UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

NOVEMBER 1 1 1983

MEMORANDUM FOR: James G. Keppler
Regional Administrator
Region III

FROM: Darrell G. Eisenhut, Director
Division of Licensing, NRR

SUBJECT: SUPPORT FOR MIDLAND PLANT UNDERPINNING EVALUATION

In response to your request, a contract is now in place with Franklin Research Center (FRC) to provide technical assistance for the Midland plant underpinning and remedial soils work review. The purpose of this memorandum is to explain the plan for communications among the various parties involved in providing this technical assistance.

The objectives of the contractural effort are to provide technical assistance (1) for review of the remedial soils work at Midland, and (2) for the evaluation of design changes to the approved underpinning plans and their effects on structural adequacy. The contractor's work will, to a large extent, provide the technical basis for associated SSERs. To accomplish these objectives, a team of engineers from the Franklin Research Center (FRC) and its subcontractor, Geotechnical Engineers, Inc. (GEI), has been organized. The contractor's deliverables are trip reports for all travel and technical evaluation reports to support these objectives.

The enclosed chart illustrates the desired lines of communication among the contractor and subcontractor, NRR Offices, and your staff. Because of the need for DL and DE to be fully cognizant of actions on Midland and their status, all technical communications are, at least initially, to be through or coordinated with J. Kane, SGEB (or D. Hood, LB#4, if Mr. Kane is unavailable). As the project evolves, we expect that working arrangements will be agreed upon which will allow less formal communication procedures with the contractor. However, any requests which could change the scope of work, project costs, or schedules, or which require contractor travel must be processed through TAPMG, DL, and the contract Project Officer, M. Carrington.

Contact:
M. Carrington, DL
492-8460

NOV 2 1 1983

8312020060 XA

If you have any questions on these procedures or their purposes, please call Jack Donohew, Acting Chief, TAPMG, on FTS 492-7230.

for Darrell G. Eisenhut, Director
Division of Licensing

Enclosure:
As stated

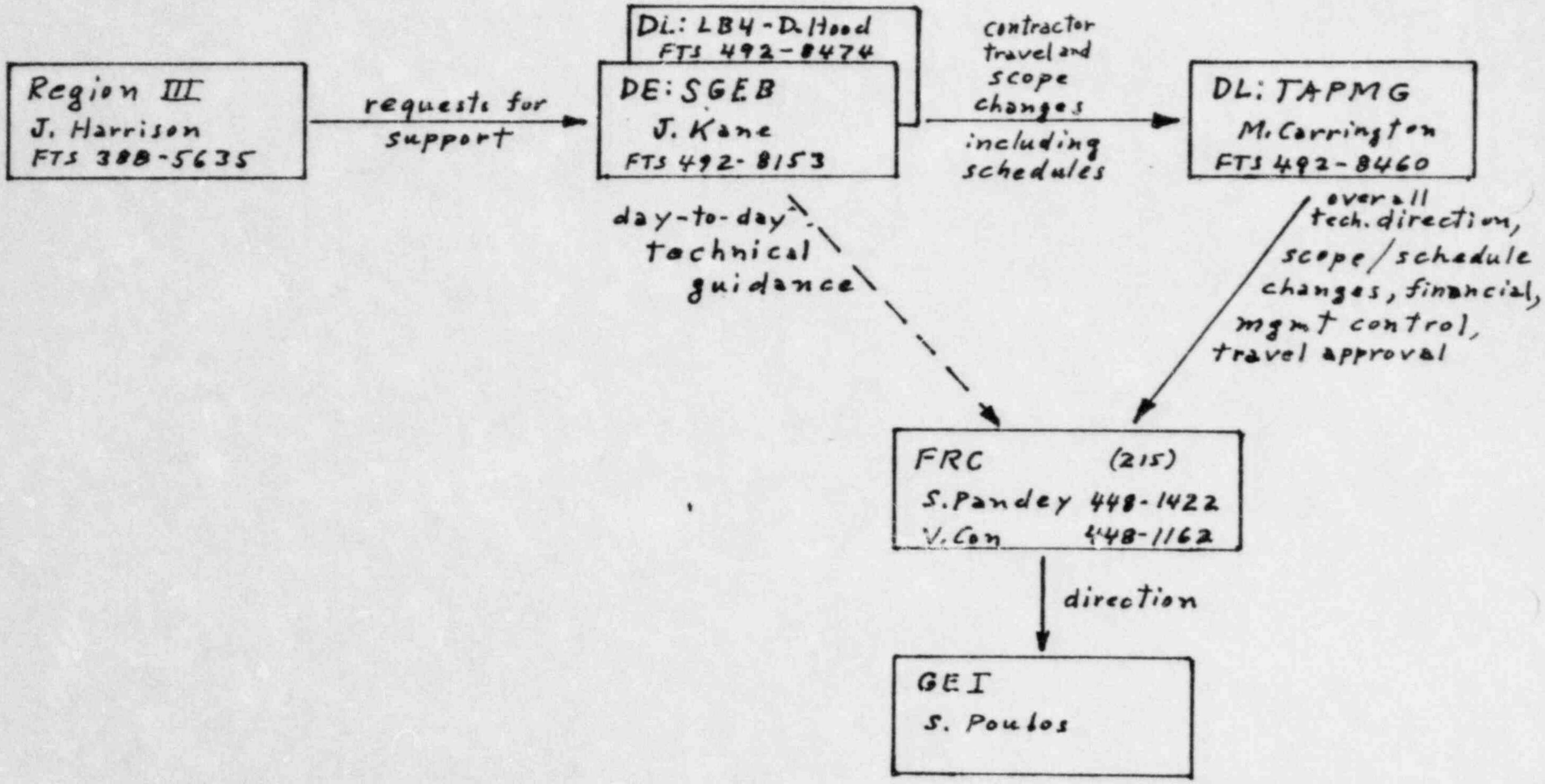
cc w/enclosure:
R. Vollmer
J. Knight
G. Lear
L. Heller
J. Kane
T. Novak
E. Adensam
D. Hood
F. Miraglia
J. Donohew
M. Carrington

MIDLAND PROJECT - EVALUATION OF UNDERPINNING

COMMUNICATION PLAN

Division of Licensing

November 1983



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

(2) DGB File

PRINCIPAL STAFF			
D/	fu		
D/			
A/			
RC			
PAO			mg 3
SGA			
ENF		File	fu

November 1, 1983

Docket Nos: 50-329 OM, OL
and 50-330 OM, OL

APPLICANT: Consumers Power Company

FACILITY: Midland, Units 1 and 2

SUBJECT: SUMMARY OF TASK FORCE VISIT ON THE MIDLAND DIESEL GENERATOR BUILDING

On August 24 and 25, 1983, a task force consisting of NRC staff and its consultants from Brookhaven National Laboratory, visited Ann Arbor and the Midland site to obtain information related to rereview of the diesel generator building (DGB). The participants are listed in Enclosure 1.

The August 24, 1983, meeting was held in Ann Arbor and provided background information to the task force. Consumers and Bechtel representatives discussed design and construction of the DGB including the building's settlement. The remedial program was explained with detailed discussion of the surcharge, dewatering, and settlement monitoring efforts. The final meeting topic was the structural reanalysis performed on the DGB, particularly including details of the finite element analysis. CPCo consultants addressed cracking effects and concluded that the DGB cracks have no effect on the strength of the building. The agenda and meeting slides are provided as Enclosures 2 and 3, respectively. The Diesel Generator Building Executive Summary, distributed at the meeting, is included as Enclosure 4.

Late August 24, and August 25 was spent viewing the actual cracks in the building. Also, the applicant's crack maps were used by the task force to better see the crack pattern of the building.

Melanie A. Miller

Melanie A. Miller, Project Manager
Licensing Branch No. 4
Division of Licensing

Enclosures:
As stated

cc: See next page

NOV 9 1983

~~8311100111~~

MIDLAND

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c/o Mr. Max Clausen
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NRC Assistance Project
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Billie Pirner Garde
Director, Citizens Clinic
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Government Accountability Project
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TERA Corporation
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Ms. Lynne Bernabei
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Supplemental page to the Midland OM, OL Service List

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Geotechnical Engineers, Inc.
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1017 Main Street
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Enclosure 1

PARTICIPANTS

DGB TASK FORCE

AUGUST 24 AND 25, 1983

NRC

P. T. Kuo*
M. Miller*

Brookhaven

A. Philippacopoulos*
C. Miller*
C. Costantino*
M. Reich*

Structural Mechanics Assoc.

R. Kennedy

Portland Cement Assoc.

G. Corley

TERA Corp.

H. Levin
J. Martore

Consumers

J. Schaub*
J. Mooney*
T. Thiruvengadam
K. Razdam
N. Ramanujam
E. Koepke*
F. Villalta
D. Budzik
M. Capicchioni**

Bechtel

N. Swanberg
M. Sozen
P. Shunmugavel
S. Afifi
T. Kumbier
D. Reeves
C. Dirnbauer
B. McConnell
D. Nims
G. Tuveson

*Attended both meeting and site visit
**Attended site visit only

Enclosure 2

AGENDA

NRC PRESENTATION ON DIESEL GENERATOR BUILDING
August 24, 1983
Ann Arbor, Michigan

I. Background

   A. Site Plan

   B. Construction Milestones

   C. General Layout of Diesel Generator Building

   D. Original Design

II. Diesel Generator Building Construction History

   A. Construction Sequence

   B. Building Settlement

III. Remedial Program

   A. Boring Program

   B. Surcharge Program

   C. Results of Remedial Program

IV. Structural Reanalysis

   A. Analytical Techniques

   B. Settlement Input

   C. Imposed Loadings

   D. Analytical Results

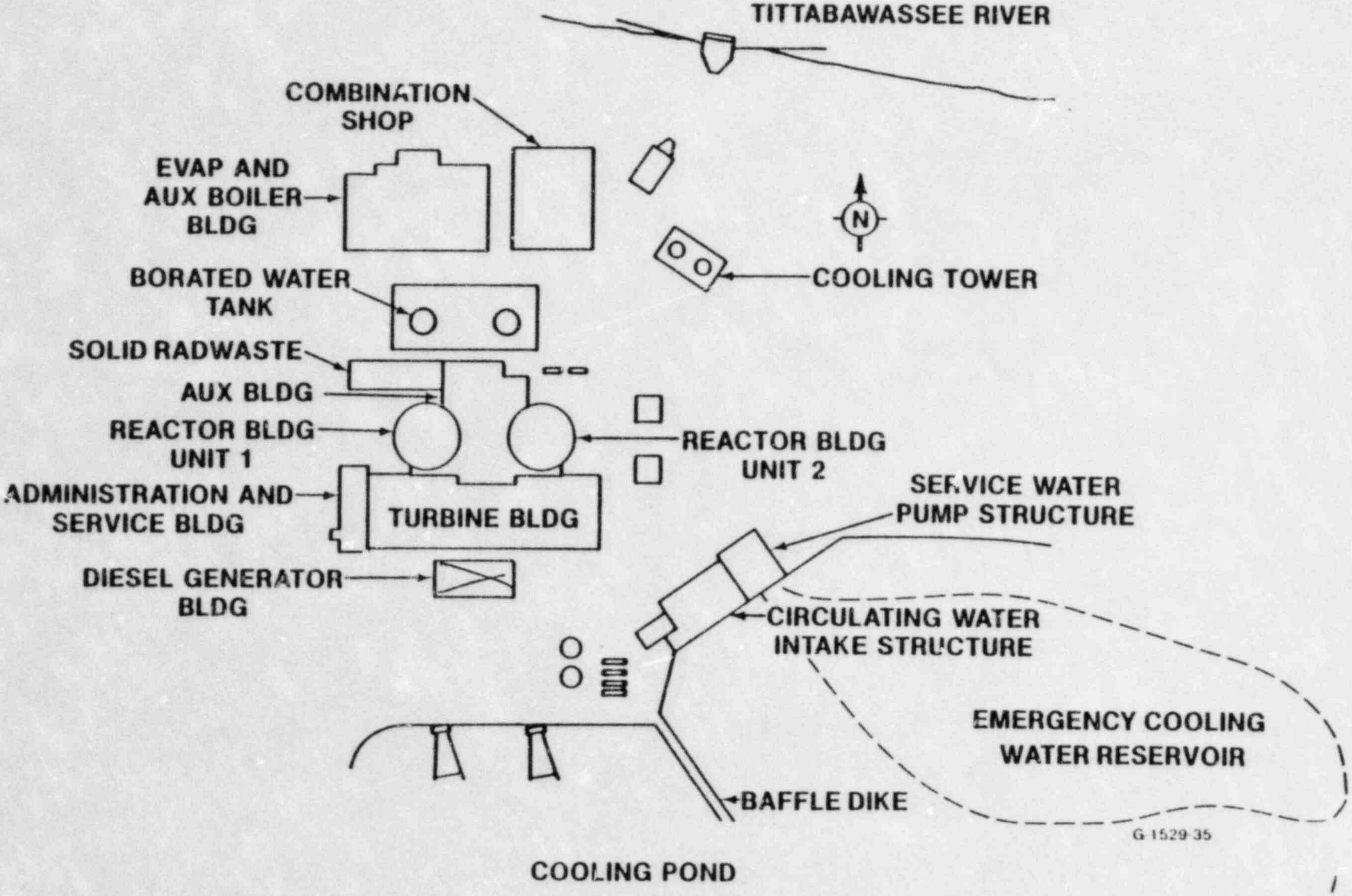
   E. Effects of Cracking

   F. Seismic Margin Review

V. Summary

ENCLOSURE 3

MIDLAND SITE PLAN



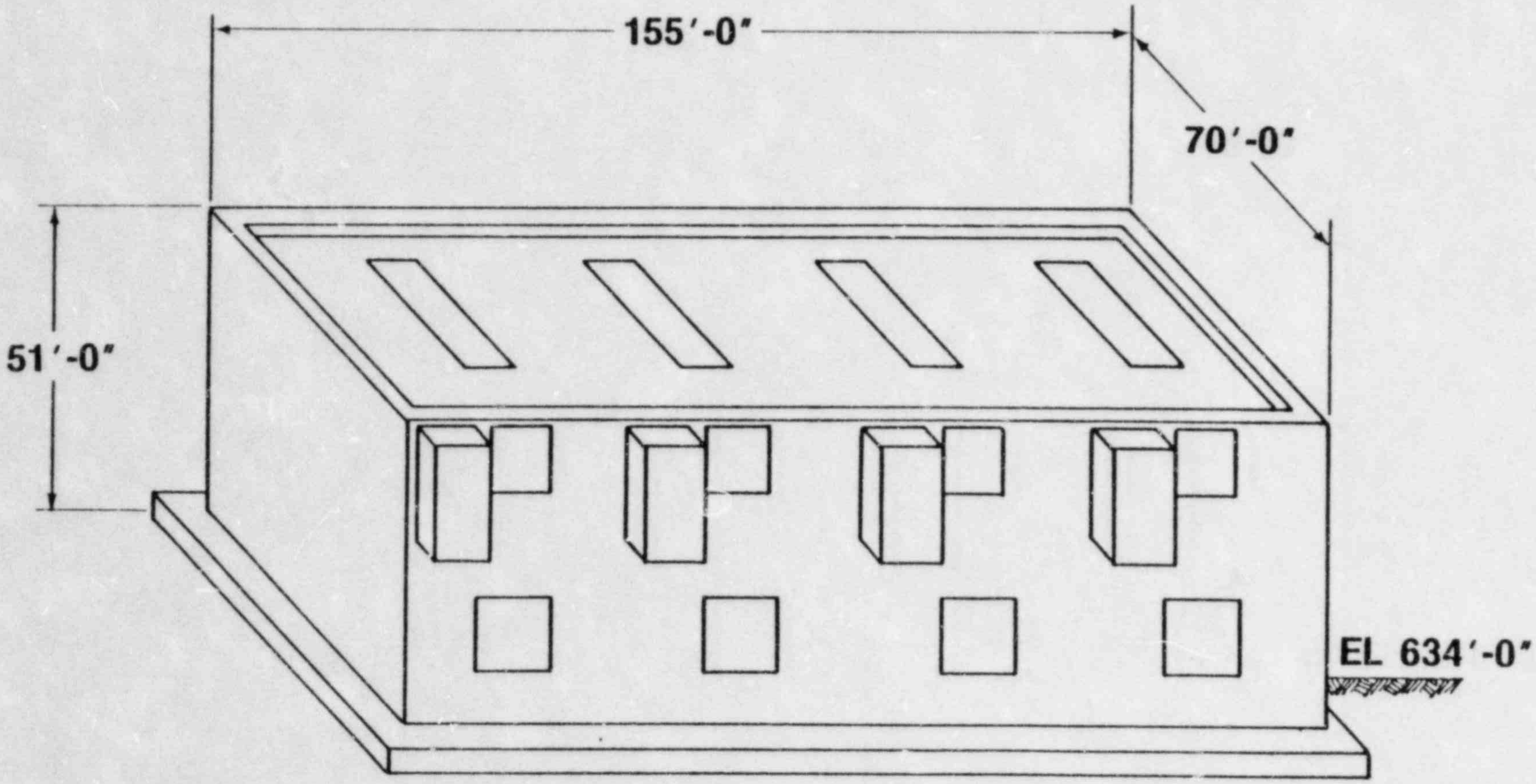
DIESEL GENERATOR BUILDING

- FOUNDED ON 30-FEET OF FILL
- FILL PLACEMENT FROM 1975 TO 1977
- CONSTRUCTION FROM SUMMER 1977 TO SPRING 1979

Tittabawassee 595

elevation of cooling pond 627
?

