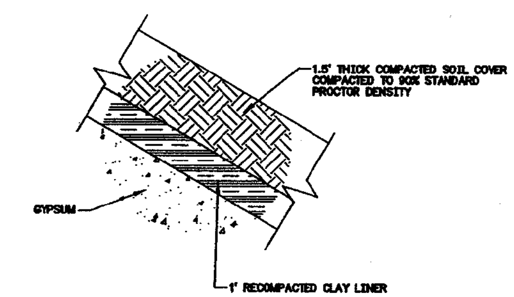
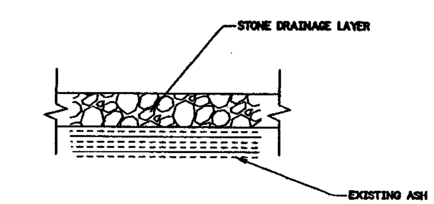


A56–A56
SCALE: VERTICAL SCALE: 1"=20'
HORIZONTAL SCALE: 1"=100'





DETAIL B56



DETAIL C56

PRELIMINARY

SCALE: 1"=100' EXCEPT AS NOTED

YARD

STUDY DRAWING FOR POTENTIAL FGD STORAGE/DISPOSAL – FINAL COVER OPTION 3A – CROSSECTIONS

DESIGNED BY: D.R. SMITH
DRAWN BY: S.S. BURT

KINGSTON FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14 | 36 | C | SK PR0637 C56 | R A

PLOT FACTOR:1200
W_TVA

C.A.D. DRAWING DO NOT ALTER MANUALLY

PARSONS | A
TASK COMPLETED BY: | REV NO.

36 | C | SK PR0637 C56

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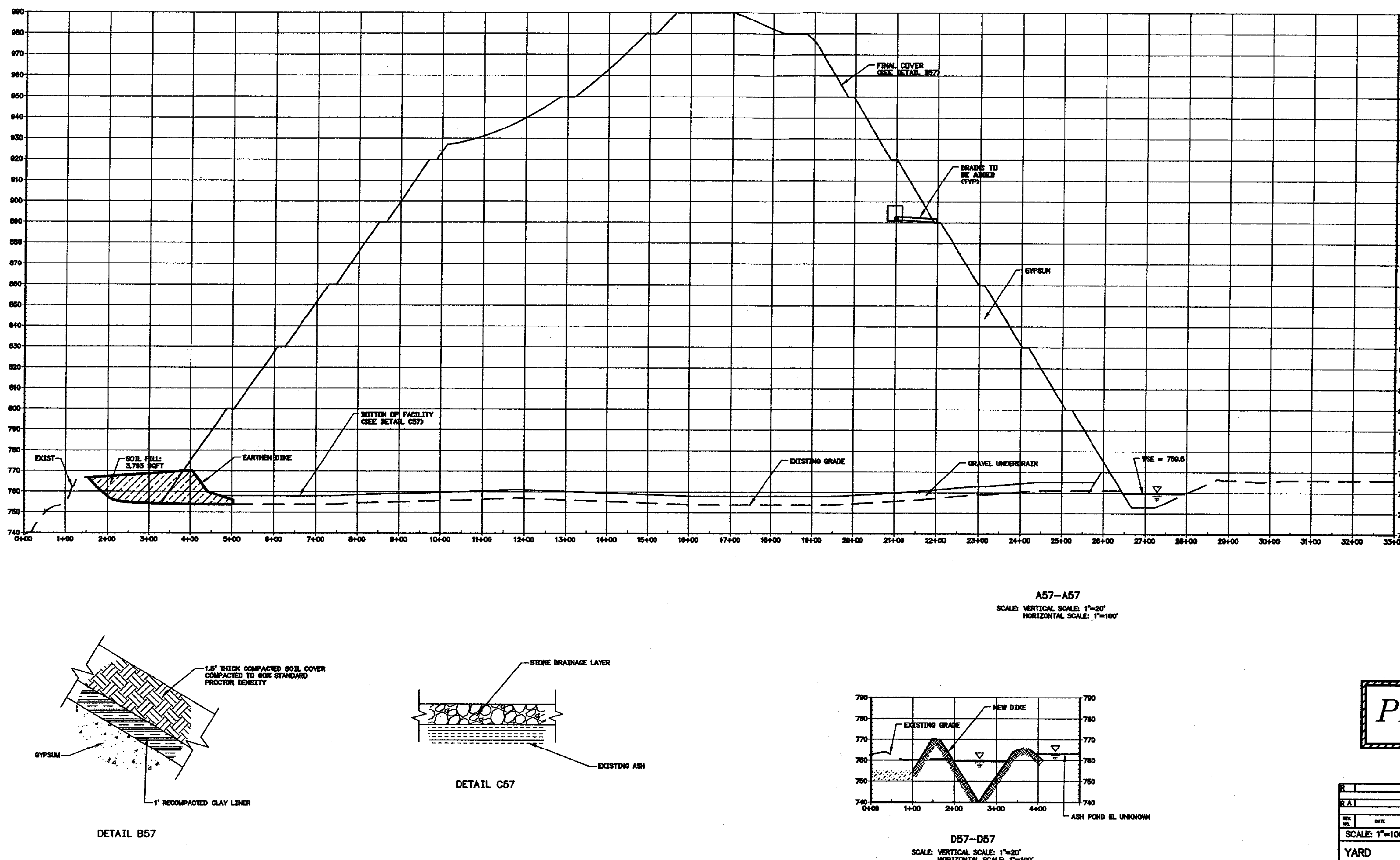

