UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
COMMONWEALTH EDISON COMPANY	)	Docket Nos. 50-454 OL
	)	50-455 OL
(Byron Nuclear Power Station,	)	
Units 1 & 2)	)	

SUMMARY OF TESTIMONY OF LAWRENCE HOLISH CONCERNING CONSOLIDATED CONTENTIONS 39 AND 109

Mr. Holish is an engineer, employed by Sargent & Lundy, the Bryon Station Architect-Engineer. He is Head of the Geotechnical Division at Sargent & Lundy, and was involved in the geologic and geotechnical work performed with respect to establishing the Byron foundation design criteria and for the Byron project design assessment. Mr. Holish's testimony characterizes the groundwater system underlying the Byron site and addresses the assumptions used in determing the time it would take radioactive contaminants released to the groundwater to travel to the nearest well.

Mr. Holish first describes the methodology used to identify and characterize the hydrogeological and geologic characteristics of the Byron site. Specifically, Mr. Holish states that the investigation of the site was conducted in a manner consistent with NRC Staff guidance. He also indicates that the investigation included extensive geophysical surveys; drilling, sampling and water pressure tests; field measurements; use of observation wells; and measurements and mapping of bedrock features. Mr. Holish also describes the extensive grouting program that has been implemented at the Byron site. He concludes that the site as been characterized correctly and that further investigation using the methods proposed by Dr. Wood is not warranted.

Mr. Holish next describes his method for determining the travel time of groundwater that might be contaminated from radionuclides as a result of a postulated accident involving a rupture of a boron recycle holdup tank or a postulated core melt accident. The travel times for these scenarios are calculated to be 30.49 and 92.7 years, respectively. Mr. Holish concludes that these travel times allow ample opportunity to take action to interdict the flow of contaminated waste, thereby mitigating the consequences of the release of contaminants to the groundwater.

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TESTIMONY OF LAWRENCE L. HOLISH
CONCERNING LEAGUE OF WOMEN VOTERS' CONTENTIONS 39 AND 109

Q.1. Please state your name.

A.1. Lawrence L. Holish

Q.2. By whom are you employed?

A.2. Sargent & Lundy Engineers.

Q.3. In what capacity?

A.3. I am Head of the Geotechnical Division.

Q.4. Please describe your educational and professional background.

A.4. In 1963 I received a B.S. in civil engineering from Michigan Technological University. Since graduation I have been employed by the West Virginia Road Commission, Charleston, West Virginia, Stone and Webster Engineering Corporation, Boston, Massachusetts, and Sargent & Lundy Engineers for 2, 5, and 10 years, respectively. During these 17 years I have participated, and in most cases, provided administrative control of the investigation, evaluation, and design of foundations for 15 nuclear generating stations and 25 fossil fuel stations.

Prior to becoming Head of the Geotechnical Division at Sargent & Lundy, I was Senior Soil Engineer. In that capacity I was responsible for the establishment and preparation of the technical criteria and procedures developed for the Byron Station foundation grouting program, and subsequent earth work. During the initial design and construction of the Byron Station, I provided the interpretation of geologic and geotechnical subsurface exploration data required for foundation design criteria and for subsequent project design assessment.

Q.5. What is the scope of your testimony?

A.5. My testimony addresses Consolidated Contentions 39 and 109 which state:

> Since the ground water system underlying the Byron site has not been characterized adequately, the consequences of

> radionuclide releases to the underlying aquifer cannot be predicted with confidence. In consequence, no proper NEPA analysis of this important subject can be made. . . .

Specifically, my testimony addresses those aspects of the contention that concern the hydrogeological characteristics of the Byron site and the analyses that were performed regarding movement of ground water.

Q.6. What do you understand the term "characterize" to mean as the term is used in Consolidated Contentions 39 and 109?

A.6. The site for a nuclear power plant must be investigated and evaluated to determine its suitability for the intended purpose. Generally, it must be demonstrated that such a site meets the requirements of NRC's regulations. One category of information that is required is a detailed description of seismic and geologic characteristics of the site.

In the context of Consolidated Contentions 39 and 109 concerning the characterization of the ground water system underlying the Byron site, it is important to investigate and identify the geologic or physical properties of the rock formation that would influence the transport of liquid radioactive materials resulting from postulated accidents. Specifically, geologic properties such as the competency of the rock foundation, the degree of jointing and variations in lithology must be identified or characterized. Such an investigation was performed for the Byron site and the results are reported in the FSAR.

Q.7. How was the geologic investigation performed for the Byron site?

A.7. The Byron site was investigated through a multiphased program that was structured in accordance with sections 2.4 and 2.5 of NRC Staff Regulatory Guide 1.70 which was in effect at the time of the investigation in the early 1970's. The results of the investigation were included first in the PSAR in 1973 and then in the FSAR in 1978.

The detailed investigation included (1) performing over four miles of geophysical surveys, (2) drilling, sampling, and selective water pressure testing of 154 borings varying in depth from 10 to 330 feet for the foundation bedrock, (3) field measurement of geologic features over the site area including outcrops and site linements, (4) installation and measurement of observation wells throughout the site and adjoining properties, (5) detailed measurements and mapping of exposed bedrock features found in the structure excavations, and (6) monitoring the behavior of structure foundations.

The NRC Staff issued additional guidance in 1978 in the form of Regulatory Guide 1.138 "Laboratory Investigations of Soils For Engineering Analysis and Design in Nuclear Power Plants," and in 1979 in the form of Regulatory Guide 1.132 "Site Investigations For Foundation of Nuclear Power Plants." The site investigation methodology used for Byron was compared with that suggested by the two regulatory guides and they were found to be consistent with one another. This conclusion is significant because these documents represent the Staff's current thinking and, Regulatory Guide 1.132, in particular, provides guidance on appropriate methods to be used in the investigation and characterization of the ground water system underlying the Byron site.

Q.8. What were the results of the geologic investigation of the Byron site?

A.8. The hydrogeological and geological characteristics of the Byron site were determined from this investigation.

Q.9. Please describe the hydrogeological characteristics of the Byron Site that influence water movement travel times.

A.9. As a preface, it should be noted that a complete and detailed description of the geologic characteristics of the Byron site is contained in Chapter 2.5 of the Byron FSAR. To aid in the understanding of the following summary description, I have attached as Exhibit I to my testimony a stratigraphic column of the Byron site geologic formations.

The four most significant hydrogeologic units at the Byron site are the glacial drift, the Galena-Platteville dolomites, the sandstone units of the Cambrian-Ordovician Aquifer (the St. Peter, Ironton and Galesville Sandstones), and the Mt. Simon Sandstone. However, only the glacial drift and the upper formations of the Galena-Platteville dolomites contribute to the calculation of aquifer travel time.

The site area is covered with a mantle of glacial drift consisting mainly of glacial till covered by a few feet of loess (windblown silt). A study of borehole logs at the site indicates that the thickness of the drift averages 16 feet. Due to the generally low permeability and thinness of the till, it is not possible to develop ground water wells by drilling into the drift. The drift is recharged by precipitation. No ground water wells were found to exist within the glacial till, except where surface erosion exposed the bedrock allowing underground springs to occur.

Beneath the thin mantle of drift are dolomites and limestones of the Ordovician-age Galena and Platteville Groups. Borehole logs indicate that the thickness of the Galena-Platteville dolomites at the site range from 100 to 225 feet below the 16 feet of glacial till. The dolomites are extensively fractured near the top 25 to 30 feet, with solutionally enlarged openings in places. These characteristics are not found at the depth where the dolomites become dense.

In the site area, the Galena-Platteville dolomites are recharged by precipitation through the overlying glacial drift and discharge into the Rock River and its associated tributaries and into shallow domestic wells.

Regionally, the Galena-Platteville dolomites are hydraulically continuous with the lower sandstone units of the Cambrian-Ordovician Aquifer. However, in the vicinity of the Byron site, groundwater in the Galena-Platteville dolomites is perched on the Harmony Hill Shale Member of the Glenwood Formation which has low permeability. The low permeability of the Harmony Hill Shale Member was demonstrated by comparing the hydrostatic head relationships measured in observation wells. Thus, the Glenwood Formation serves a hydraulic barrier preventing any contamination of the lower aquifers.