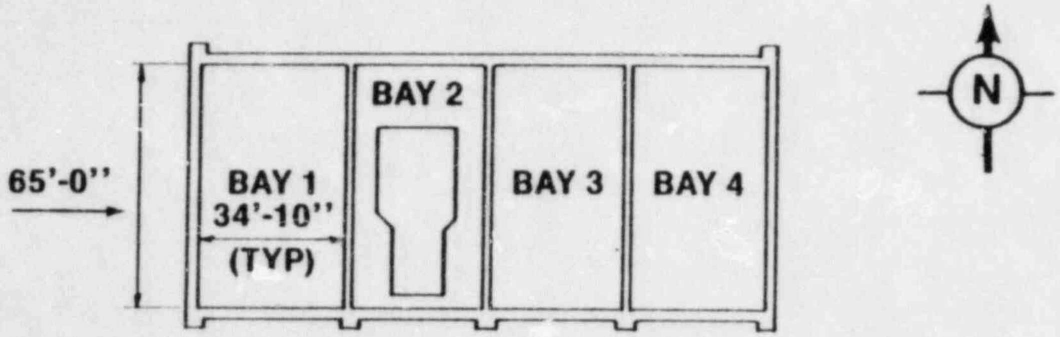
DIESEL GENERATOR BUILDING



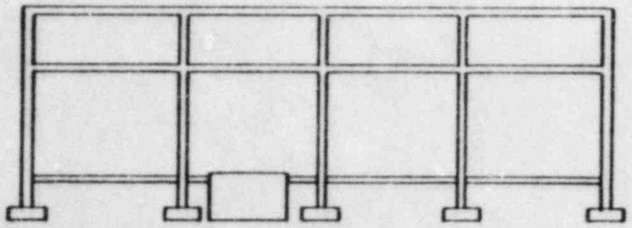
MIDLAND UNITS 1 AND 2
AUGUST 1983

30-G-3063-01

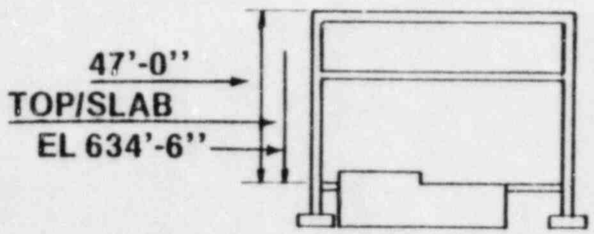
DIESEL GENERATOR BUILDING



PLAN



SECTION (Looking North)



SECTION (Looking West)

G-1534 59

DIESEL GENERATOR BUILDING
SIZE

- LENGTH = 155'-0'' (outside face to outside face of walls)
- WIDTH = 70'-0'' (same)
- HEIGHT = 47'-6'' (above grade)
  = 51'-0'' (above top of foundation)
- EXTERIOR WALL THICKNESS = 30''
- INTERIOR WALL THICKNESS = 18''
- ROOF THICKNESS (slab) = 18''
- FLOOR THICKNESS (slab) = 21''
- FOUNDATION THICKNESS = 30''

G-1530-06

DIESEL GENERATOR BUILDING
MATERIALS

- CONCRETE STRENGTH

  f_c' = 4,000 psi (walls, foundation, and floor)
  = 5,000 psi (roof)

- REINFORCING STEEL STRENGTH

  f_y = 60,000 psi

- STRUCTURAL STEEL — ASTM A 36

G-1530-07

6

DIESEL GENERATOR BUILDING

CODES AND STANDARDS

- AMERICAN CONCRETE INSTITUTE ACI-318, 1971 CODE

- AMERICAN INSTITUTE OF STEEL CONSTRUCTION, AISC 1969 EDITION

G-1530-08

DIESEL GENERATOR BUILDING
LOADS

- NORMAL OPERATION
  - Concrete

    U = 1.4D + 1.7L
    U = 1.25 (D + L + E)
    U = 1.25 (D + L + W)
    U = 1.4 (D + L + E) (for shear wall only)
    U = 0.9D + 1.25E
    U = 0.9D + 1.25W
  - Structural Steel

    D + L
    D + L + E
    D + L + W

DIESEL GENERATOR BUILDING
LOADS (cont'd)

- ACCIDENT CONDITIONS
  - Concrete
    $U = 1.0 (D + L + E')$
    $U = 1.0 (D + L + W')$
  - Structural Steel
    $D + L + E'$
    $D + L + W'$

Tornado wind loads include missile effects when applicable

G 1530 10

DIESEL GENERATOR BUILDING
TORNADO ANALYSIS

- V_M = 360 MPH
- R_M 150′-0″
- VELOCITY PRESSURE = 332 PSF
- DIFFERENTIAL BURSTING PRESSURE = 3 PSI = 432 PSF

DIESEL GENERATOR BUILDING

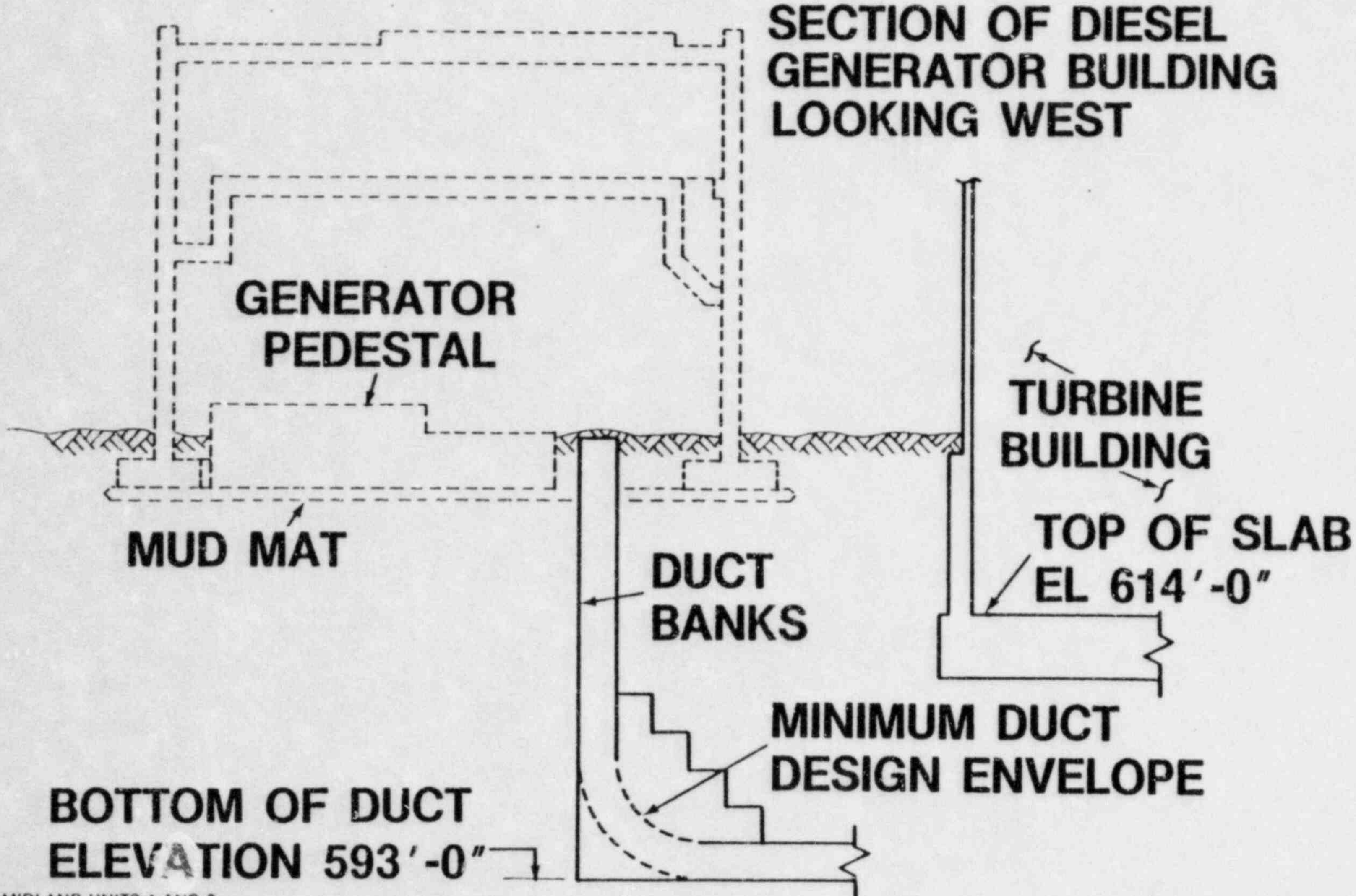
ANALYSIS TECHNIQUE

- WALLS
  - North Wall
    - Computer analysis
    - Plate analysis
  - All Other Walls
    - Moment distribution
    - Plate analysis
- FLOOR AND ROOF
  - Moment Distribution - Slab on Steel Beams
  - Plate Analysis (roof only)
- GROUND SLAB
  - Computer Analysis, Finite Element Method
- DIESEL GENERATOR FOUNDATION
  - Manual Analysis
- BUILDING FOUNDATIONS
  - Statics and Moment Distribution