PRELIMINARY

SCALE: 1"=100' EXCEPT AS NOTED

YARD

STUDY DRAWING FOR POTENTIAL FGD STORAGE/DISPOSAL – FINAL COVER OPTION 3A – CROSSECTIONS

DESIGNED BY: D.R. SMITH | DRAWN BY: B.S. BURT

KINGSTON FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14 | 36 | C | SK PR0637 C57 | R A

PLOT FACTOR:1200
W_TVA

C.A.D. DRAWING DO NOT ALTER MANUALLY

PARSONS | A
TASK COMPLETED BY: | REV NO.

36 | C | SK PR0637 C57

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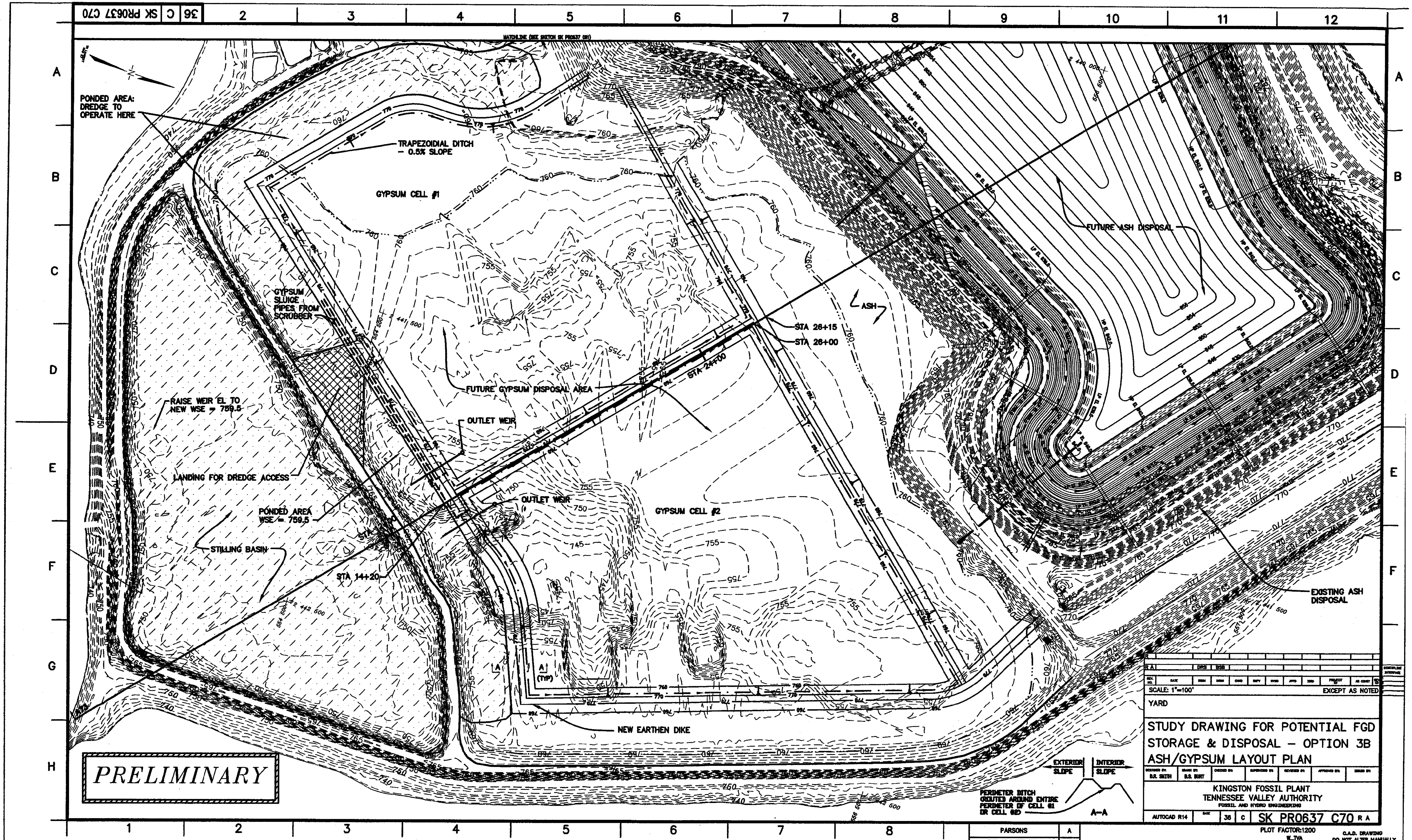