The next series of lower bedrock formations which comprise the regional/site hydrogeologic description supply most all drinking water supplies for municipal uses. As explained previously, these water supply aquifers are hydraulically separated within the site region by the Glenwood Formation.

The Glenwood Formation grades down into the thick sandstones of the St. Peter Sandstone. The

Ordovician-age St. Peter Sandstone is permeable and has a relatively uniform lithology through the area. In the regional area, the St. Peter Sandstone is discharged primarily through wells for small municipalities, subdivisions, parks, and small industrial concerns.

Lower in the stratigraphic column are the Ironton and Galesville Sandstones comprising a portion of the aquifer which is about 150 feet thick in the regional area. In the site area, the Ironton and Galesville Sandstones are about 105 to 115 feet thick. The sandstones are discharged primarily through wells serving various industries and municipalities. The Ironton and Galesville Sandstones are considered the best bedrock aquifer in northern Illinois because of their consistent permeability and thickness. Yields on the order of hundreds of gallons per minute may be obtained from the Ironton and Galesville Sandstones in wells less than 1,000 feet deep.

Below the Ironton and Galesville Sandstones is the Eau Claire Formation, about 405 feet thick. The basal part of the Eau Claire Formation and the underlying Mt. Simon Sandstone (which is about 1,430 feet thick) form the basal Cambrian-age Mt. Simon Aquifer. Wells which terminate in the Mt. Simon Sandstone have yielded many hundreds of gallons per minute.

Thus to summarize, groundwater contamination that might eminate from the Byron Station would only travel through the glacial drift and upper formations of the Galena-Platteville dolomites. The Glenwood Formation would prevent the contamination from reaching the lower bedrock aquifers that serve as the main source of drinking water for the region.

Q.10. Please describe the geologic characteristics of the Byron plant site that influence water movement travel times.

A.10. The Durleith Formation, located within the Galena-Platteville dolomites, is the upper bedrock unit at the site. It provides topographic control and forms the foundation of the power block or safety related structures for the Byron station. Since the Dunleith Formation is the upper bedrock unit, it has been slightly to moderately weathered. Solution activity has occurred along many of the joints, fractures, and bedding planes, and reddish-brown clays or yellow silty sands may be found along these planes.

The Dunleith Formation contains zones of thin green shale partings which are predominant in its lower portions. At the plant location, these shale partings grade in at the base mat elevation of the reactor vessel (approximately 66 below the surface).

During foundation preparation activities for the Byron Plant, 154 borings, ranging in depth from 10 to 350 feet, were drilled. Rock samples were cored from the bedrock using 2-3/4 inch diameter double tube core barrels. Results of the drilling indicate that the Dunleith formation is fractured, jointed, and thin bedded, but there are no large openings along joints and bedding planes. The variation in the quality of bedrock at the plant location results from vertical variations in lithology and the proximity of the boring to principal joints which traverse the site.

Four joint patterns are present in the site. They are: (1) a northwest trending pattern paralleling the regional structural trend; (2) a northeast pattern essentially perpendicular to the regional structure; (3) a north-south pathway transverse to the structure; and (4) an east-west pattern transverse to the structure.

Based on analysis of aerial photography data, the joint patterns have a normal spacing of approximately 200 to 500 feet. Examination of bedrock exposures indicates that these four patterns are detectable below the surface, and that the spacing decreases with depth. Near-surface joint patterns mapped in the plant area are reported in chapter 2.5 of FSAR. Some joints are clean with openings ranging from 1/16 to 1/4 inches. Some joints are clay filled due to in situ weathering and rock solutioning. Examination of outcrops and cores indicate that fracturing and weathering appears to decrease below the Dunleith-Guttenburg Formational contact. Specifically, rock quality measurement values of rock in the Dunleith are always low; whereas in the formations below the Dunleith rock, quality measurement values are higher except near areas of joints. Zones of solution activity, low rock core recovery, and low rock quality measurements have served as channelways for the movement of groundwater, and examination of the rock cores suggest that solution activity has occurred along these channelways.

Because of the dolomite bedrock characteristics, it was decided to fill and seal all major solution enlarged joints, bedding plane, and other planar features of the bedrock by pressure rock cement grouting. The geologic descriptions indicated that grouting of the main plant area down to the Platteville-Ancell contact would significantly retard the downward and horizontal percolation of groundwater, and hence also limit the rate of solution activity.

Q.11. How was the grouting injected into the dolomite bedrock?

A.11. The grouting program consisted of two phases (1) perimeter or curtain grouting and (2) consolidation grouting of the Galena-Platteville bedrock formation to a depth of 225 feet. The objective of the curtain grouting was to establish a horizontal impermeable barrier around the entire perimeter of the Byron Station building foundation by drilling and grouting holes on spacing of 2.5 feet measured center to center. Upon completion of the curtain grouting the second phase of consolidation grouting was started by drilling holes within the building foundation area on an initial grid spacing of 20 feet reducing to a 5 feet grid. In excess of 200,000 cubic feet of concrete grout was used.

Q.12. Was any testing performed to determine the success of the grouting program?

A.12. During the performance of the foundation grouting a detailed grout injection surveillance record was maintained by experienced grouting engineers as a part of the Quality Assurance records. These records, which indicated the areas of major grout consumption, served as the basis for locating grout verification or acceptance borings.

The verification borings were pressure tested and the records were compared to previous values of water pressure testing made during the initial site exploration.

In situ testing of the grouted foundation rock mass verified that the grouting program resulted in making the rock mass significantly more impermeable than it had been prior to grouting. This would greatly restrict the seepage of any accidentally released effluents into the surrounding groundwater environment.

Q.13. Have you performed any field tests designed to determine the water movement characteristics of the Galena-Platteville dolomites aquifer underlying the Byron site?

A.13. Yes. Data from field pumping tests was used to determine the water movement characteristics of the Galena-Platteville dolomites aquifer. These tests were performed in 1974 on wells located on the western edge of the site to determine whether there were significant levels of cyanide in the water drawn from these wells. At the time, we were concerned that well water may have been contaminated due to the existence of a land burial waste dump in the area. It was later believed, during the preparation of the FSAR for Byron, that this data could be used to evaluate the water movement characteristics of the site area. However, I have determined recently that this data is not suitable for determining water movement travel time.

Q.14. Why is the pumping test data unsuitable for determining water movement travel time?

A.14. Pump test data can be used for determining travel time; however, the wells from which the data is derived must first be pumped for a time period con. .stent with the establishment of equilibrium and also have drawdown measured at several locations around the well. The wells that provided the 1974 data were not pumped for the requisite period of time nor were supplemental measurements made away from the well to determine the drawdown effect. Therefore, I believe the data not to be suitable. I should also point out that in checking the data I discovered a typographical error in the reference where the 1974 pump data was reported. The transmissivity valve of 2,000 should have been reported as 20,000. This error is of no significance to my evaluation since I am no longer using the 1974 pump test data to determine travel time.

Q.15. What data are you now using to determine water movement travel time?

A.15. Travel time is principally a function of the permeability of the bedrock, the imposed hydraulic gradient, and the effective porosity of the aquifer. Peizometric level measurements have conclusively established the Galena-Platteville Formation as the only aquifer to be considered in the analysis because an impermeable boundary consisting of the Harmony Hill Member of the Glenwood Formation prevents further downward percolation. The permeability of the aquifer has been established by comprehensive incremental in situ measurements of pressure testing throughout the aquifer thickness. The specific borings tested included P2 through P7, P9, P10, P15A, P22, D23 and several G series borings representative of plant site bedrock. Interpretation of the individual pressure test data and accumulation of the values from representative geologic formations yield an average permeability of 0.52 feet per day.