G 1530-13

DIESEL GENERATOR BUILDING

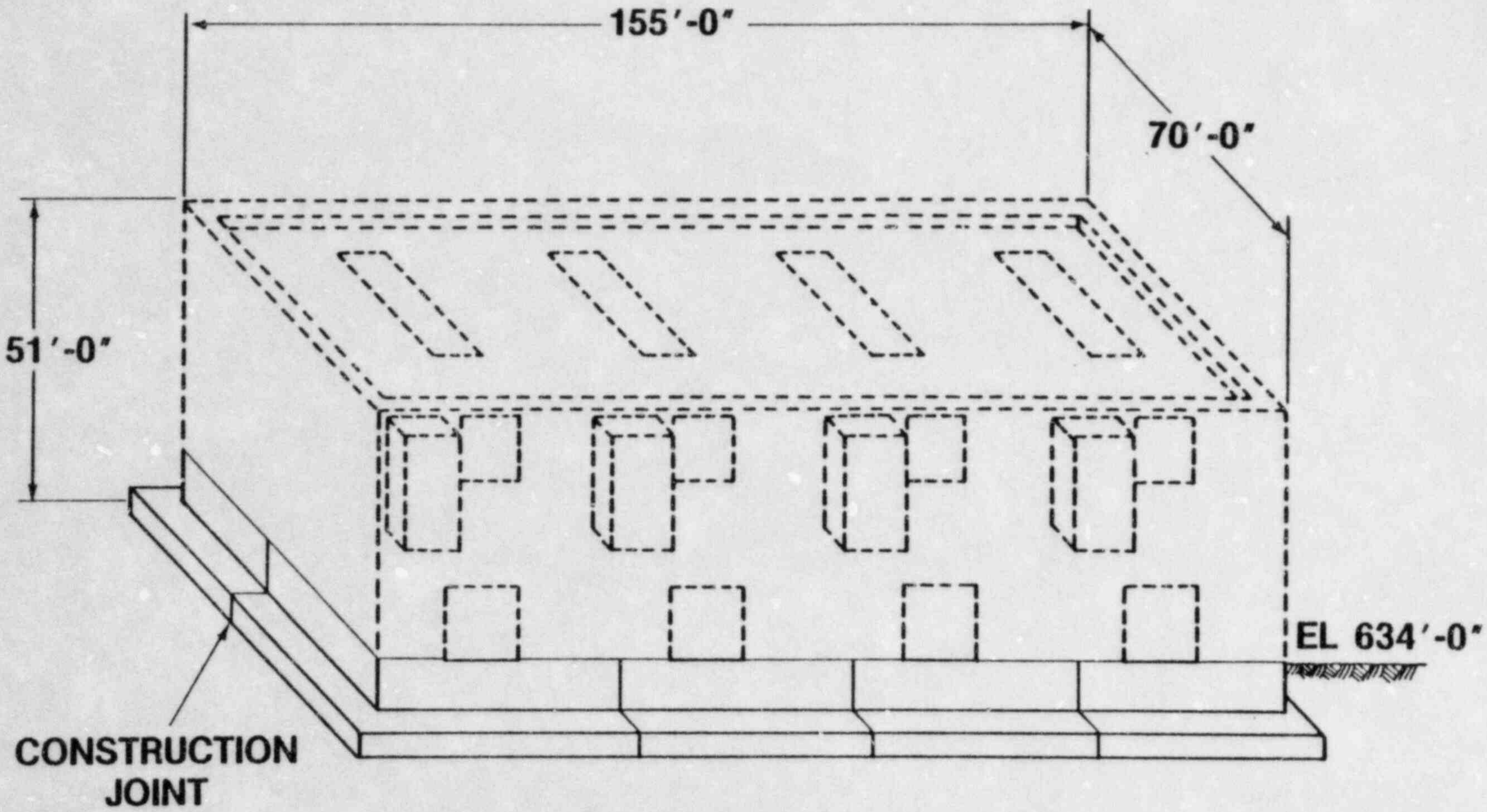
DUCT BANK ELEVATION



MIDLAND UNITS 1 AND 2
AUGUST 1983

30-G-3063-04

DIESEL GENERATOR BUILDING



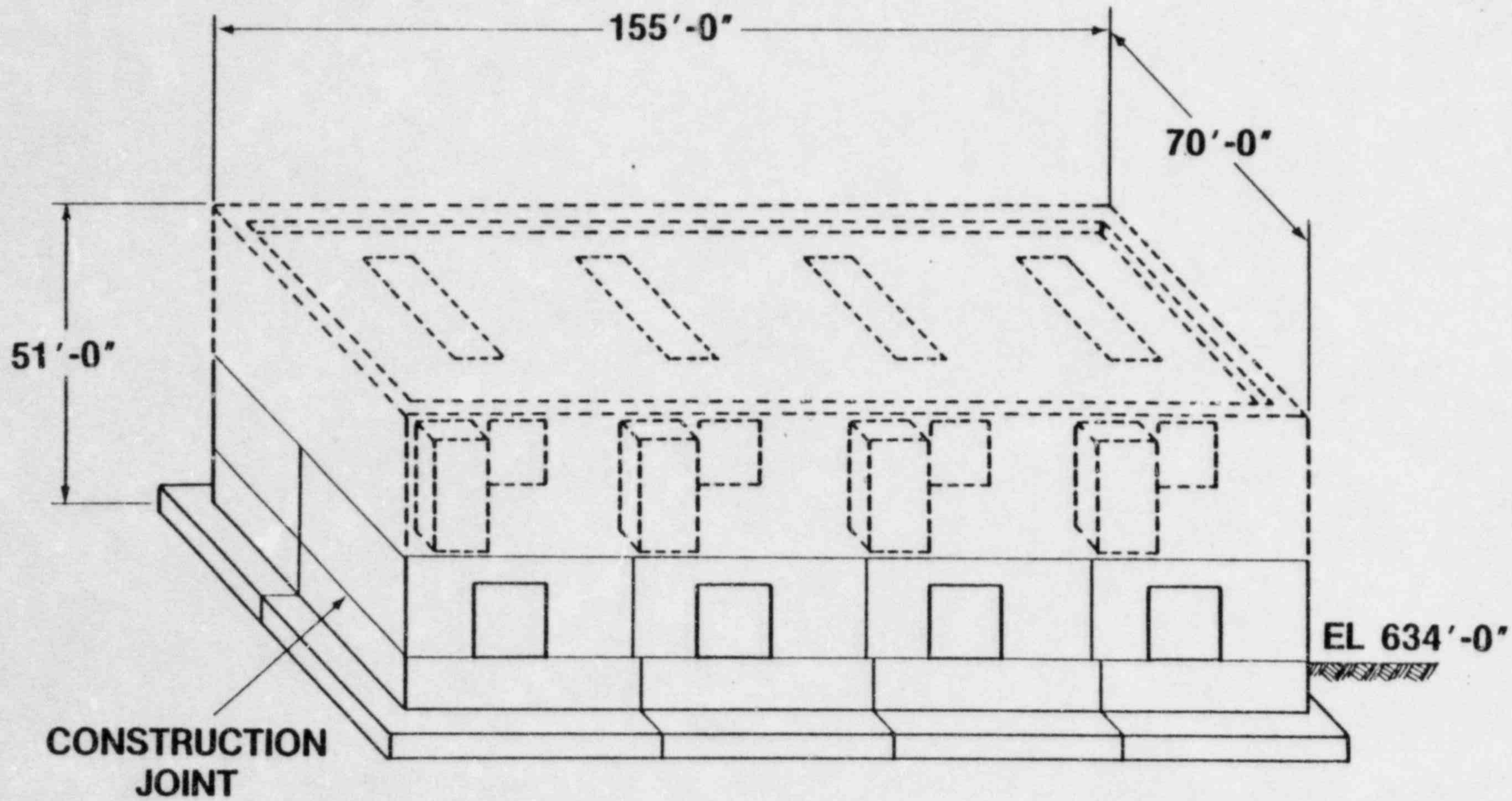
FEBRUARY 1978

MIDLAND UNITS 1 AND 2
AUGUST 1983

30-G-3063-05

13

DIESEL GENERATOR BUILDING



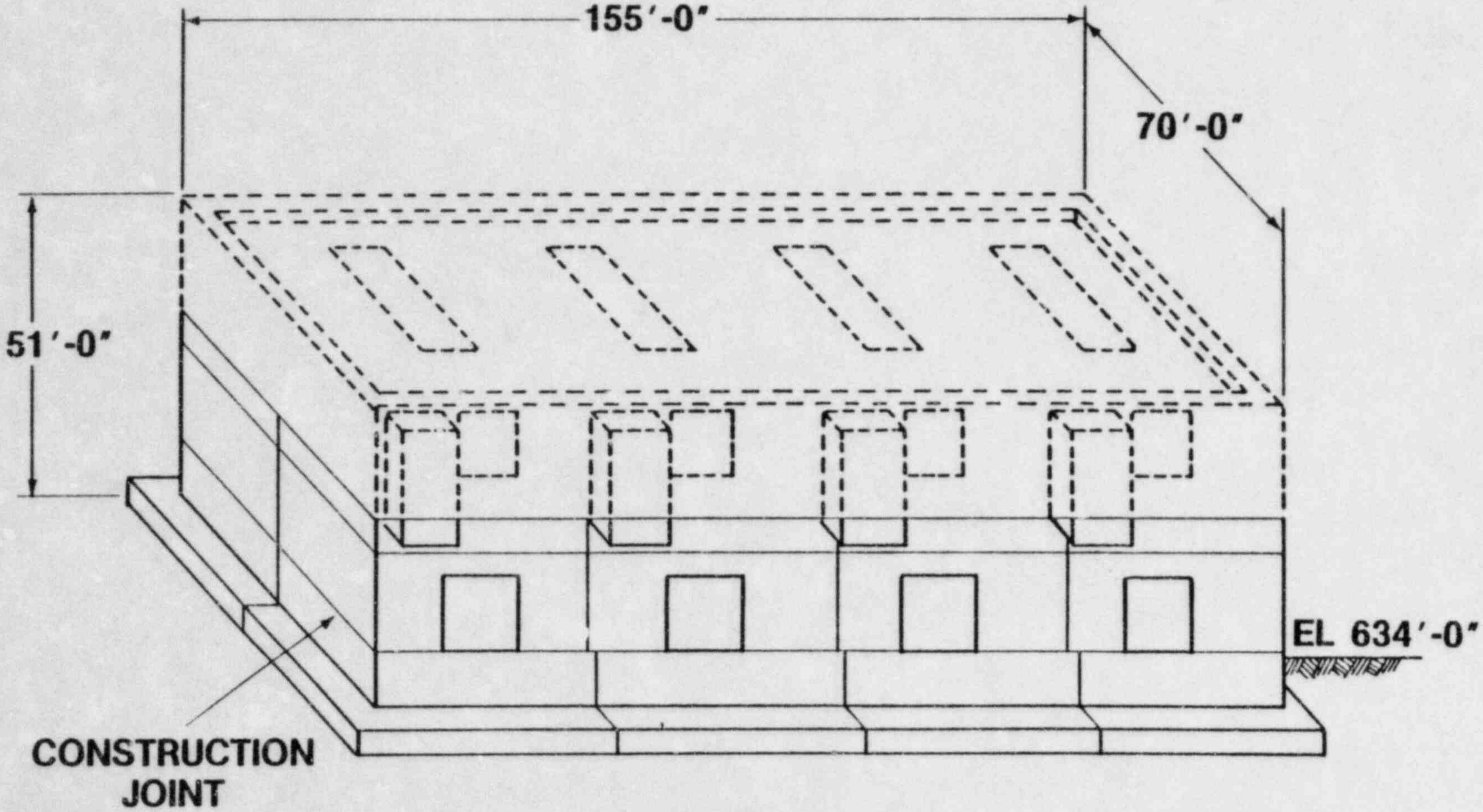
APRIL 1978

MIDLAND UNITS 1 AND 2
AUGUST 1983

30-G-3063-06

14

DIESEL GENERATOR BUILDING

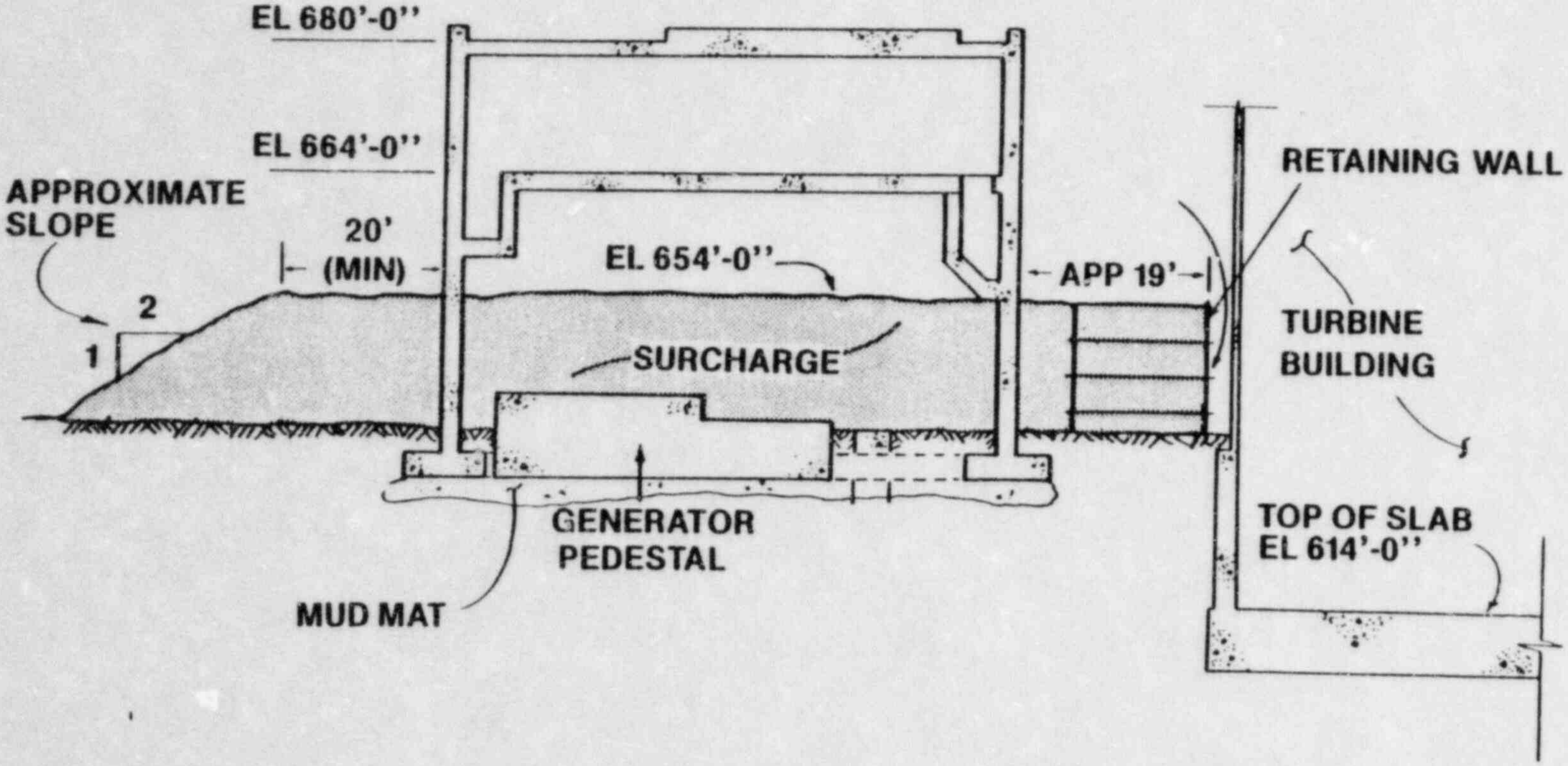


AUGUST 1978

MIDLAND UNITS 1 AND 2
AUGUST 1983

30-G-3063-07

DIESEL GENERATOR BUILDING

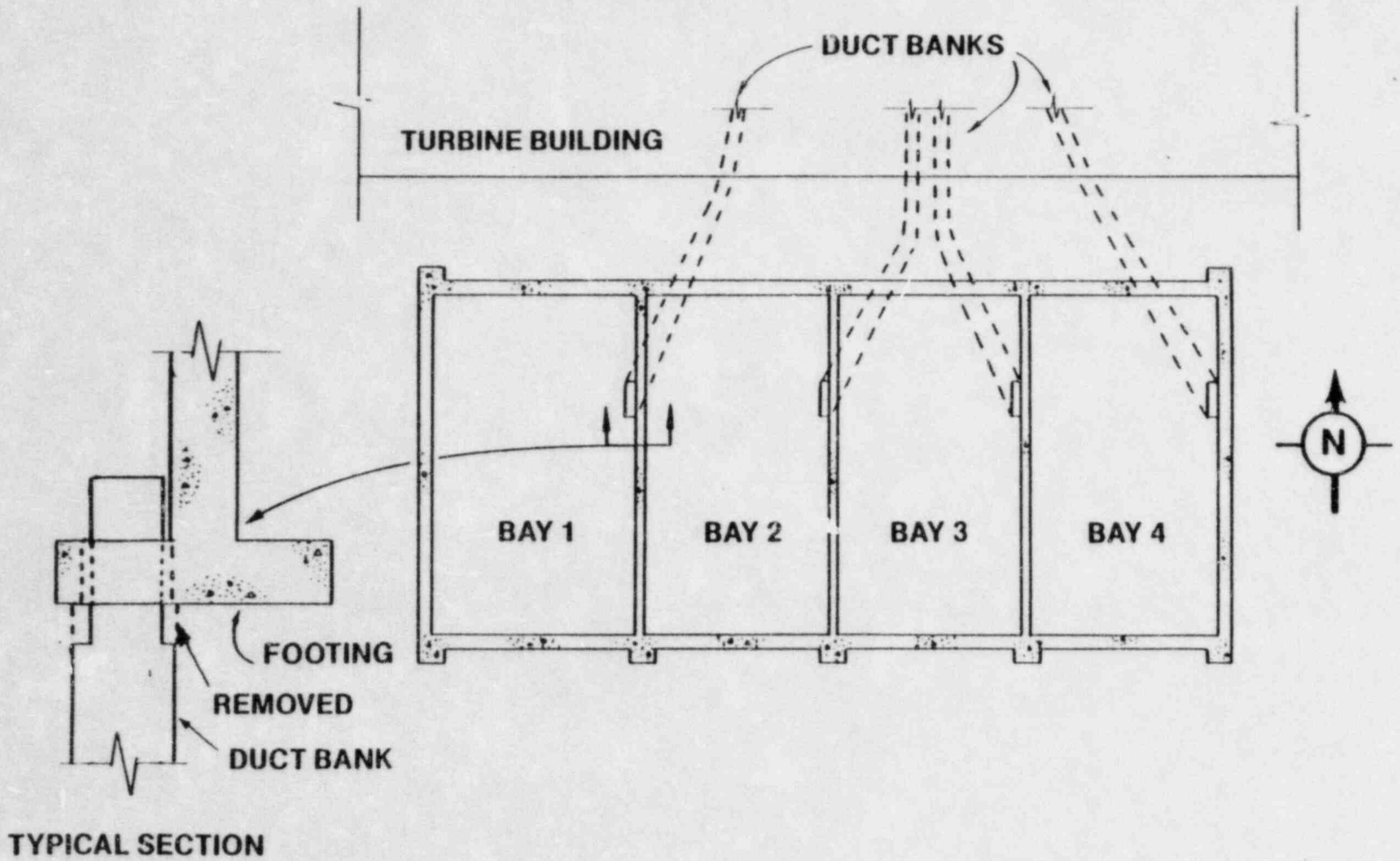


MIDLAND UNITS 1 AND 2
DIESEL GENERATOR BUILDING 2/3/82

G-1948-10

16

DIESEL GENERATOR BUILDING
DUCT BANK LAYOUT

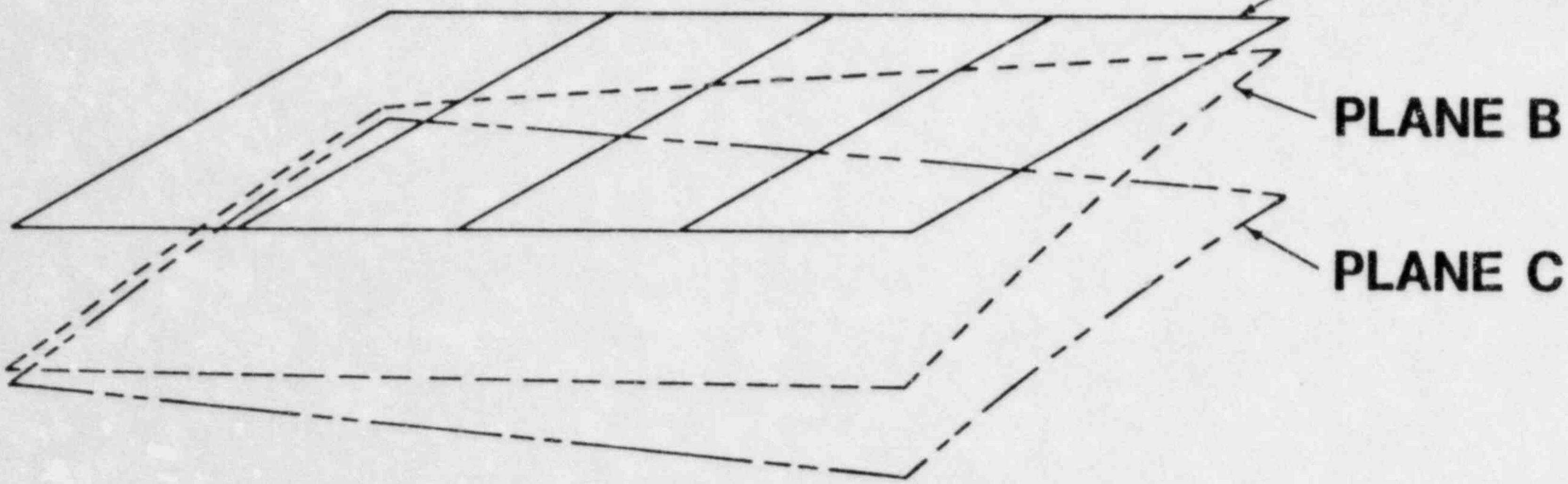


MIDLAND UNITS 1 AND 2
DIESEL GENERATOR BUILDING 2/3/82

G-1948-09

DIESEL GENERATOR BUILDING

TREND OF MEASURED SETTLEMENT



Plane A Nominal reference plane

Plane B Settlement plot as of 11/16/78 before cutting duct banks loose

Plane C Settlement plot as of 12/28/78 approximately a month after cutting duct banks