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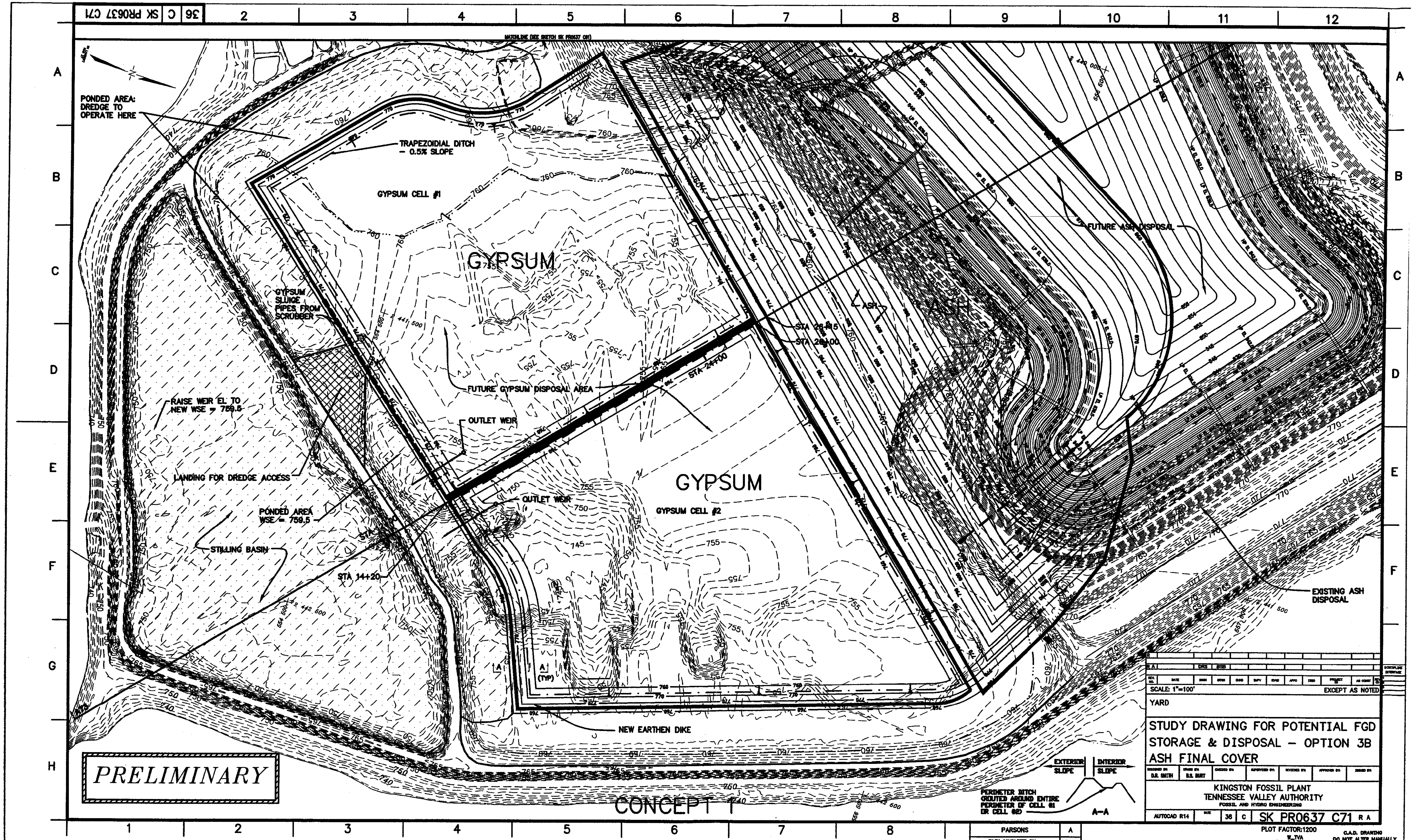