A hydraulic gradient is simply the slope of the water surface from one point to another within the aquifer. Conservatively, the maximum hydraulic gradient resulting in the shortest travel time, has been established through water level measurements taken in and around the site. For the postulated ruptured tank accident discussed by Mr. Lahti, a maximum water level was assumed at the base of the tank foundation mat (62 feet below the ground surface). The lowest water level measured at the nearest well was used to compute the maximum gradient, that is, 1.861×10^{-2}. Since the nearest well is owned by Commonwealth Edison Company, the hydraulic gradient was also determined for the nearest off-site water source. This water source is a spring along walnut creek and the maximum calculated gradient is equal to 1.1×10^{-2}.

The third significant parameter concerns the effective porosity of the Galena-Platteville aquifer which was determined from geophysical logging techniques used during the site exploration and compared to published values from the Illinois Geologic Survey. Effective porosity was found to vary between 2 and 10 percent.

Based on the foregoing, the travel time of radionuclides from the postulated tank rupture to the nearest well is approximately 30.49 years, thereby allowing time interdictive measures to be taken. The travel time to the spring is approximately 61.7 years.

Q.16. Does the radioactivity in the water leading from the BRH tank become diluted when it mixes with the groundwater underlying the Byron site?

A.16. Yes, the radioactivity concentrations of the various radionulides decrease as they become diluted with the groundwater. I have calculated a dilution factor for Mr. Lahti's use in his evaluation. The value is 2,200.

Q.17. How did you calculate the dilution factor of 2,200?

A.17. A dilution factor may be determined by taking the ratio of the flow of groundwater to the flow of contamination fluids to the ground water body.

The tank rupture accident considered by Mr. Lahti assumes the development of a .1 inch wide crack through the width of the auxiliary building. Under these circumstances the percolation rate through this crack into the aquifer was calculated to be 2.03×10^{-8} cfs per foot of crack (the velocity through the crack is 0.17 feet/day). Based on the groundwater hydraulic gradient and aquifer porosity and thickness, the ground water flow was calculated to be 4.47 10^{-5} cfs per foot of aquifer width assuming uniform mixing with no credit being taken for transverse mixing. The dilution factor is a ratio of the flow through the aquifer to the flow through the crack. Thus, the dilution factor of 2,200 is represented by the following equation:

$$\frac{4.47 \times 10^{-5}}{2.03 \times 10^{-8}} = 2200.$$

Q.18. It has been suggested by Dr. Wood during his deposition that additional methods should be used to characterize the Byron site. Are you aware of Dr. Wood's suggestions?

A.18. Yes. Dr. Wood suggested that field measurements of the hydrologic properties of the dolomite aquifer using pump tests and tracer studies combined wit the development of an appropriate model encompassing the entire site describing the various joint networks from the ground surface down approximately 200 feet to the Glenwood Formation. He further suggested the program be similar to the contaminant migration study made by the Illinois Geologic Survey.

Q.19. Do you agree with these suggestions?

A.19. No.

Q.20. Why not?

A.20. The hydrologic properties of the Byron site have been established through the characterization of hydrogeologic properties using generally accepted geologic techniques that are consistent with NRC guidance, such as Regulatory Guide 1.132. The type of studies and modeling suggested by Dr. Wood are not warranted for the investigation of the Byron site. Moreover, NRC Staff guidance does not suggest the use of such techniques.

In my opinion the characterization of the groundwater system underlying the Byron site has resulted in conservative calculations for groundwater flow velocities, travel times and the location of potential contamination pathways between the site and the nearest water user. Hydrologic data were determined by detailed in situ permeability measurements which were made for the plant site bedrock throughout the entire Galena-Platteville aquifer. Identification of geologic data directly below the station structures including the lithologic, stratigraphic, and structural (jointing) conditions have been described through the interpretation of boring data and mapping of the station excavation.

The jointing system has been identified by detailed geologic mapping of the excavation made for the station structures. It may be determined from these data that the joint systems have clearly finite dimensions. Therefore, the role a jointing system plays in groundwater flow is predicated upon the flow in a given joint and insofar as it intersects other conducting fractures. Thus the permeability of a network of fractures is not simply the sum of the permeability of each fracture as suggested by Dr. Wood. Characterization of a joint system is considered complete when each joint is described in terms of (1) size or effective aperture, (2) orientation, (3) location and (4) size. Exhibit II is a reproduction of the geologic mapping presented in the FSAR in which each of the joints found were characterized.

As previously indicated the hydraulic character of the rock has been identified under the plant site by water pressure testing 10 feet intervals of selected borings. Water pressure testing is conducted by injecting water in isolated portions of the bore hole and measuring the rate of flow through various pump pressures. These data when summarized yield a hydraulic conductivity or permeability accounting for joint aperature, length and size. On the basis of the thorough understanding of the geologic conditions present under the plant site, and the measured hydraulic characteristics it is my opinion the site has been characterized correctly.

With regard to the contaminant study conducted by the Illinois State Geologic Survey (ISGS), the investigation was concerned with a surface or near surface groundwater flow as a result of contamination from uncontrolled dumping of industrial wastes. The ISGS study was directed to measurement of surface flows with it subsequent inflow and recharge to lower shallow dolomite aquifers. Our studies of the rock quality indicate the upper bedrock units are more susceptible to flow since solution and joint openings are more prevalent near the upper bedrock surface. Groundwater flow from the plant site during the postulated accident behaves in a different manner than the flows described in ISGS study for the following reasons:

1. The source of the effluent is stratigraphically lower therefore the jointing aperture is smaller.

2. Near surface groundwater flow is directly controlled by topography; whereas subsurface flows are controlled infiltration and recharge.

The combined effect of near surface flows and varied bedrock conditions preclude the use of contaminant study data for the accidental release postulated at the Byron station.

Q.21. Have you considered the hydrogeologic aspects of a postulated core melt event at Byron?

A.21. For the purpose of addressing concerns raised by the intervenors, we have performed two alternative qualitative evaluations of fluid flow. Using the previously collected hydrogeologic data, the groundwater flow was analyzed in conjunction with the radionuclide release postulated from a reactor core meltdown scenario.

The first evaluation assumed the existence of the hydrogeologic parameters used in performing the boron recycle holdup tank analysis. Initially, only the hydraulic gradient was varied by assuming that the molten core would reach a depth of 20 feet below the reactor basemat foundation. For this accident evaluation, the final position of the core debris would exist 24 feet below the point where the tank effluent would enter the groundwater. No credit for additional impermeability of the rock mass was taken despite the likely creation of ceramic surface due to melting of the shales in the Dunleith foundation bedrock. In addition, no consideration was given to the initial hydraulic gradient reversal that occurs as the molten mass moves below the phreatic surface and flashes the groundwater to steam which is then vented to the containment. The lower effluent egress evaluation for the core melt mixing zone amounts to an 78% reduction in the hydraulic gradient by assuming depletion of the available water at the principal recharge area for the site. The determination of travel time along the postulated pathway of the effluents from the unit one reactor core location to the nearest well is estimated to be approximately 92.7 years.

The second evaluation considers the approach of D. T. Snow as reported in the American Society of Civil Engineers Journal of Soil Mechanics, Foundation Division Volume 94, 1973. Snow's work indicates that, for a rock of given conductivity, the fracture porosity depends on the joint (fracture) spacing and to some extent on aperture widths and joint (fracture) orientations. He also reported that joint porosity decreases with depth approximately logarithmically although certain weathered zones were excluded from the study. For the Byron site, the principal joint systems spacing and patterns have been identified through air photo interpretation and examination of rock outcrops. In addition, 43 comprehensive detailed geologic maps were constructed of the main plant excavations and are reported in the FSAR. Detailed descriptions were provided of the foundation material type; the location, arrangement, attitude and aperture size of all joints and location of fault data. Based upon the (1) measured hydraulic conductivity of the foundation bedrock for both the grouted and ungrouted rock; (2) the closest joint spacing noted during the geologic mapping program; and (3) a corresponding aperture opening, effective porosity was calculated. The effective porosity is 1/2 to as much as 10 times less than porosities determined from in situ water pressure test and geophysical data collected at and adjoining the station site. The calculated reduction in porosity would reduce the effluent flow rate thereby increasing the radionuclide release travel time.