REMEDIAL PROGRAM

I EXPLORATION

II EVALUATION OF OPTIONS AND DECISION TO SURCHARGE

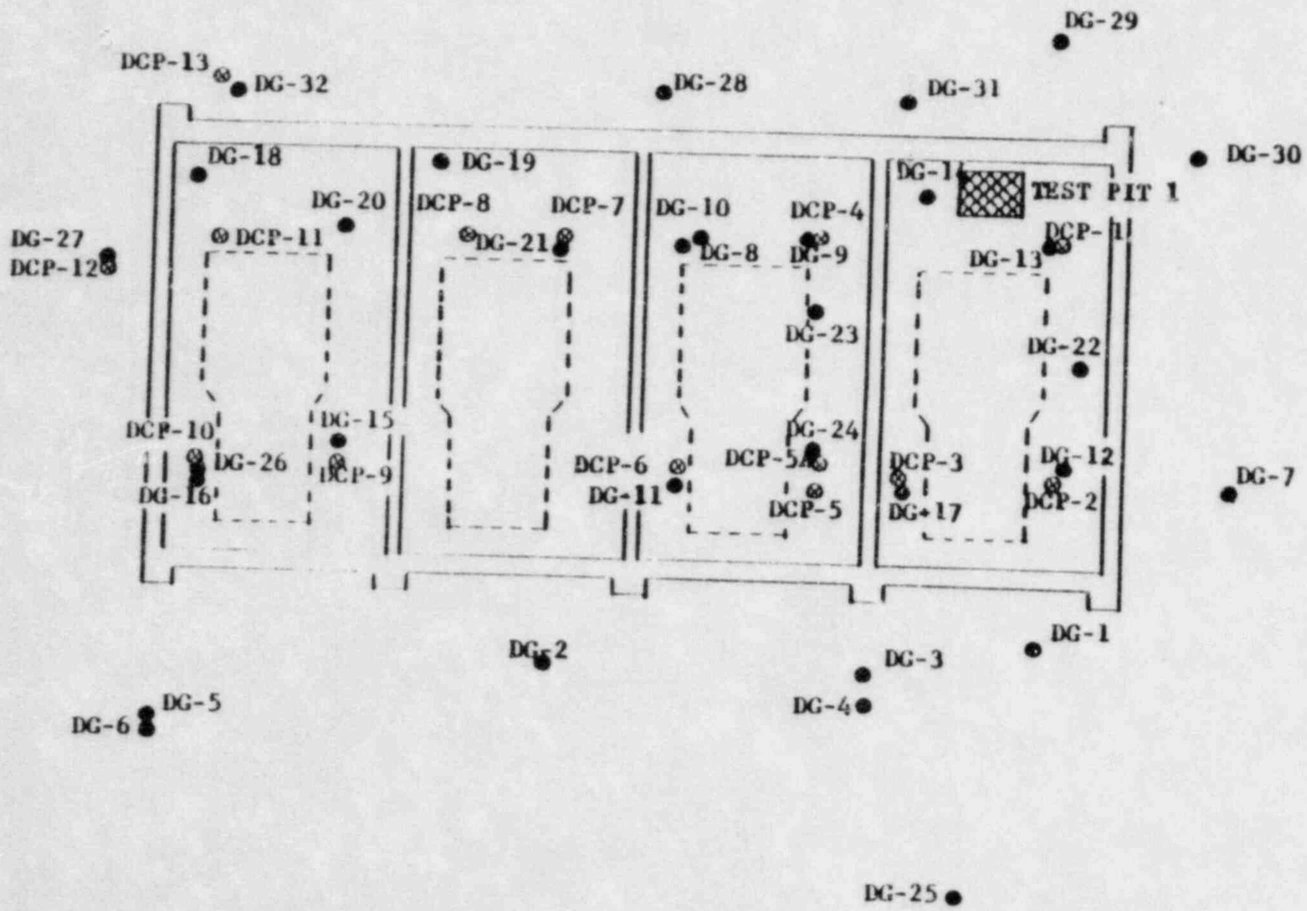
III PERMANENT DEWATERING

IV RESULTS

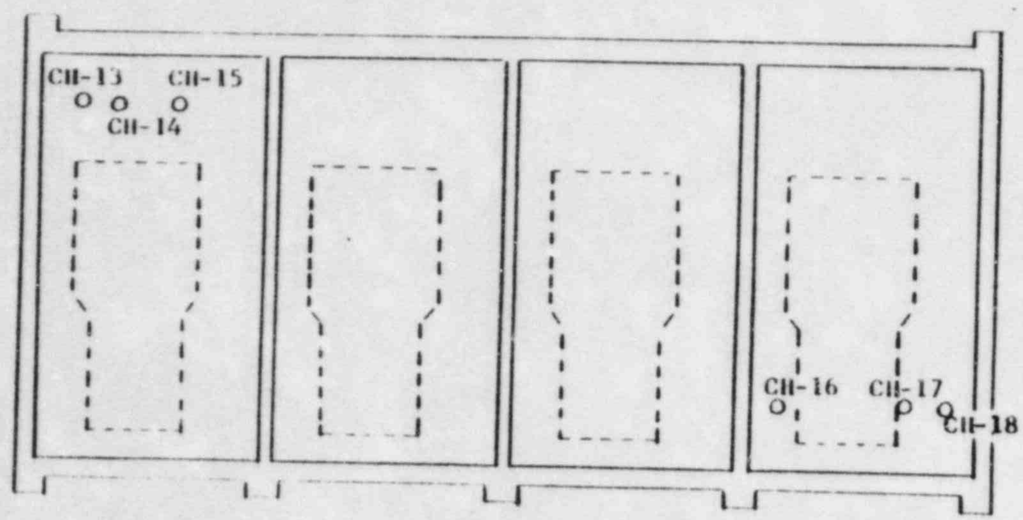
V FUTURE MONITORING

I. EXPLORATION PROGRAM

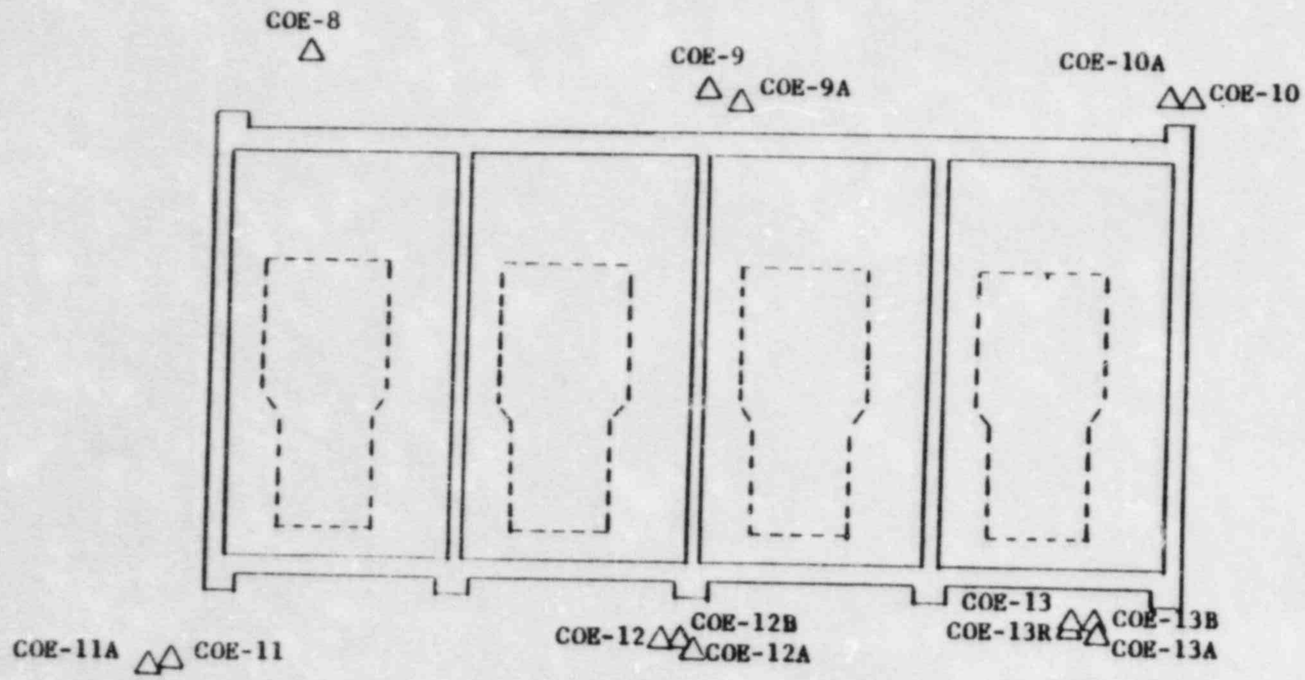
- BEFORE SURCHARGE
  - 32 Borings
  - 14 Dutch Cone Soundings
  - Laboratory Testing
- AFTER SURCHARGE
  - 6 Borings With Cross-Hole Shear Wave Velocity Tests
  - 11 Borings With Undisturbed Sampling
  - Laboratory Testing