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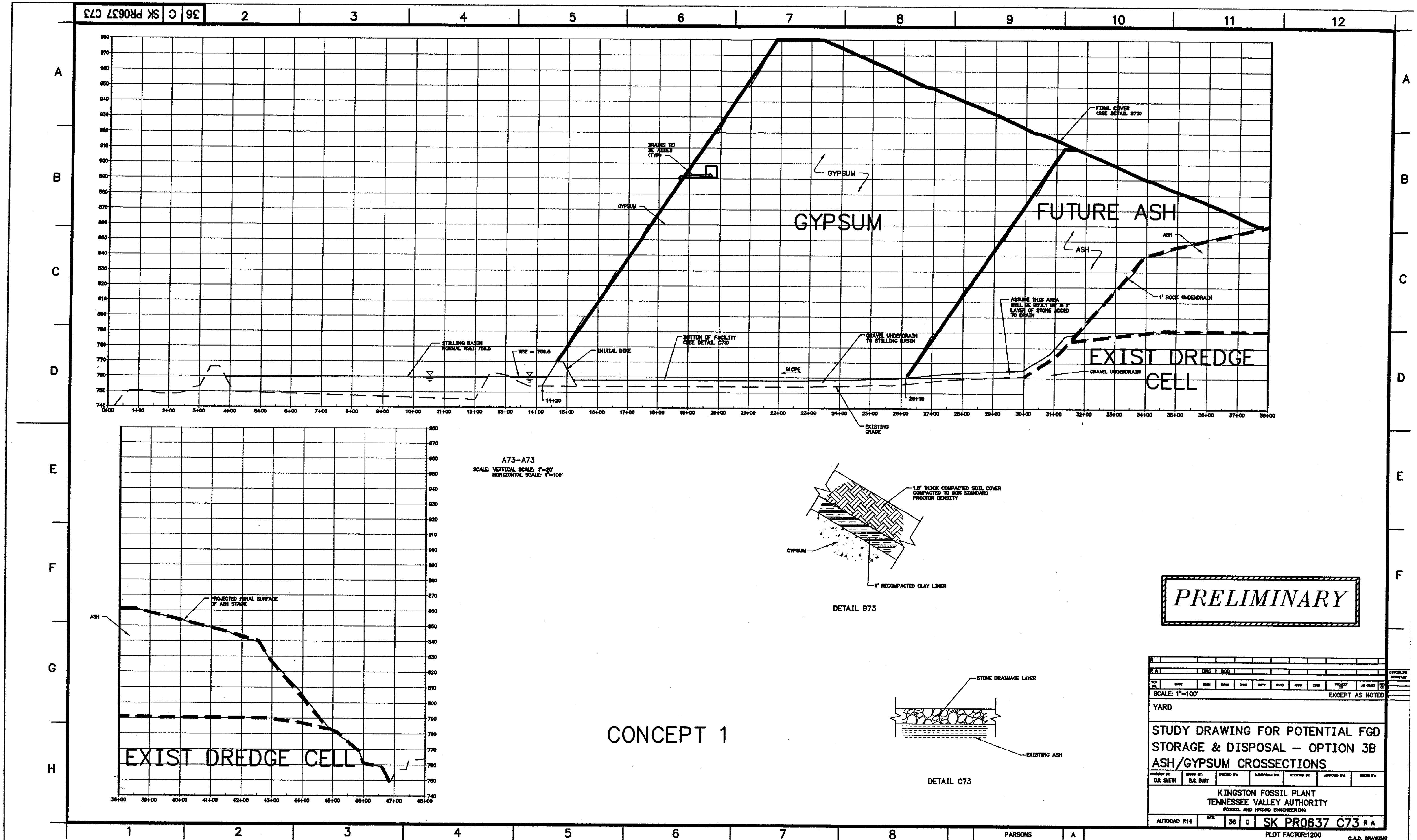