Q.22. Are you aware of any steps which could be taken to reduce the flow of groundwater in the event of a radioactive release?

A.22. Yes. Two possible methods exist. The first method consists of pumping and retrieving contaminated groundwater and storing it for treatment. This can be done by installing multiple groundwater wells at the perimeter of the Station's property that extend down to the Galena-Platteville formation. These wells would be close enough together so that the area the wells influence overlap to create an extensive drawdown of the groundwater and reverse the hydraulic gradient. Groundwater monitoring wells also would be installed down gradient from the spill at varying elevations.

The second method of retarding the flow of contaminated groundwater would involve constructing an impermeable barrier in rock. This could be accomplished through pressure rock cement grouting the entire Galena-Platteville rock formation down gradient from the spill.

AGE (MILLIONS OF YEARS BEFORE PRESENT)	SYSTEM	SERIES	FORMATION	GRAPHIC COLUMN	THICKNESS (FEET)	LITHOLOGY
	QUATERNARY	PLEISTOCENE[1]			0-113	ALLUVIUM, LOESS, TILL
2	ORDOVICIAN	CHAMPLAINIAN[1]	DUNLEITH		29.5-101.0	DOLOMITE, BUFF, MEDIUM GRAINED
430			GUTTENBERG		3.5 - 6.0	DOLOMITE, BUFF, RED SPECKLED
			QUIMBYS MILL		7.0 - 13.0	DOLOMITE, BUFF AND GRAY
			NACHUSA		12.5 - 24.0	DOLOMITE AND LIMESTONE, BUFF
			GRAND DETOUR		30.0 - 46.0	DOLOMITE AND LIMESTONE, GRAY MOTTLING
			MIFFLIN		13.0 - 26.0	DOLOMITE AND LIMESTONE, ORANGE SPECKLED
			PECATONICA		14.5 - 31.0	DOLOMITE, BROWN, FINE GRAINED
			GLENWOOD		18.5 - 37.0	SANDSTONE AND DOLOMITE
			ST. PETER		100 - 600	SANDSTONE, FINE; RUBBLE AT BASE
		CANADIAN	SHAKOPEE[2]		0 - 67	DOLOMITE, SANDY
			NEW RICHMOND[2]		0 - 35	SANDSTONE, DOLOMITIC
			ONEOTA[2]		190 - 250	DOLOMITE, SLIGHTLY SANDY; OOLITIC CHERT
500			GUNTER[1]		0 - 15	SANDSTONE, DOLOMITIC
	CAMBRIAN	CROIXAN	EMINENCE[2]		50 - 150	DOLOMITE, SANDY; OOLITIC CHERT
			POTOSI[2]		90 - 220	DOLOMITE, SLIGHTLY SANDY AT TOP AND BASE, LIGHT GRAY TO LIGHT BROWN; GEODIC QUARTZ
			FRANCONIA		(100)	SANDSTONE, DOLOMITE AND SHALE; GLAUCONITIC
			IRONTON-GALESVILLE		(150)	SANDSTONE, MEDIUM TO FINE GRAINED, DOLOMITIC IN PART
			EAU CLAIRE		(400)	SILTSTONE, SHALE, DOLOMITE, SANDSTONE, GLAUCONITE
			MT. SIMON		(1500)	SANDSTONE, FINE TO COARSE GRAINED
600	PRE-CAMBRIAN					GRANITE AND GRANODIORITE, PINK AND GRAY

NOTES:

1. INDICATES UNITS ENCOUNTERED DURING SITE EXPLORATION.
2. INDICATES PRESENCE OF UNIT NOT VERIFIED AT SITE LOCATION.
3. THICKNESSES IN PARENTHESES ARE INFERRED FROM ISOPACH MAPS AT THE ILLINOIS GEOLOGICAL SURVEY.
4. THE SYMBOL ～～ INDICATES THE PRESENCE OF AN UNCONFORMITY.

REFERENCE:

MODIFIED FROM: BUSCHBACH T.C., 1964, CAMBRIAN AND ORDOVICIAN STRATA OF NORTHEASTERN ILLINOIS: ILLINOIS GEOLOGICAL SURVEY, REPORT OF INVESTIGATIONS 218, p.14.