BORING LOCATION PLAN
DG SERIES, DCP SERIES AND TEST PIT 1



BORING LOCATION PLAN
CH SERIES

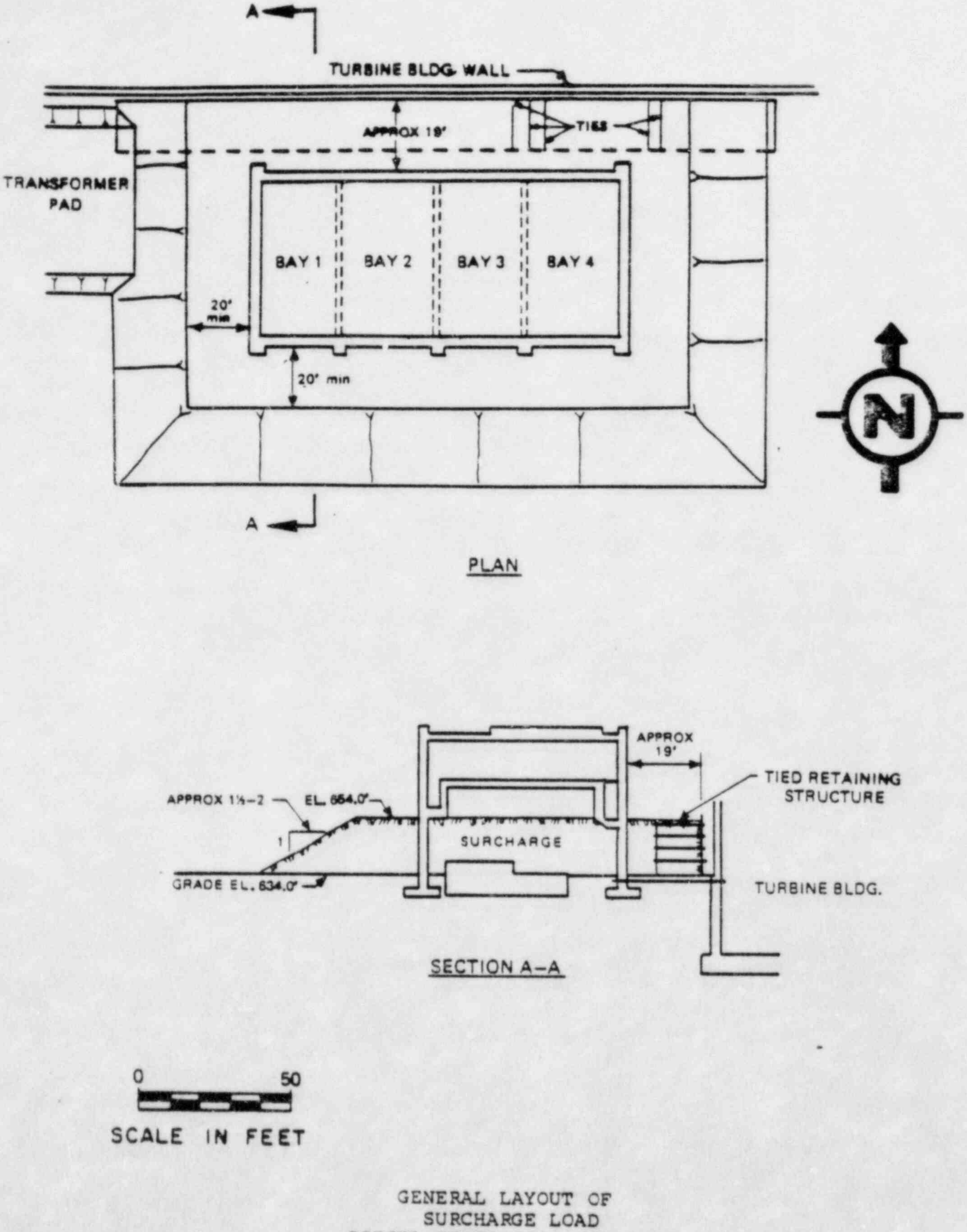


BORING LOCATION PLAN
COE SERIES

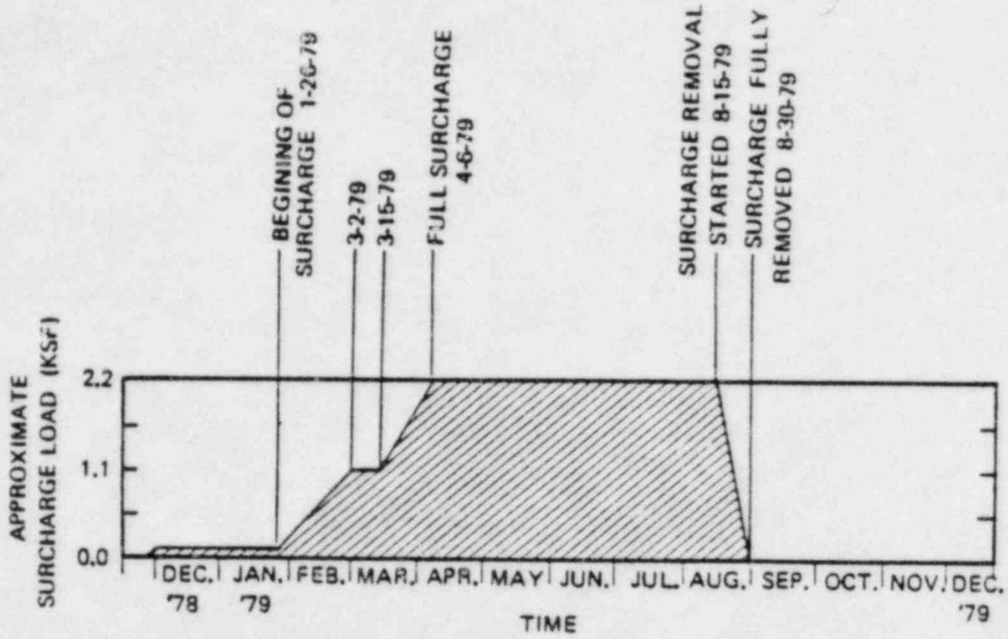
5

II. SURCHARGE PROGRAM

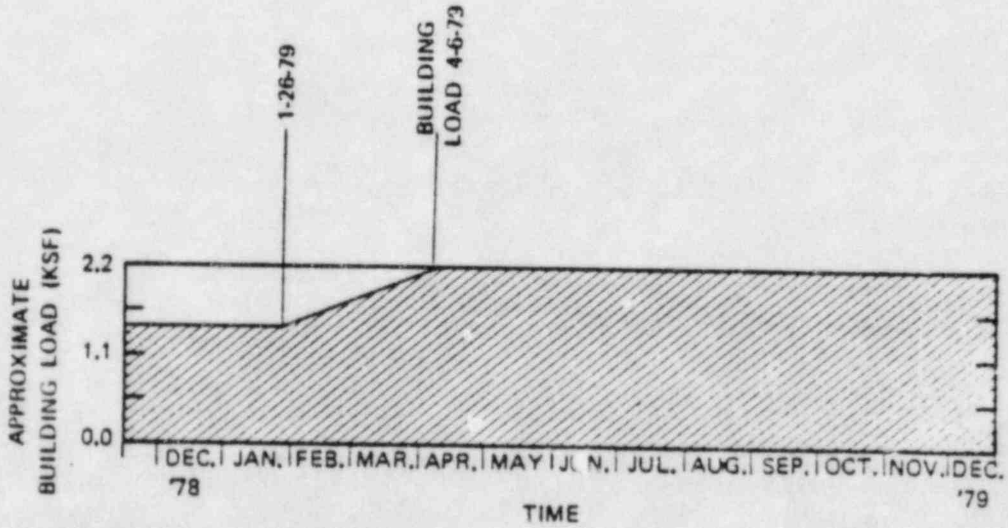
- PURPOSE
- GEOMETRY
- INSTRUMENTATION



GENERAL LAYOUT OF
SURCHARGE LOAD
DIESEL GENERATOR BUILDING

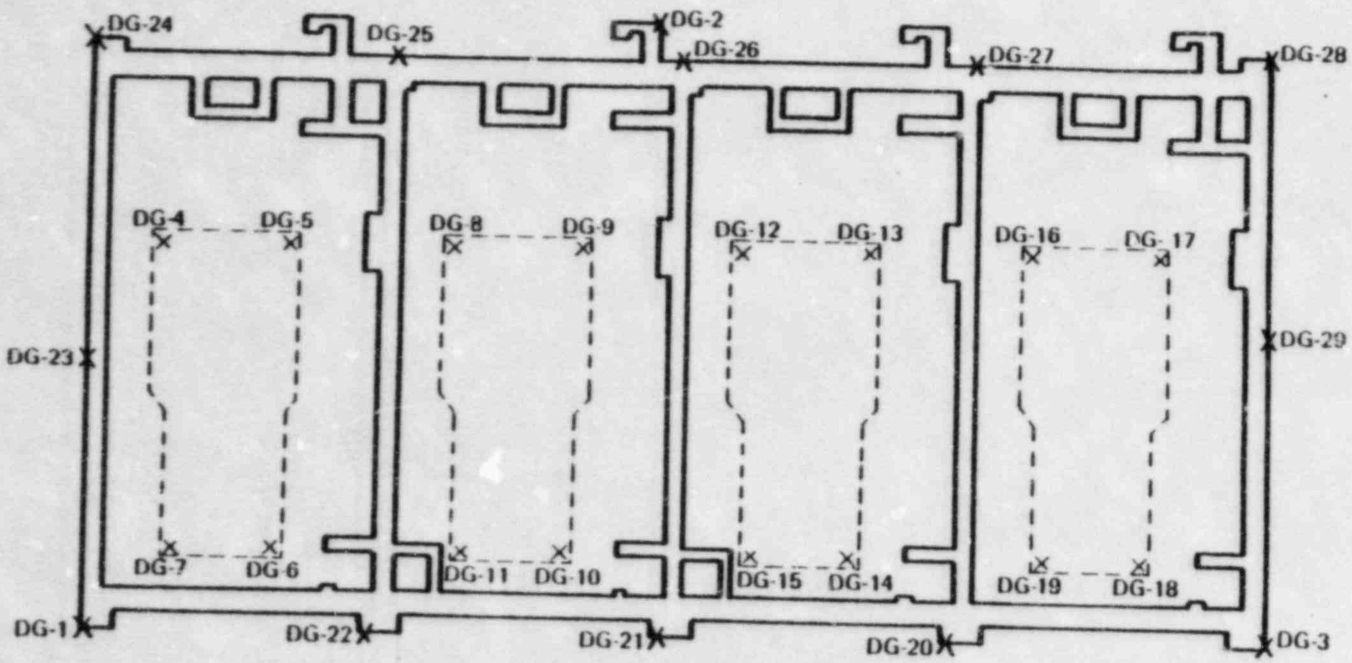


(A) IDEALIZED SURCHARGE LOAD HISTORY



(B) IDEALIZED STATIC BUILDING LOAD HISTORY

DIESEL GENERATOR BUILDING
IDEALIZED SURCHARGE AND
BUILDING LOAD HISTORIES



DIESEL GENERATOR BUILDING

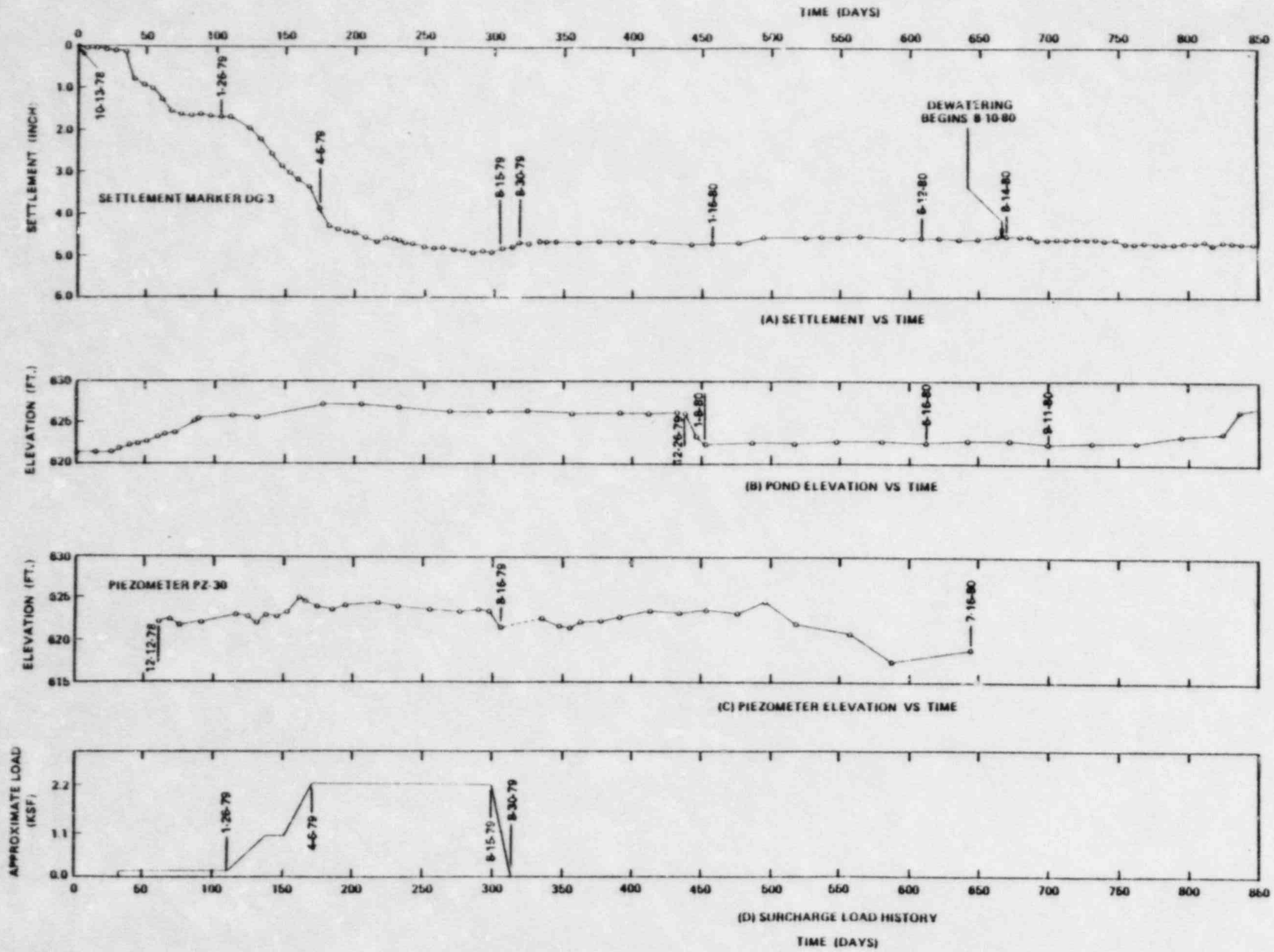
LOCATION OF BUILDING SETTLEMENT MARKERS

9

III. PERMANENT DEWATERING

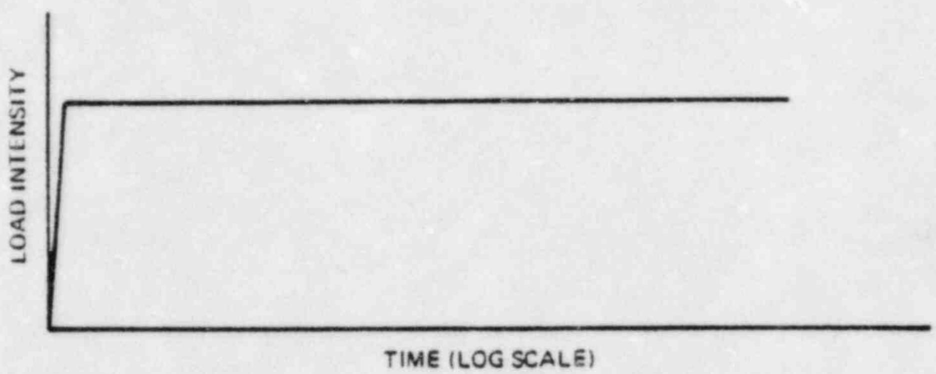
IV. RESULTS OF REMEDIAL PROGRAM

- SETTLEMENTS
  - Predictions
  - Observations
- FOUNDATION MATERIAL PROPERTIES
  - Settlement Calculations
  - Bearing Capacity
  - Dynamic Properties
  - Surcharge Effectiveness