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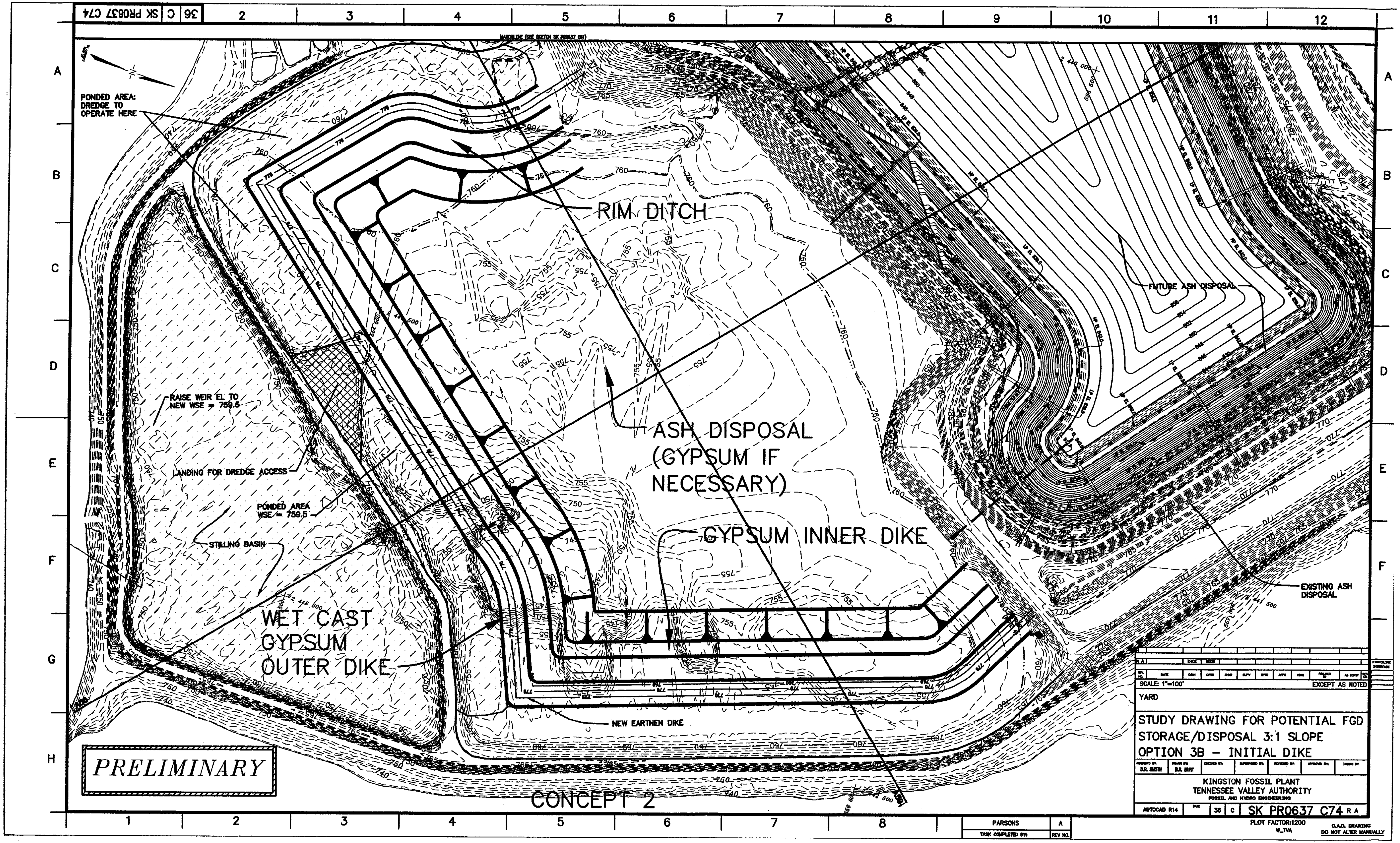