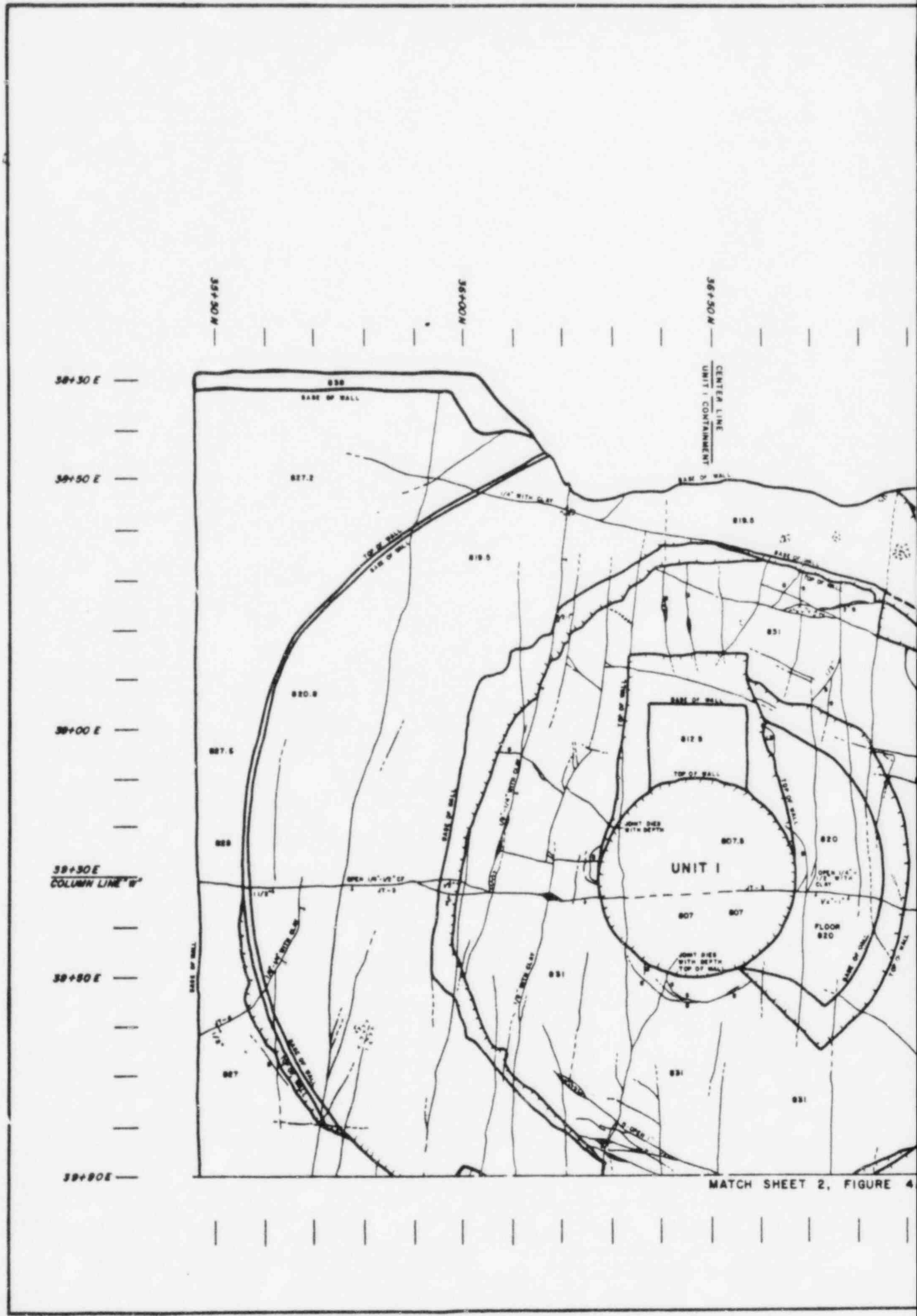
BYRON STATION

FINAL SAFETY ANALYSIS REPORT

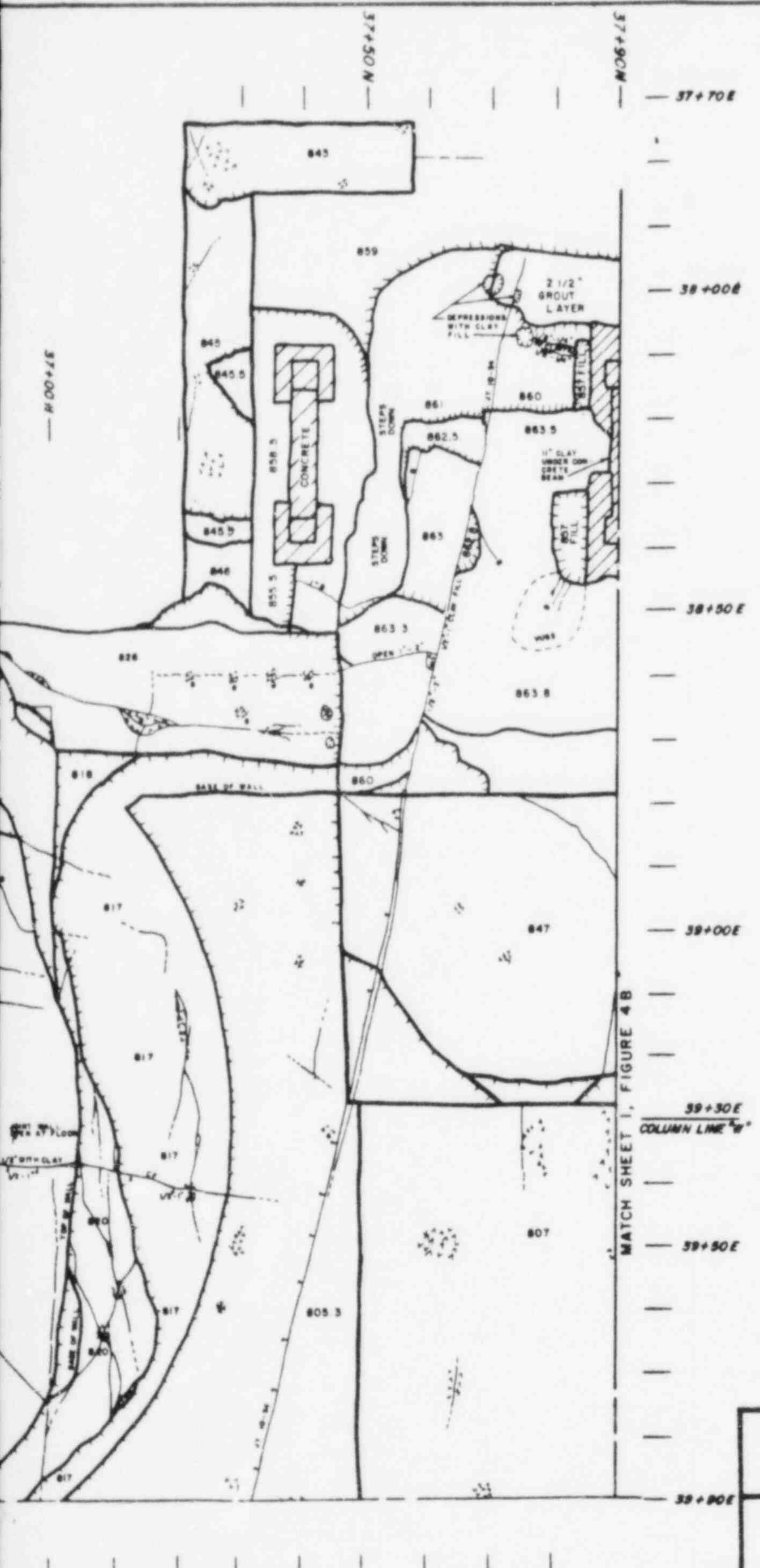
FIGURE 2.5-8

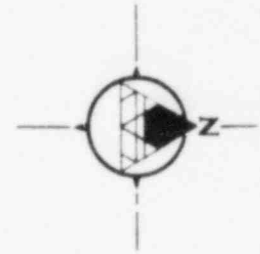
REGIONAL STRATIGRAPHIC COLUMN

Exhibit 1


35+50 N
36+00 N
36+50 N
CENTER LINE
UNIT I CONTAINMENT
38+30 E
38+50 E
39+00 E
39+30 E
COLUMN LINE "B"
39+90 E
BASE OF WALL
TOP OF WALL
827.2
819.5
820.9
827.5
812.5
831
807.5
820
807
FLOOR
820
UNIT I
JOINT DIES WITH DEPTH
MATCH SHEET 2, FIGURE 4

(REV. 1)

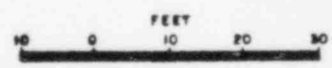




NOTES:

THE LOCATION AT WHICH THIS MAP MATCHES OTHER MAPS IS SHOWN ON FIGURE 2.5D-1 AREAS OF FLOOR MAPPING - MAIN EXCAVATION.

REFER TO FIGURE 2.5D-4 FOR EXPLANATION OF MAP SYMBOLS.