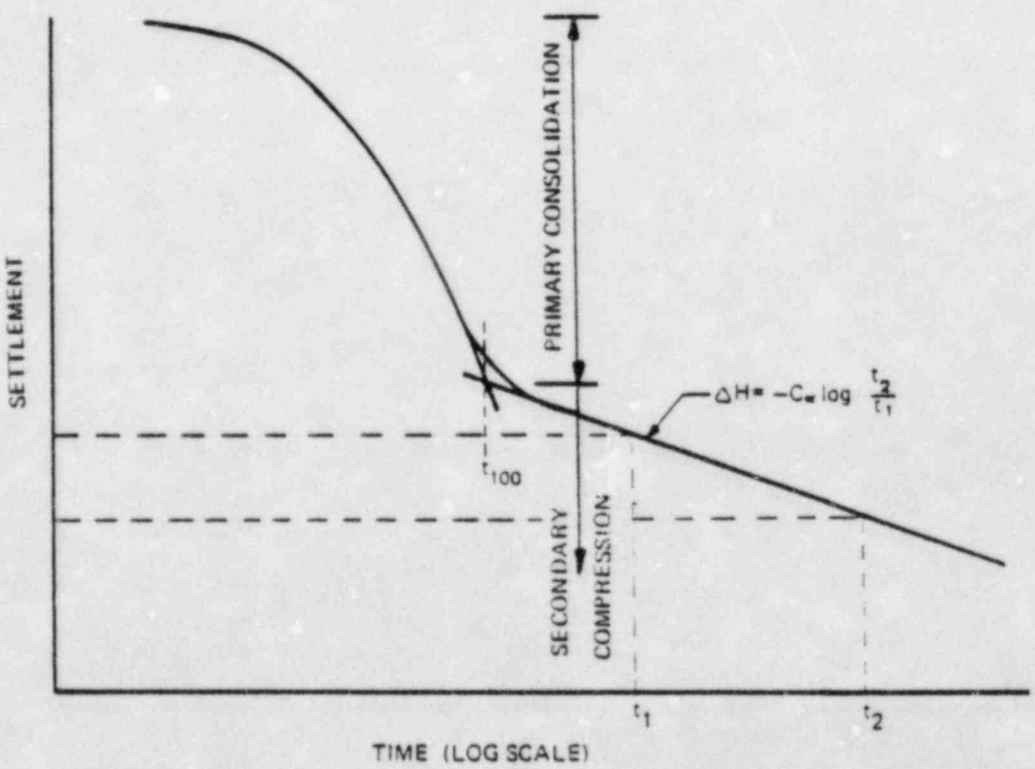


DIESEL GENERATOR BUILDING
TYPICAL SETTLEMENT, COOLING POND LEVEL, PIEZOMETER LEVEL AND SURCHARGE LOAD HISTORY

12

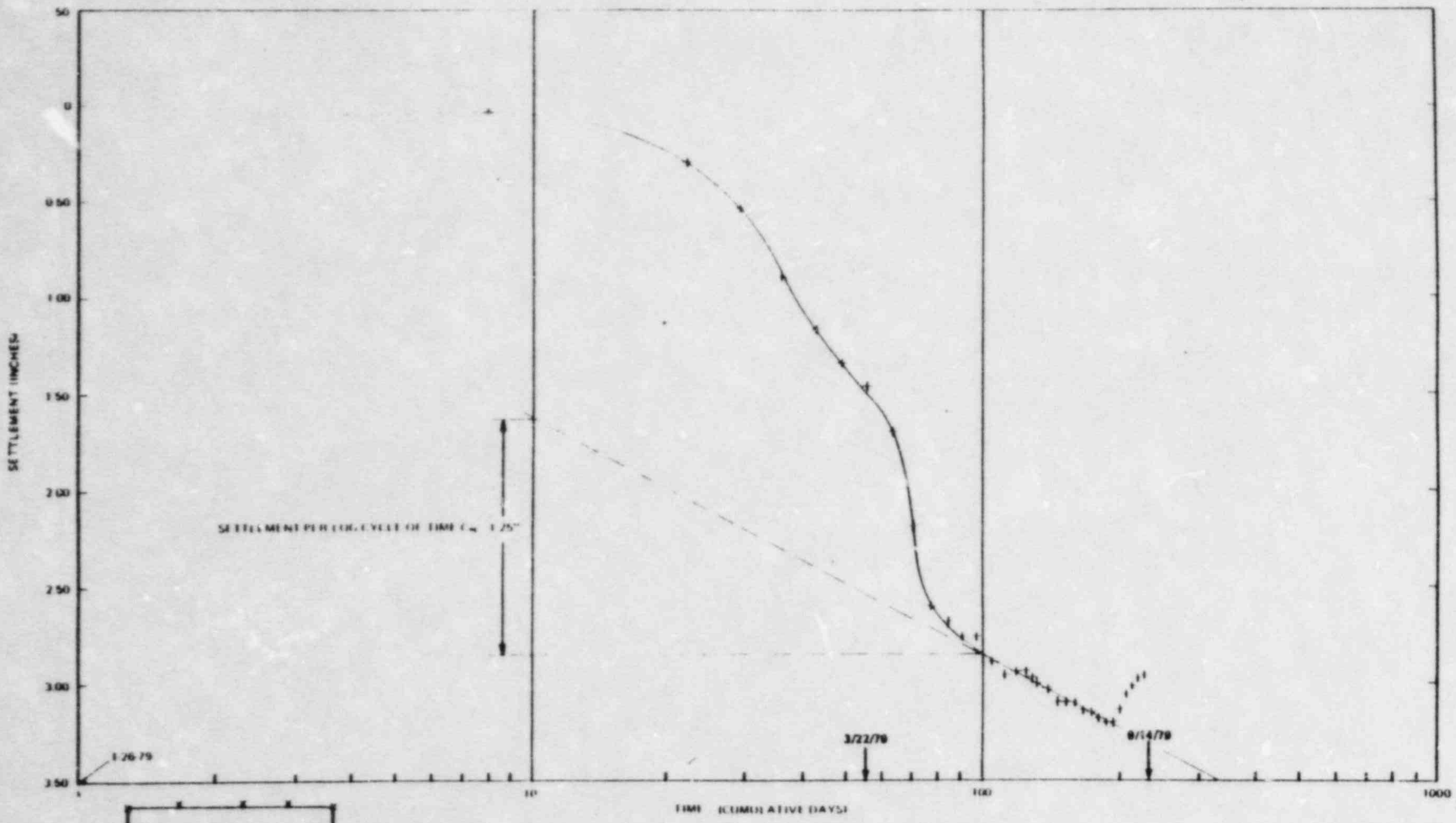


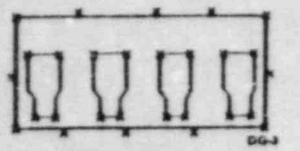
(A) LOAD HISTORY



(B) TIME - SETTLEMENT CURVE

TYPICAL LABORATORY LOAD HISTORY
AND TIME - SETTLEMENT PLOTS



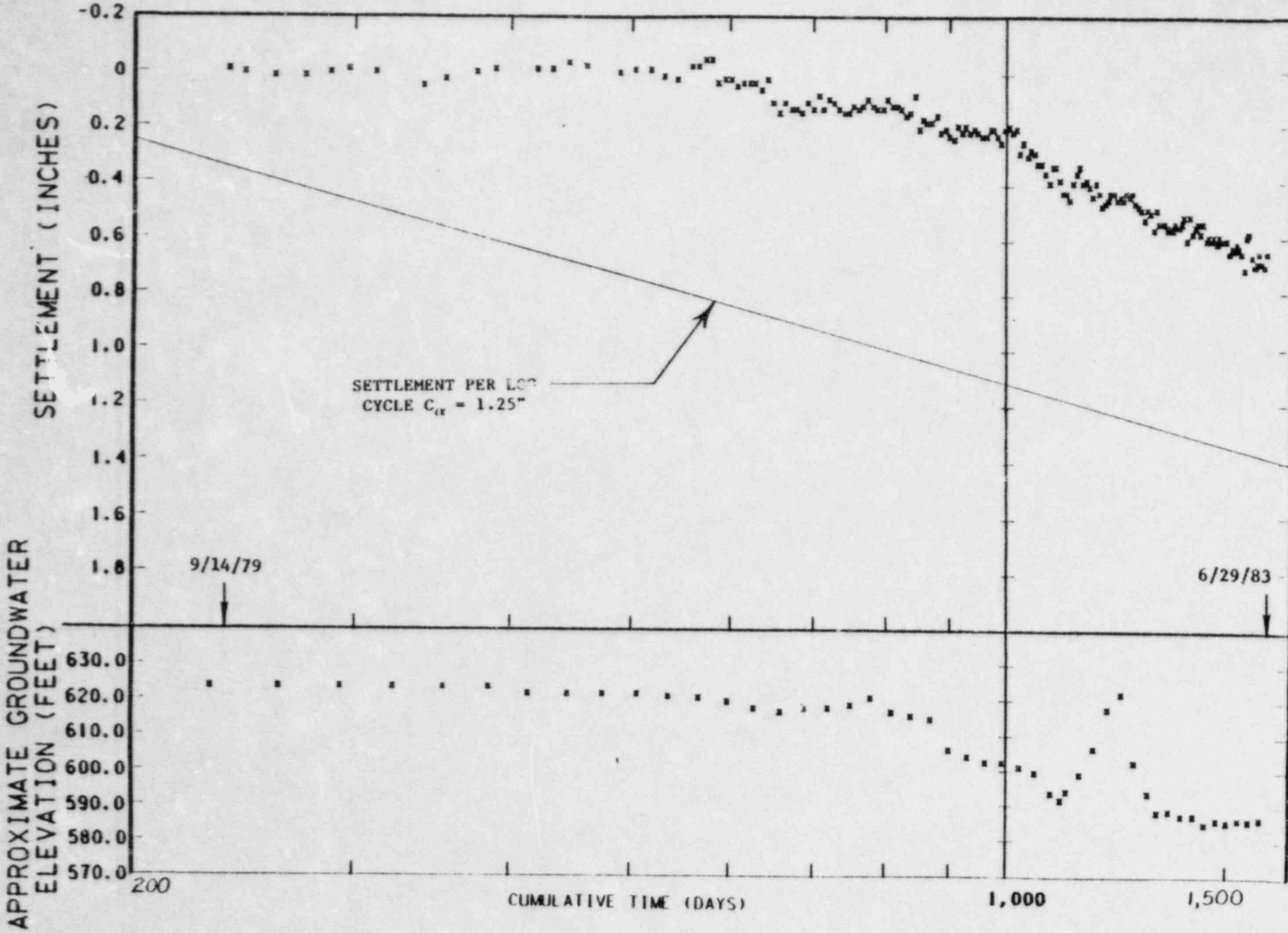


SETTLEMENT MARKER LOCATION PLAN
DIESEL GENERATOR BUILDING
(NOT TO SCALE)

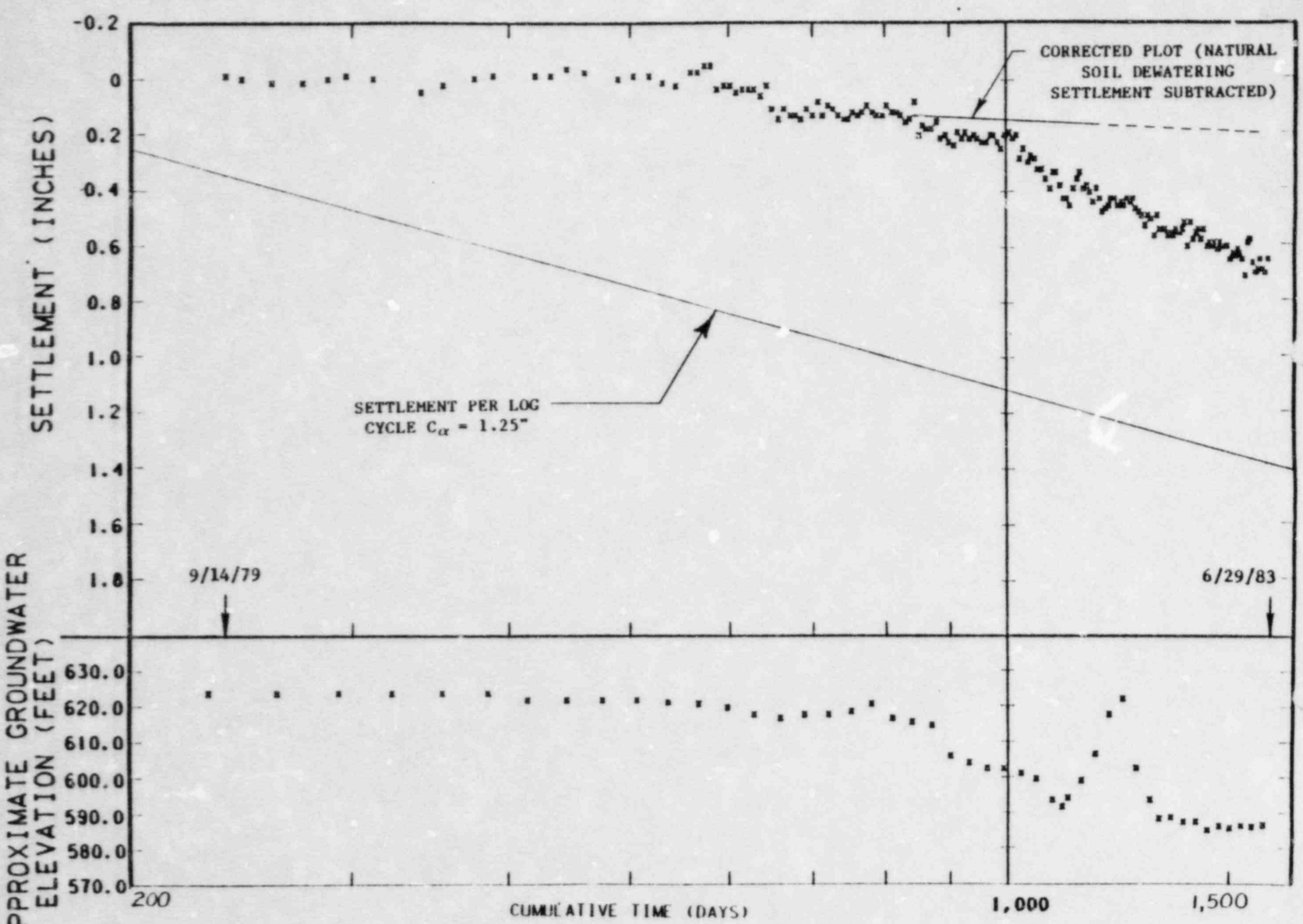
NOTE
The permanent marker could not be monitored from 3/22/79 to 9/14/79 due to surcharge. Temporary markers at elevation 664'-0" ± were used during this period to estimate the settlement of the permanent marker. On 9/14/79 the settlement was again based directly upon the permanent marker.

SETTLEMENT vs. LOGARITHM OF TIME
FROM 1/26/79 TO 9/14/79
MARKER DG-3

14



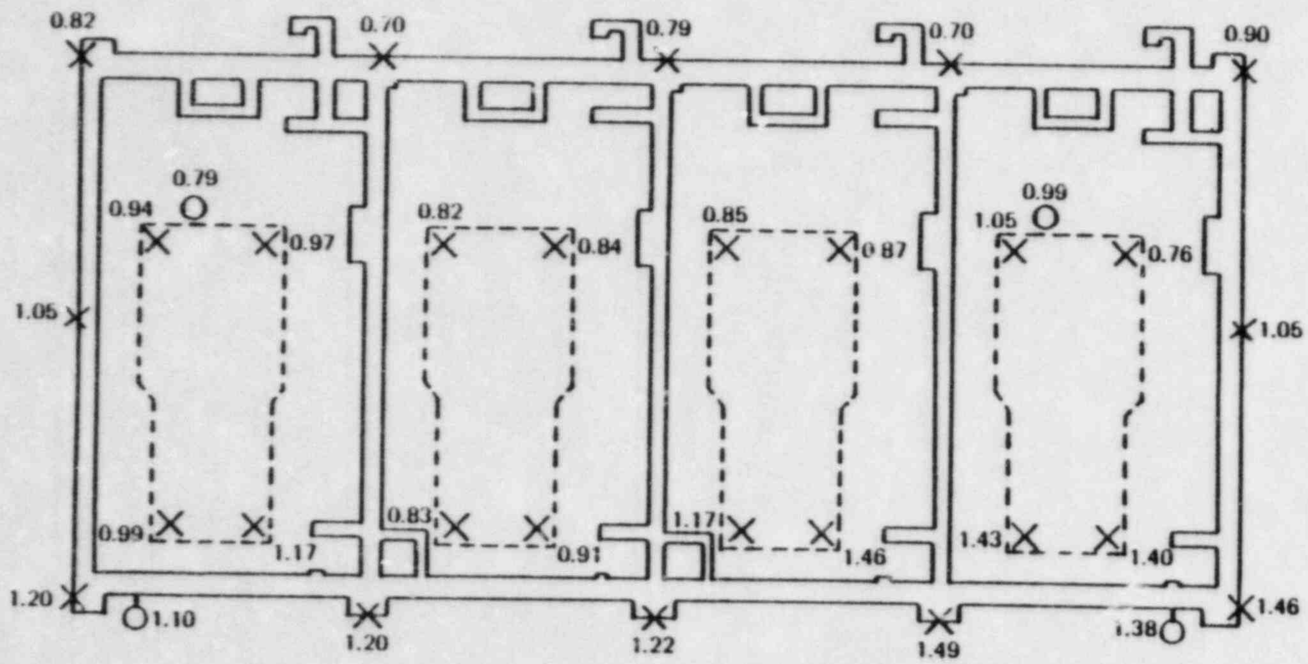
SETTLEMENT vs. LOGARITHM OF TIME SINCE 9/14/79
MARKER DG-3



SETTLEMENT vs. LOGARITHM OF TIME SINCE 9/14/79
SHOWING CORRECTED SLOPE
MARKER DG-3

16

DIESEL GENERATOR BUILDING



LEGEND

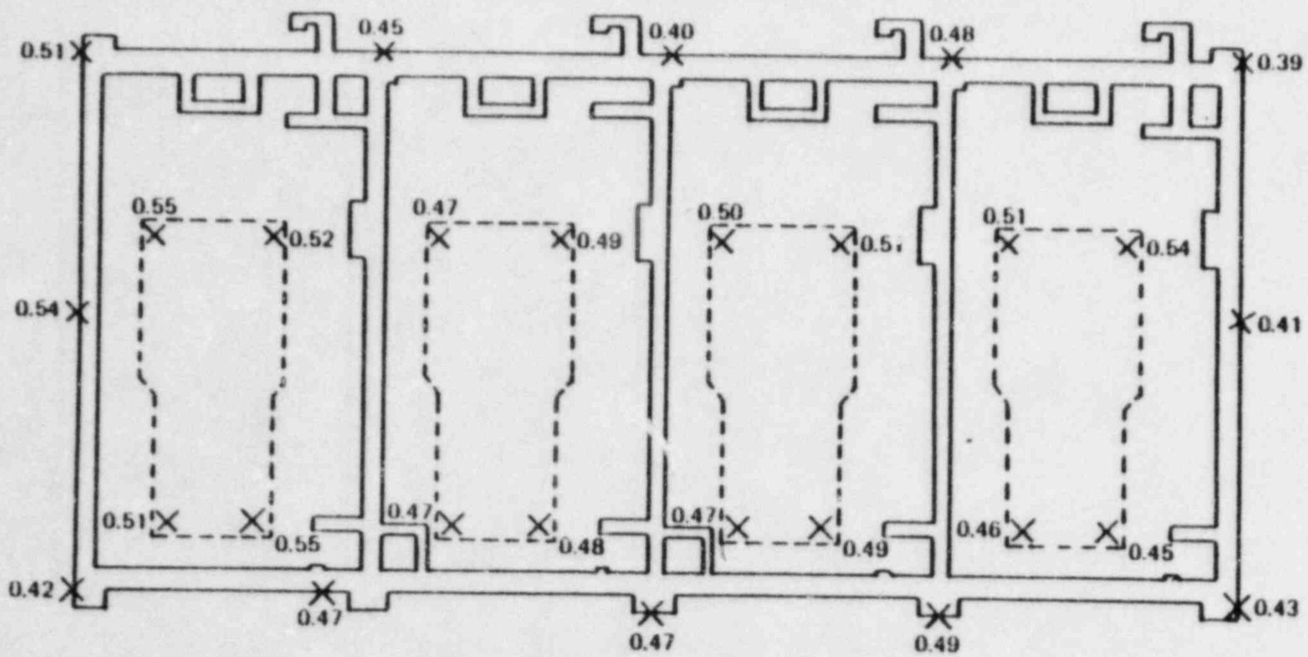
O —— DEEP BORROS ANCHOR

X —— BUILDING / PEDESTAL SETTLEMENT MARKER

1.20 —— SETTLEMENT IN INCHES

DIESEL GENERATOR BUILDING
ESTIMATED SECONDARY COMPRESSION
SETTLEMENTS FROM 12/31/81 TO 12/31/2025
ASSUMING SURCHARGE REMAINS