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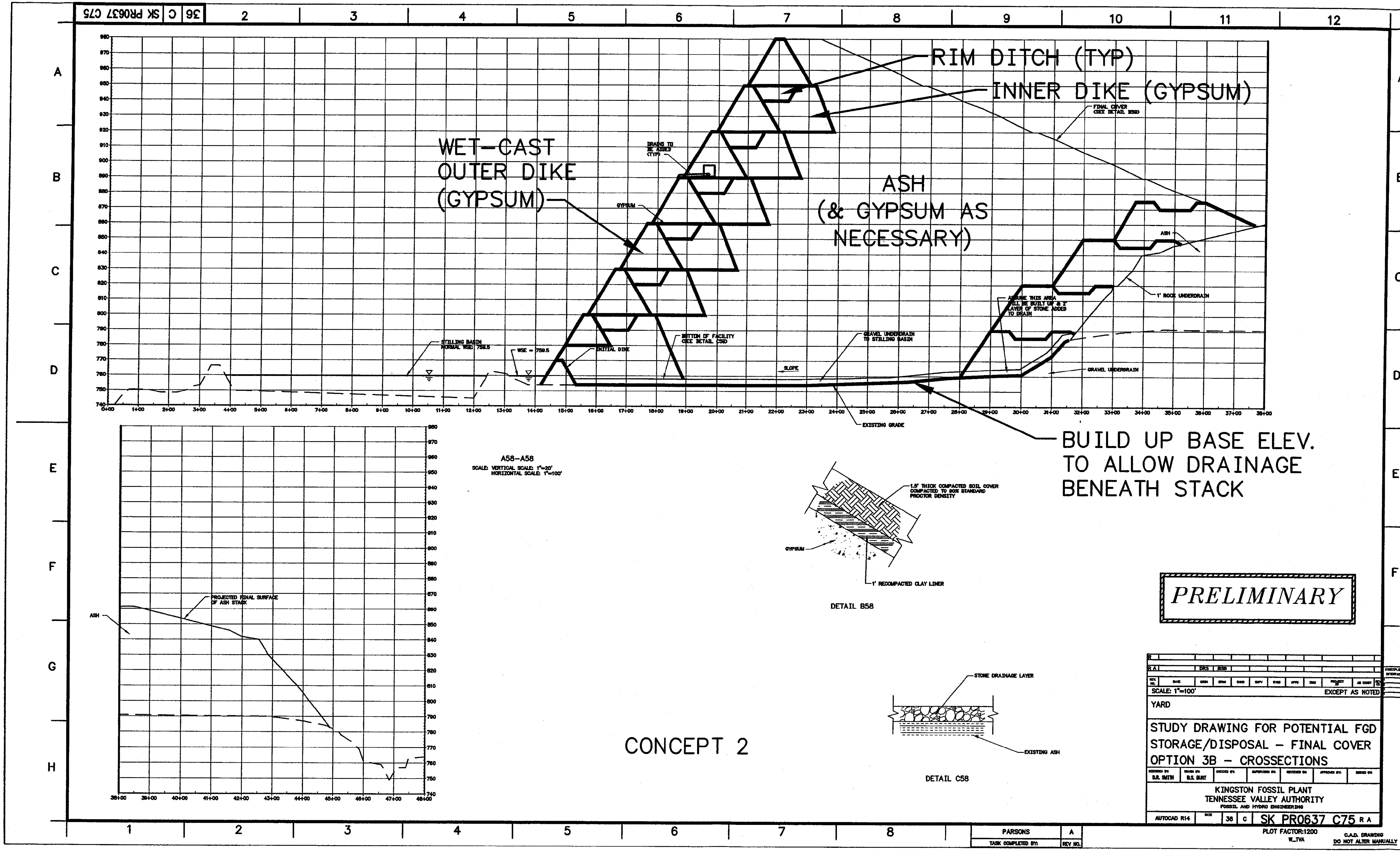