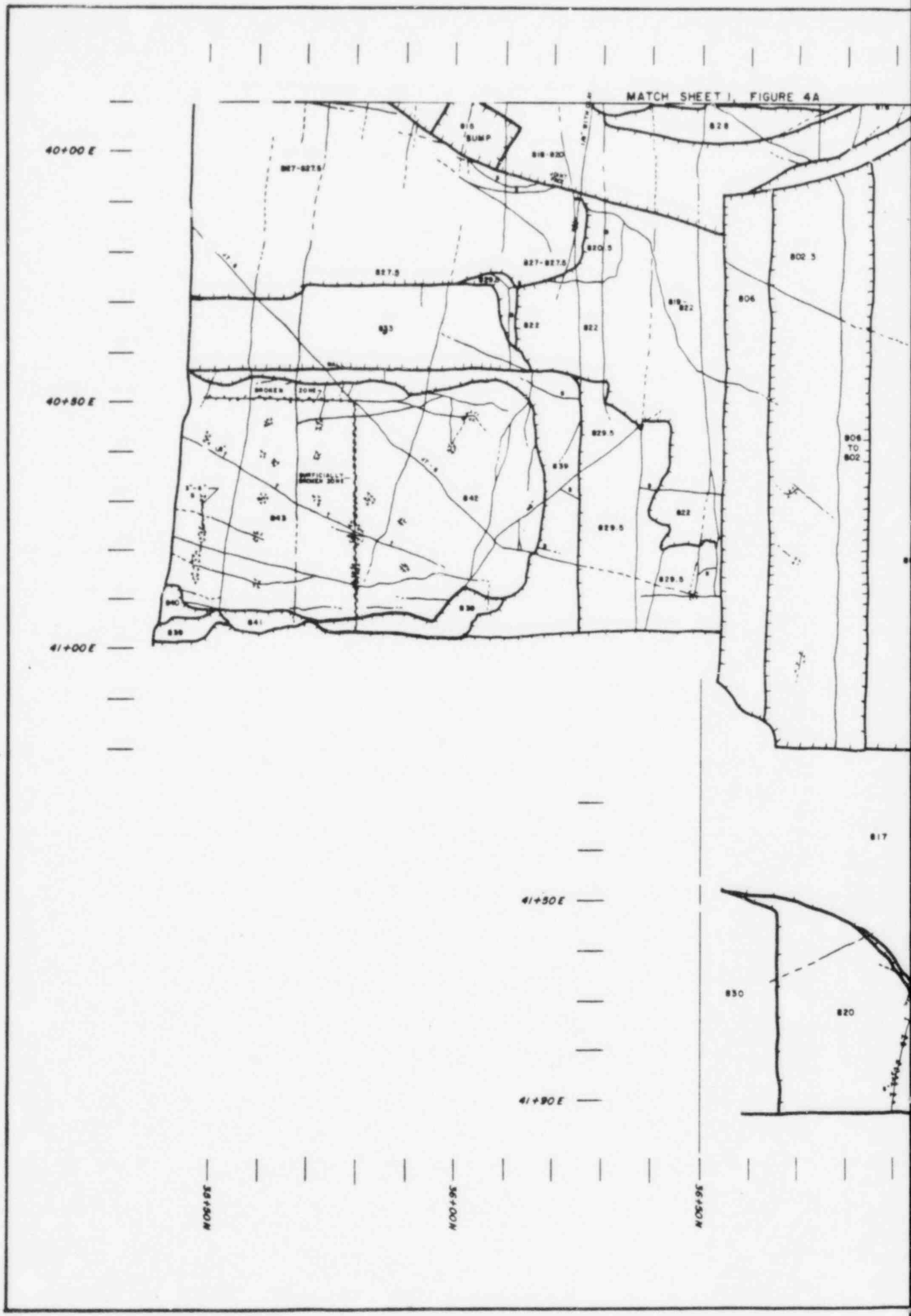
BYRON STATION

FINAL SAFETY ANALYSIS REPORT

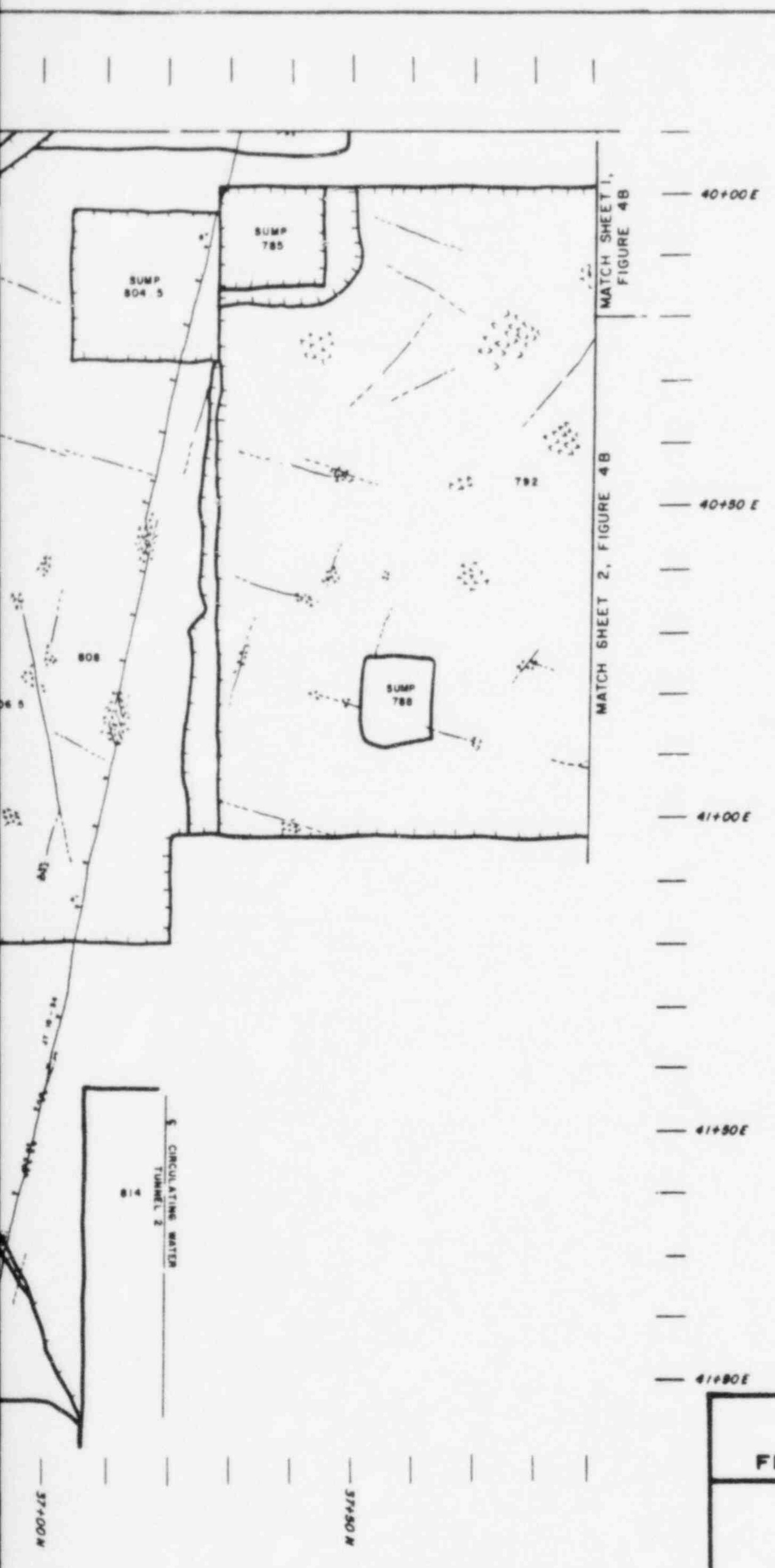
FIGURE 2.5D-5

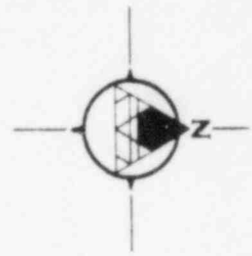
UNIT 1 - FLOOR MAP

(SHEET 1 of 2)



MATCH SHEET 1, FIGURE 4A
40+00 E
40+50 E
41+00 E
41+50 E
41+90 E
35+50N
36+00N
36+50N
SUMP
827-827.5
827.5
827-827.5
820.5
802.5
806
822
822
833
BROKEN ZONE
806 TO 802
829.5
839
842
843
822
829.5
829.5
841
840
839
817
830
820

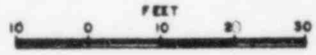




NOTES

THE LOCATION AT WHICH THIS MAP MATCHES OTHER MAPS IS SHOWN ON FIGURE 2.5D-1 AREAS OF FLOOR MAPPING - MAIN EXCAVATION.

REFER TO FIGURE 2.5D-4 FOR EXPLANATION OF MAP SYMBOLS.