DIESEL GENERATOR BUILDING



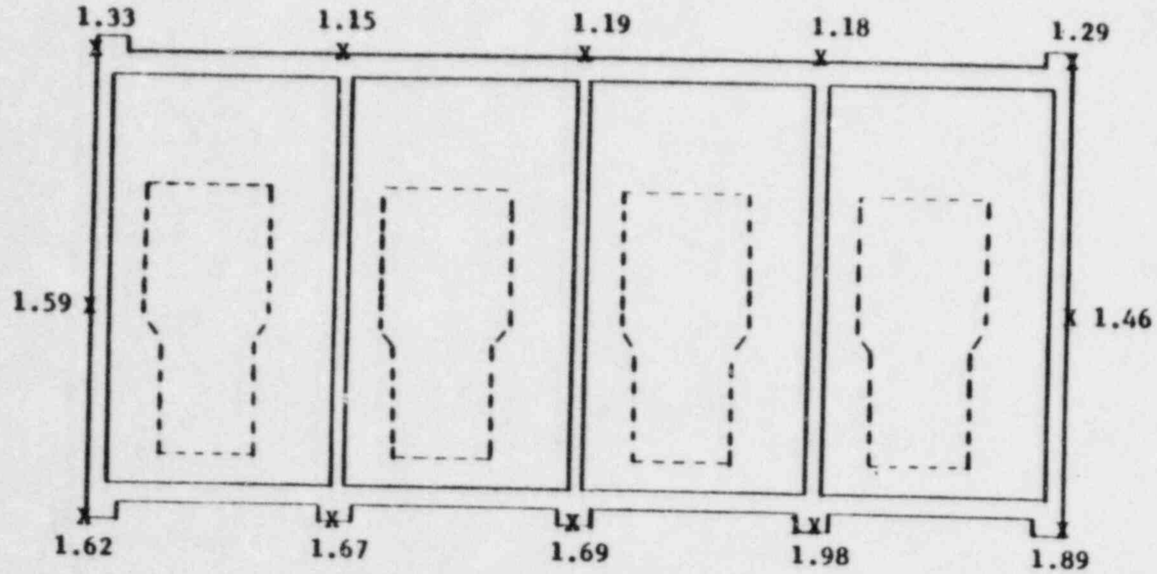
LEGEND

X ——— BUILDING / PEDESTAL SETTLEMENT MARKER

0.42 ——— MEASURED SETTLEMENT BETWEEN 9/14/79 AND 12/31/81.

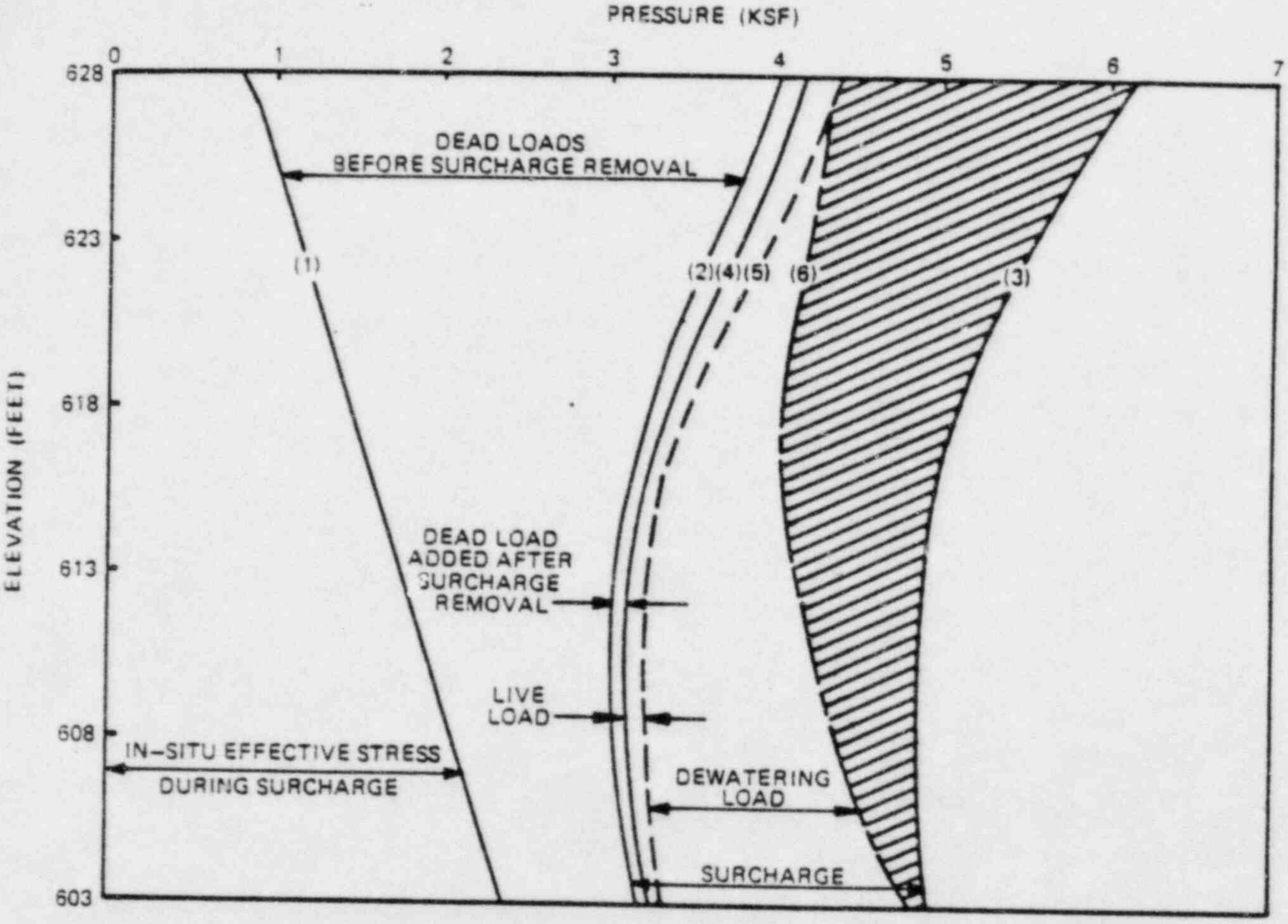
DIESEL GENERATOR BUILDING
MEASURED SETTLEMENT FROM
9/14/79 TO 12/31/81

DIESEL GENERATOR BUILDING



SUM OF MEASURED SETTLEMENT
FROM 9/14/79 to 12/31/81 AND PREDICTED
SETTLEMENT FROM 12/31/81 TO 12/31/2025
(GROUNDWATER ELEVATION TO 595')

19



EXPLANATIONS

(1) In-situ effective overburden pressure (GWT at 627).

(2) Total effective pressure before surcharge removal due to In-situ effective overburden pressure and structural dead loads present during surcharge.

(3) Total effective pressure at the end of surcharge due to In-situ effective overburden pressure, structural dead loads, and surcharge loads.

(4) Total effective pressure due to In-situ effective overburden pressure and total structural dead loads (loads present during surcharge plus dead loads added after surcharge removal).

(5) Total effective pressure due to In-situ effective overburden pressure, total structural dead loads, and expected live loads.

(6) Total effective pressure during the life of plant operation due to In-situ effective overburden pressure, structural dead loads, dewatering loads, and expected live loads.

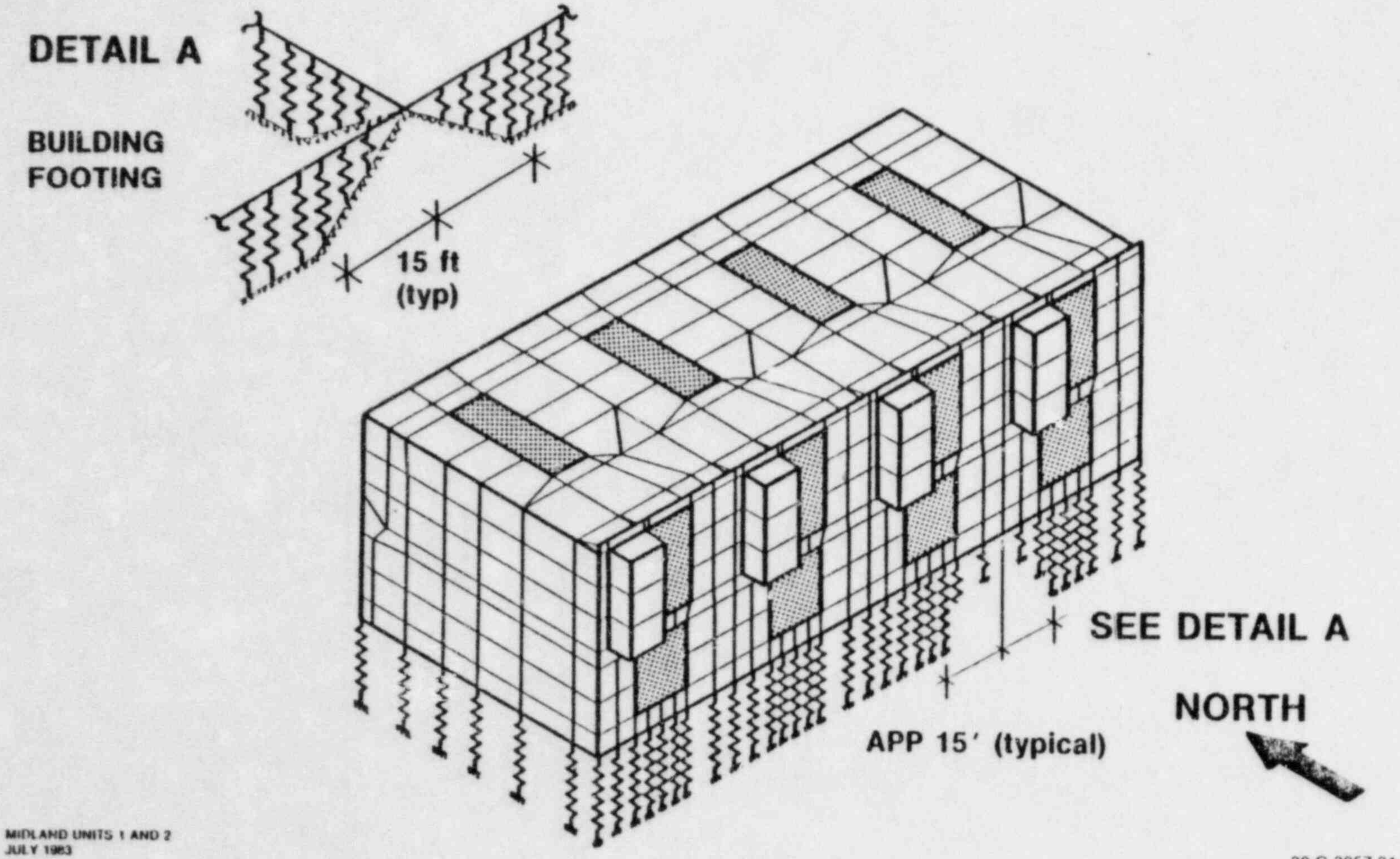
COMPARISON OF EFFECTIVE STRESS
BEFORE AND AFTER SURCHARGE
SOUTHWEST CORNER
DIESEL GENERATOR BUILDING