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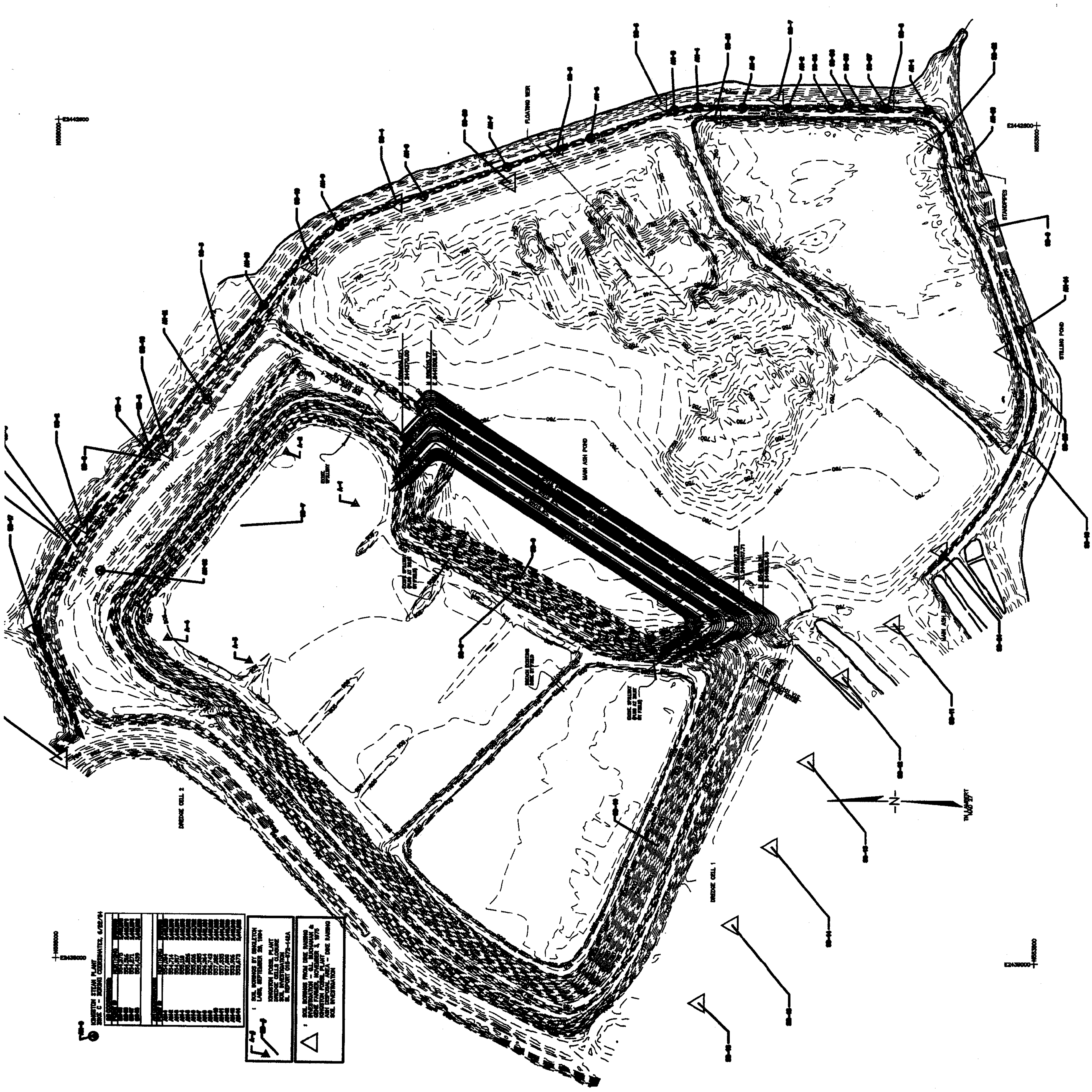