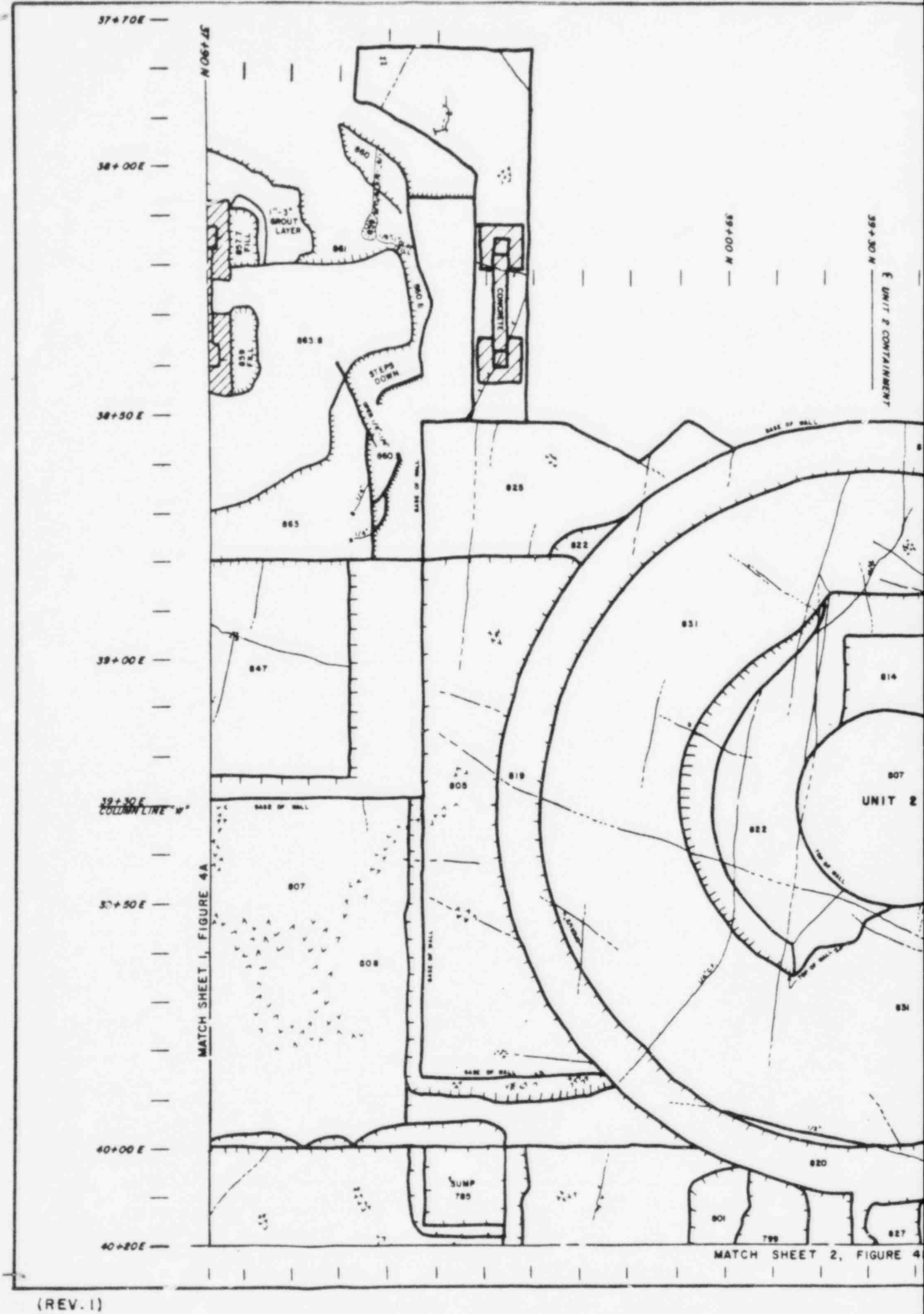
BYRON STATION

FINAL SAFETY ANALYSIS REPORT

FIGURE 2.5D-5

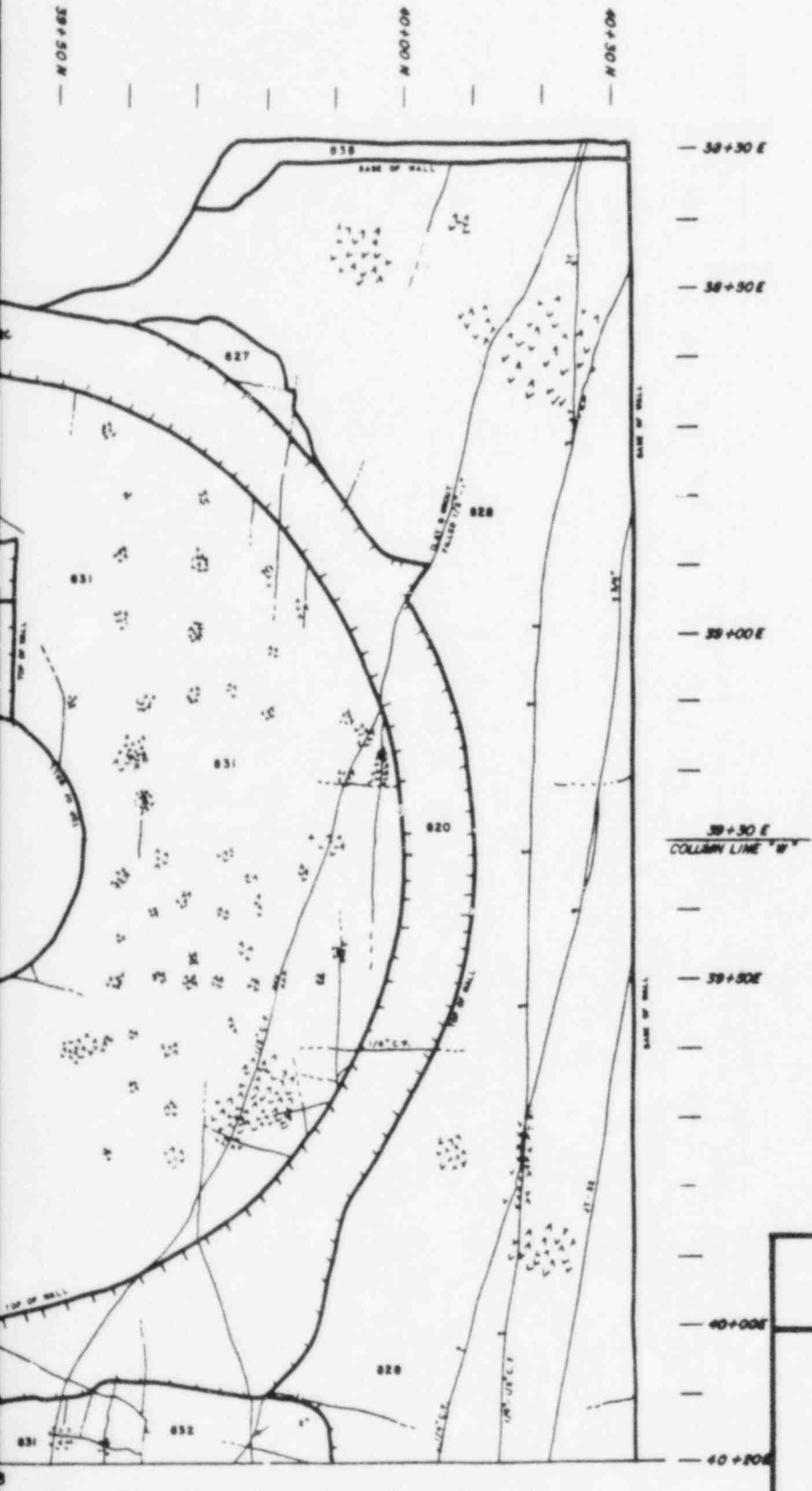
UNIT 1 - FLOOR MAP

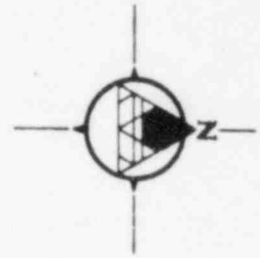
(SHEET 2 of 2)



37+70E
38+00E
38+50E
39+00E
39+30E
COLUMN LINE "M"
39+50E
40+00E
40+20E
37+90N
39+00N
39+30N
℄ UNIT 2 CONTAINMENT
GROUT LAYER
FILL
CONCRETE
STEPS DOWN
BASE OF WALL
SUMP
785
UNIT 2
MATCH SHEET 1, FIGURE 4A
MATCH SHEET 2, FIGURE 4

(REV. 1)





NOTES:

THE LOCATION AT WHICH THIS MAP MATCHES OTHER MAPS IS SHOWN ON FIGURE 2.5D-1 AREAS OF FLOOR MAPPING - MAIN EXCAVATION.

REFER TO FIGURE 2.5D-4 FOR EXPLANATION OF MAP SYMBOLS.

FEET
10 0 10 20 30

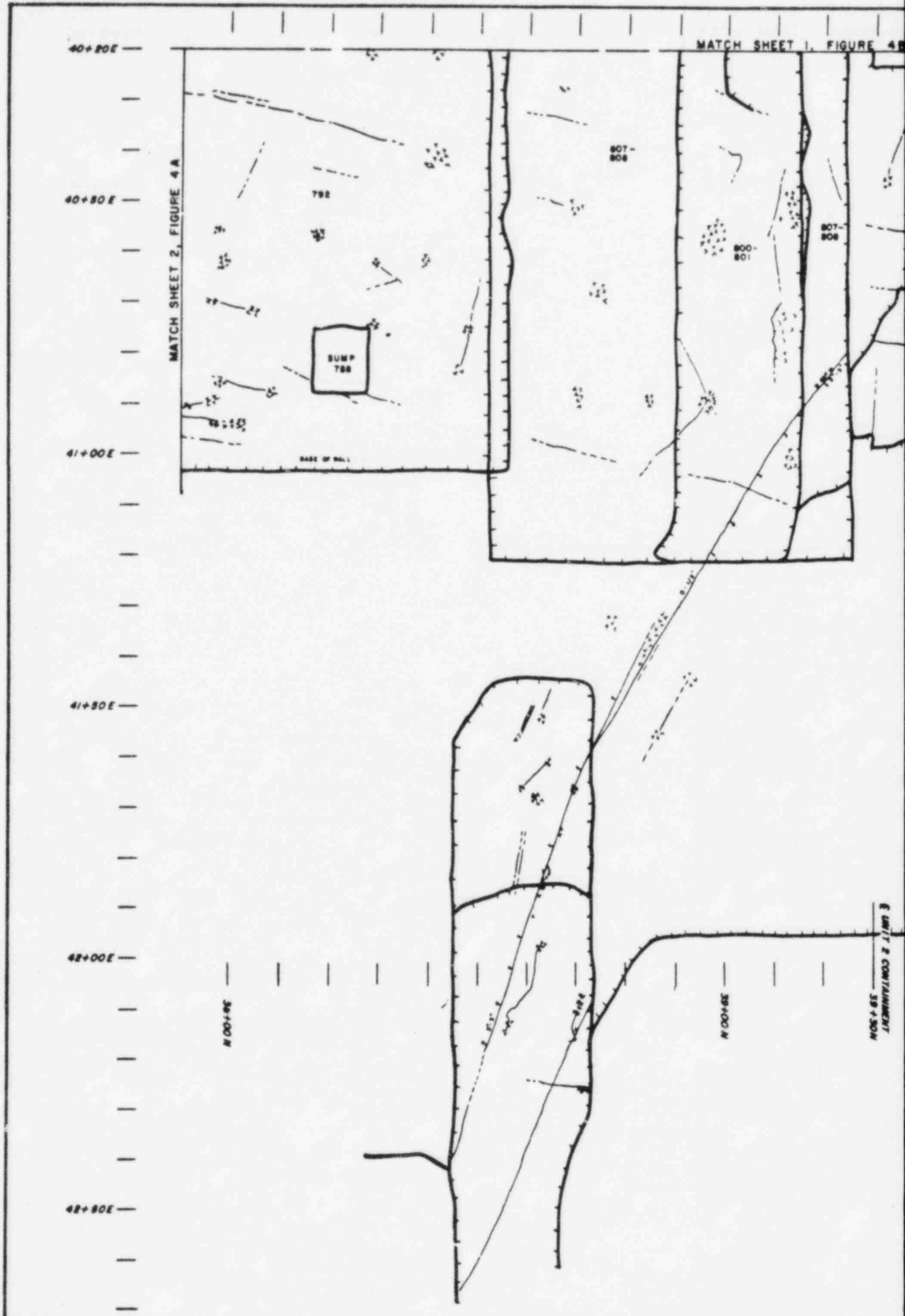
BYRON STATION

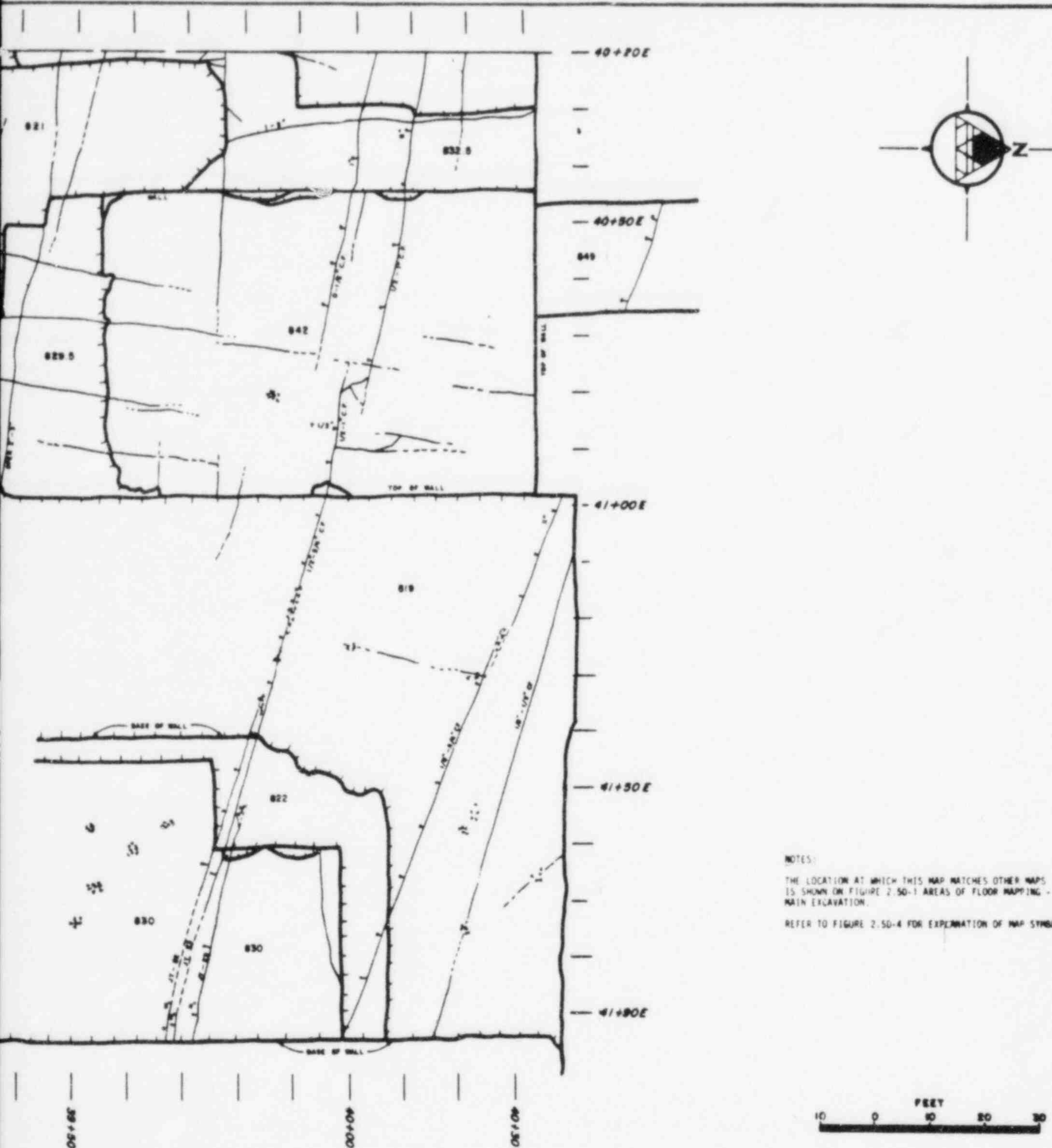
FINAL SAFETY ANALYSIS REPORT

FIGURE 2.5D-6

UNIT 2 - FLOOR MAP

(SHEET 1 of 2)


MATCH SHEET 1, FIGURE 4B
MATCH SHEET 2, FIGURE 4A
40+20E
40+50E
41+00E
41+50E
42+00E
42+50E
792
SUMP 788
BASE OF WALL
807-808
800-801
38+00 N
39+00 N
℄ UNIT 2 CONTAINMENT 39+30N



NOTES:

THE LOCATION AT WHICH THIS MAP MATCHES OTHER MAPS IS SHOWN ON FIGURE 2.5D-1 AREAS OF FLOOR MAPPING - MAIN EXCAVATION.

REFER TO FIGURE 2.5D-4 FOR EXPLANATION OF MAP SYMBOLS.

BYRON STATION

FINAL SAFETY ANALYSIS REPORT

FIGURE 2.5D-6

UNIT 2 - FLOOR MAP

(SHEET 2 of 2)