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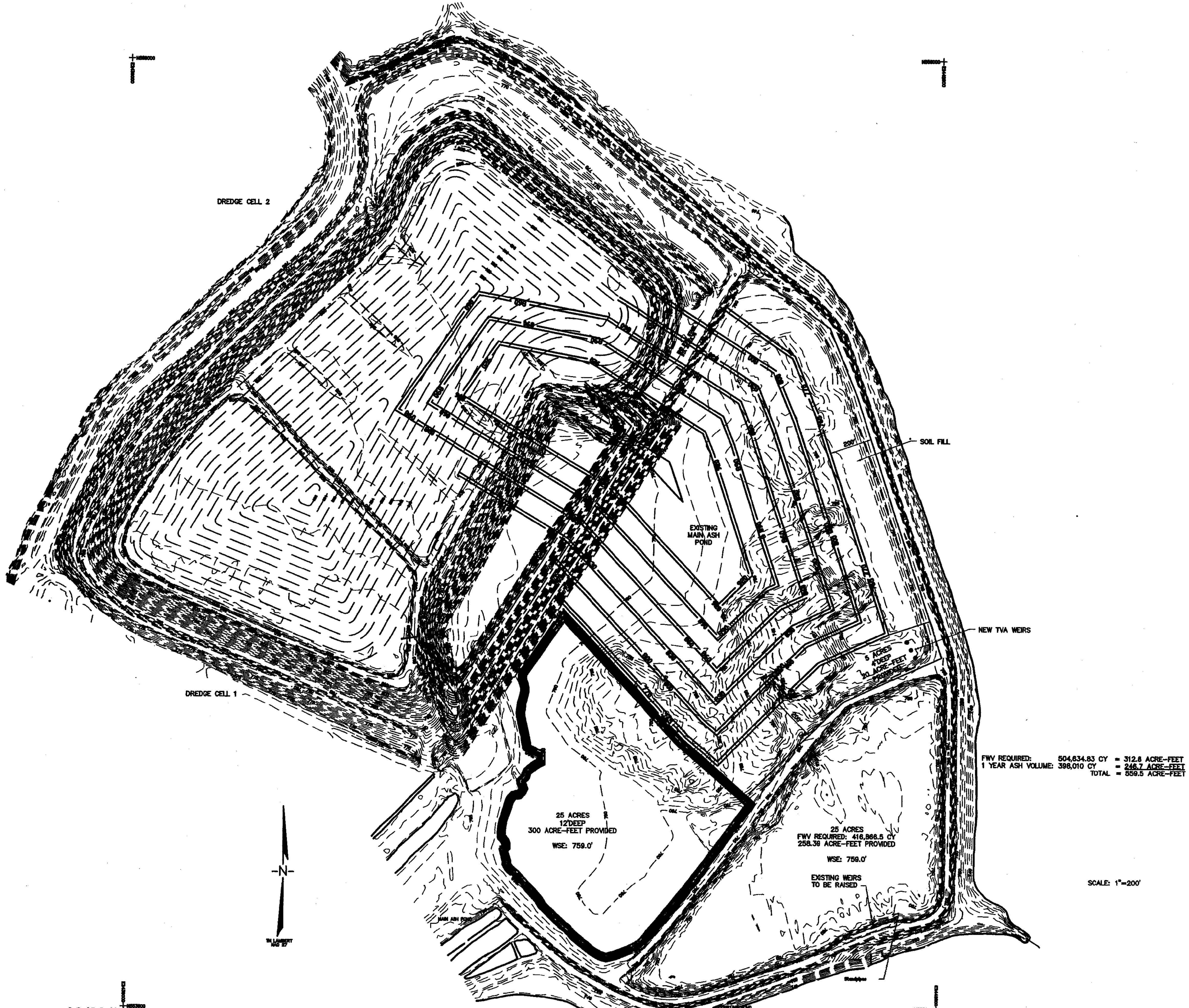

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