V. SETTLEMENT MONITORING

- PRESENT
- FUTURE

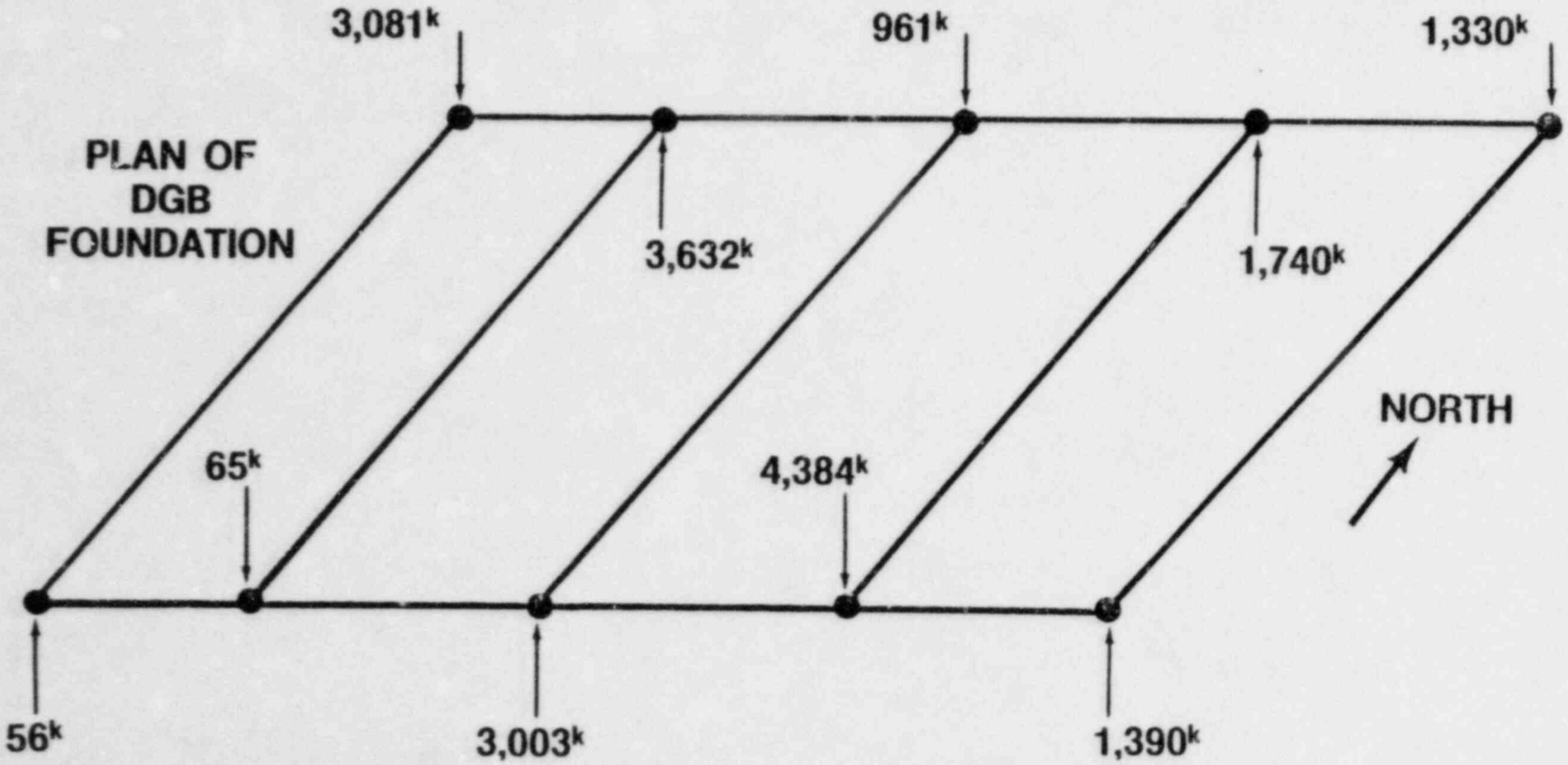
DIESEL GENERATOR BUILDING

FINITE ELEMENT MODEL FOR ZERO SPRING CONDITION



DIESEL GENERATOR BUILDING

FORCES REQUIRED TO DEFORM BUILDING TO GEOTECH'S 40-YEAR ESTIMATES



MIDLAND UNITS 1 AND 2
JULY 1983

30-G-3057-32

DIESEL GENERATOR BUILDING

KEY ISSUES

1. DISTORTION OF BUILDING DUE TO SETTLEMENT
   - MEASURED
   - PREDICTED

2. CONCRETE CRACKS
   - DUE TO HANG-UP ON DUCT BANKS
   - OTHER CRACKING

3. STRUCTURAL REANALYSIS
   - ACCEPTANCE CRITERIA
   - ADDITIONAL ANALYSES
   - CONSERVATISM

DIESEL GENERATOR BUILDING
MATHEMATICAL MODEL
ELEVATION LOOKING WEST

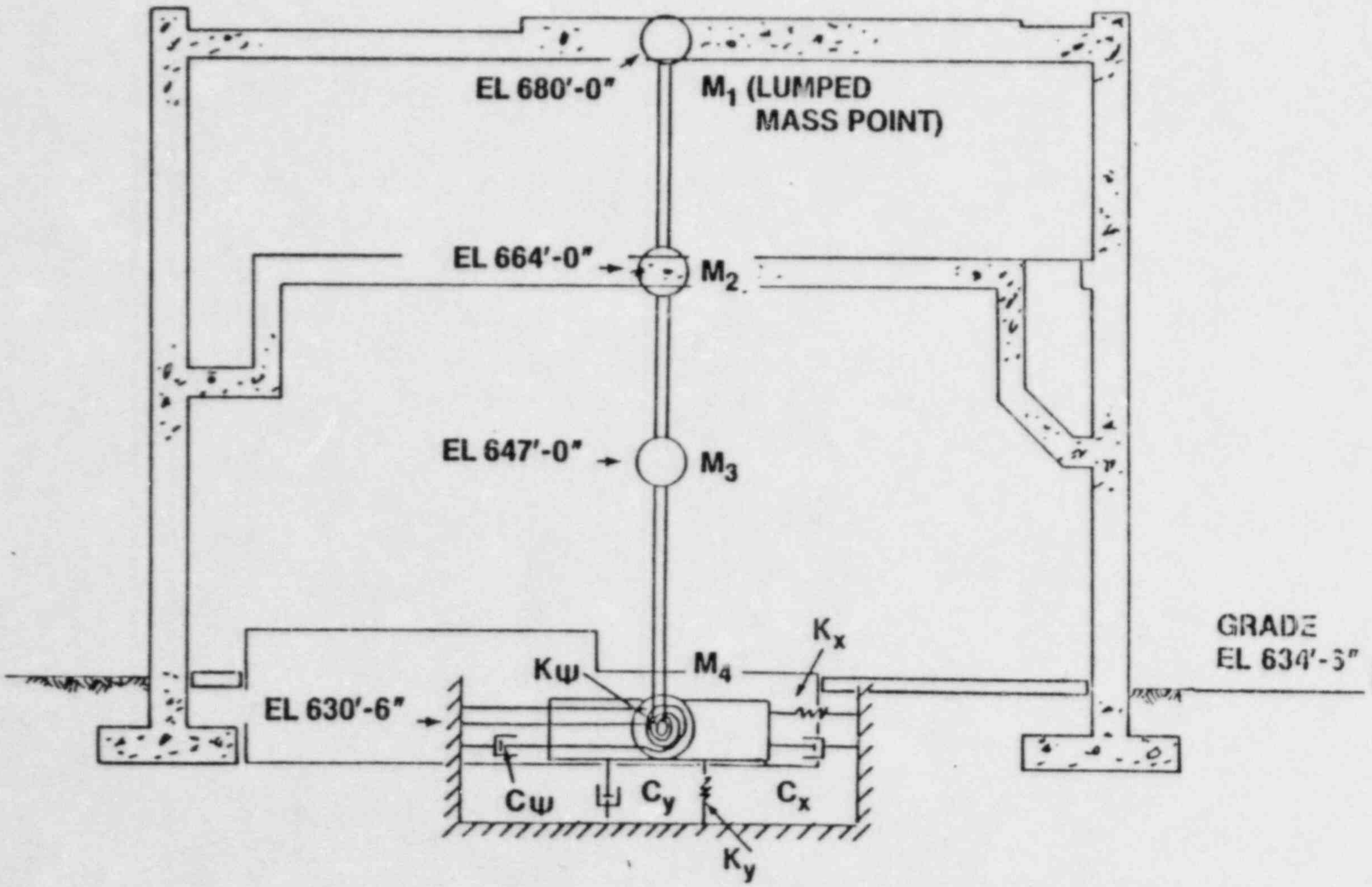


FIGURE 9

88-G-2643-13

TABLE 2

MASS PROPERTIES OF DIESEL GENERATOR BUILDING

For Horizontal Earthquake:

Elevation	Node	Mass (kips)	Mass Moment of Inertia ($K\text{-}FT^2$) North-South Earthquake	Mass Moment of Inertia ($K\text{-}FT^2$) East-West Earthquake
680'-0"	1 (M1)	5,338	2.8955×10^6	1.2247×10^7
664'-0"	2 (M2)	7,642	4.5120×10^6	1.8476×10^7
647'-0"	3 (M3)	4,185	2.9140×10^6	1.0012×10^7
630'-6"	4 (M4)	12,155	3.0670×10^6	1.0528×10^7
		Σ = 29,320	Σ = 1.3388×10^7	Σ = 5.1263×10^7

For Vertical Earthquake:

Elevation	Node	Mass* (kips)
680'-0"	1 (M1)	5,338
664'-0"	2 (M2)	7,642
647'-0"	3 (M3)	4,185
630'-6"	4 (M4)	4,274
		Σ = 21,439

*In weight units

TABLE 3

MEMBER PROPERTIES OF DIESEL GENERATOR BUILDING

	North-South Earthquake		East-West Earthquake	
Beam	Effective Shear Area (ft^2)	Moment of Inertia (ft^4)	Effective Shear Area (ft^2)	Moment of Inertia (ft^4)
1	799.4	1.143×10^6	863.1	3.926×10^6
2	799.4	1.143×10^6	863.1	3.926×10^6
3	799.4	1.143×10^6	863.1	3.926×10^6

TABLE 4

SOIL SPRING AND DAMPERS FOR DIESEL GENERATOR BUILDING
NORTH-SOUTH EARTHQUAKE

V_s (ft/sec)	ρ (pcf)	G (ksf)	E (ksf)	ν	K_x (k/ft)	K_ψ (k-ft/rad)	C_x (k-sec/rad)	C_ψ (k-sec-ft/rad)
471	115.6*	7,965.0	2,310.0	0.45	2.491×10^5	6.3614×10^8	17,603	2.1234×10^7
500	125.0	971.0	2,719.0	0.40	2.9451×10^5	7.1052×10^8	19,581	2.2391×10^7
666	115.6*	1,593.0	4,618.0	0.45	4.9805×10^5	1.2719×10^9	24,892	3.0023×10^7
796	115.6*	2,275.0	6,598.0	0.45	7.1150×10^5	1.8170×10^9	29,750	3.5882×10^7
816	115.6*	2,390.0	5,931.0	0.45	7.4746×10^5	1.9087×10^9	30,493	3.6779×10^7

*Values from weighted average method

TABLE 5

SOIL SPRING AND DAMPERS FOR DIESEL GENERATOR BUILDING
EAST-WEST EARTHQUAKE

V_s (ft/sec)	ρ (psf)	G (ksf)	E (ksf)	ν	K_x (k/ft)	K_ψ (K-ft/rad)	C_x (k-sec/rad)	C_ψ (K-sec-ft/rad)
471	115.6	796.5	2,310.0	0.45	2.4623×10^5	1.3006×10^9	18,887	4.54×10^7
500	125.0	971.0	2,719.0	0.40	2.9130×10^5	1.4524×10^9	21,022	4.76×10^7
666	115.6	1,593.0	4,618.0	0.45	4.9237×10^5	2.6000×10^9	26,706	6.4182×10^7
796	115.6	2,275.0	6,598.0	0.45	7.0338×10^5	3.7150×10^9	31,920	7.6723×10^7
816	115.6	2,390.0	6,931.0	0.45	7.3894×10^5	3.9025×10^9	32,717	7.846×10^7

TABLE 6

SOIL SPRING AND DAMPERS FOR DIESEL GENERATOR BUILDING VERTICAL EATHQUAKE

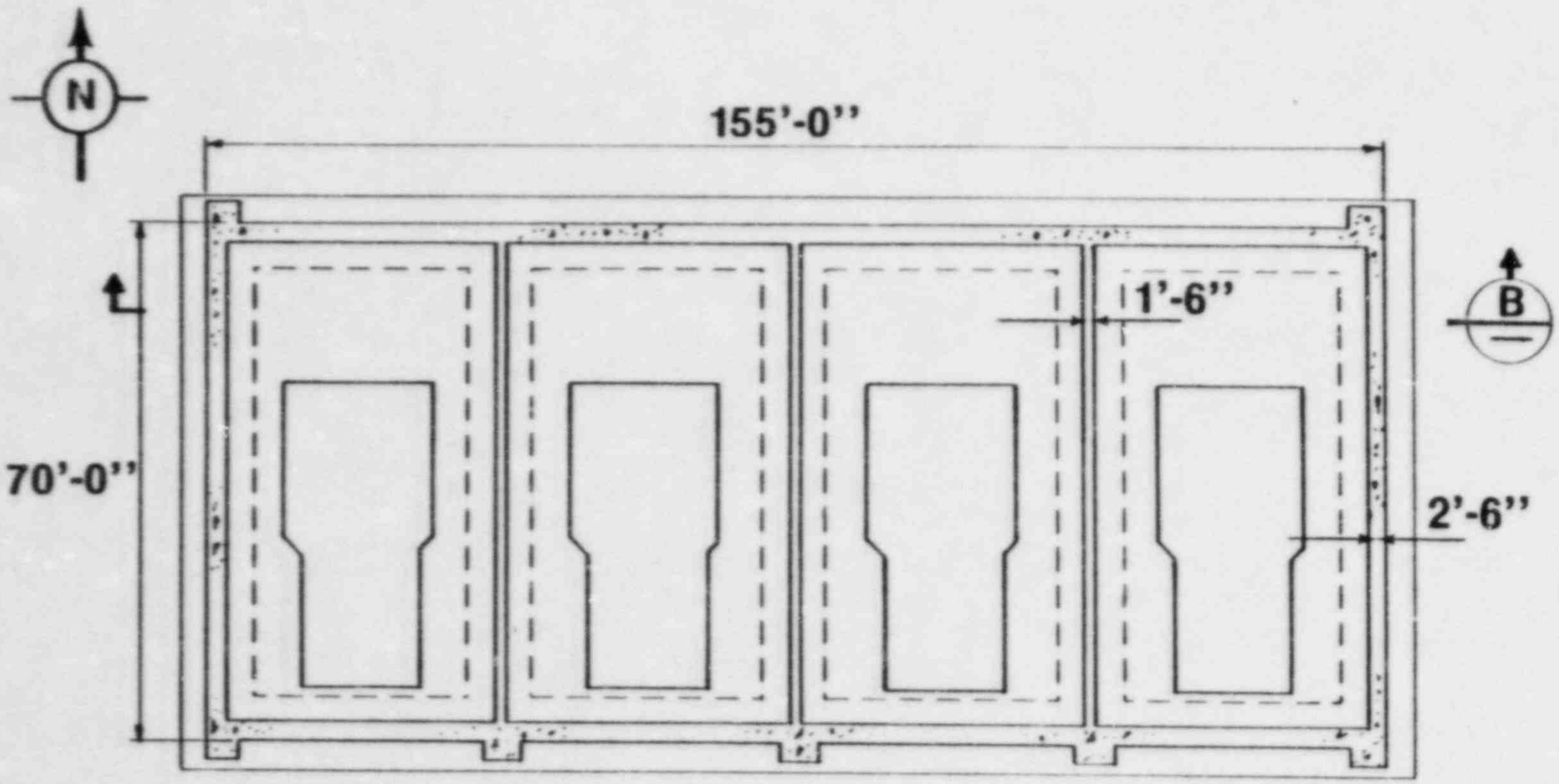
V_S (ft/sec)	ρ (pcf)	G (ksf)	E (ksf)	ν	Ky (K/ft)	Cy (K-sec/ft)
471	115.6	796.5	2,310.0	0.45	3.3349×10^5	25,638
500	125.0	971.0	2,609.0	0.40	3.7247×10^5	26,979
666	115.60	1,593.0	4,618.0	0.45	6.6676×10^5	36,251
796	115.60	2,275.0	6,598.0	0.45	9.5252×10^5	43,303
816	115.60	2,390.0	6,931.0	0.45	1.0007×10^6	44,410

DIESEL GENERATOR BUILDING
STRUCTURAL REANALYSIS

- BEHAVIOR
- LOADS AND LOAD COMBINATIONS
- MATERIALS
- ALLOWABLES
- SEISMIC MODEL
- FINITE ELEMENT MODEL
- EVALUATION AND RESULTS
- CONCLUSION

DIESEL GENERATOR BUILDING

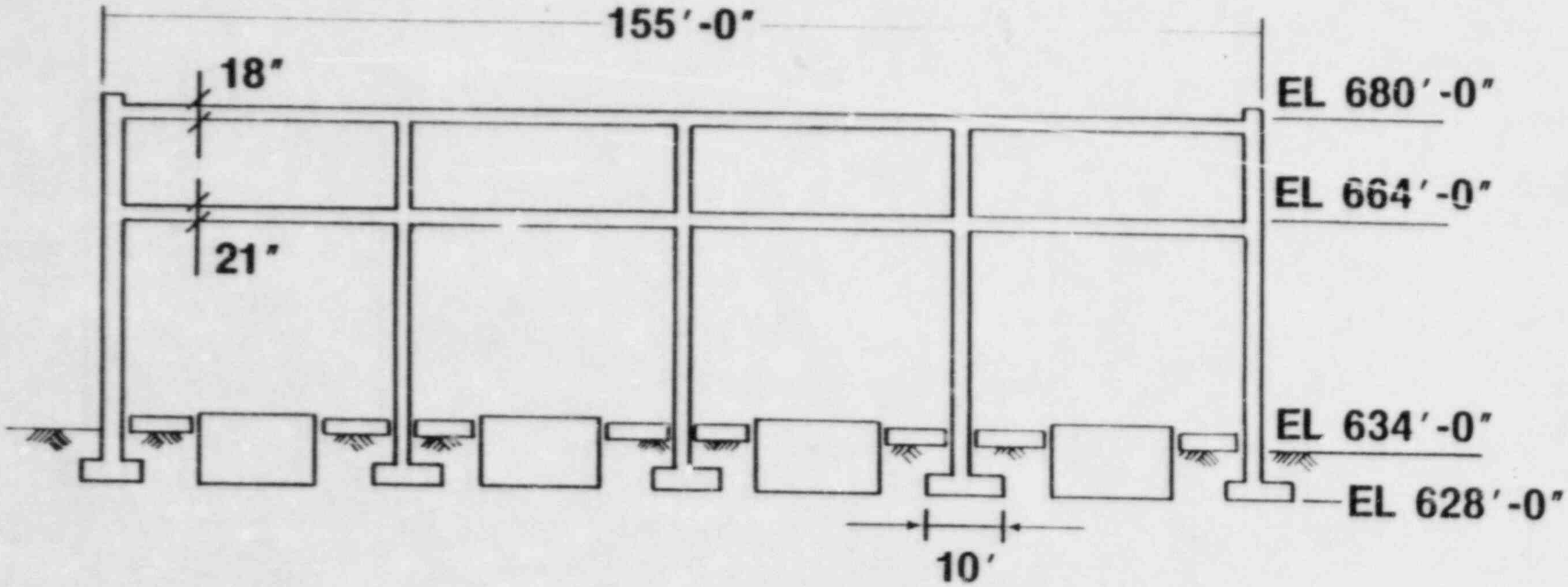
FLOOR PLAN AT EL 634'-6"



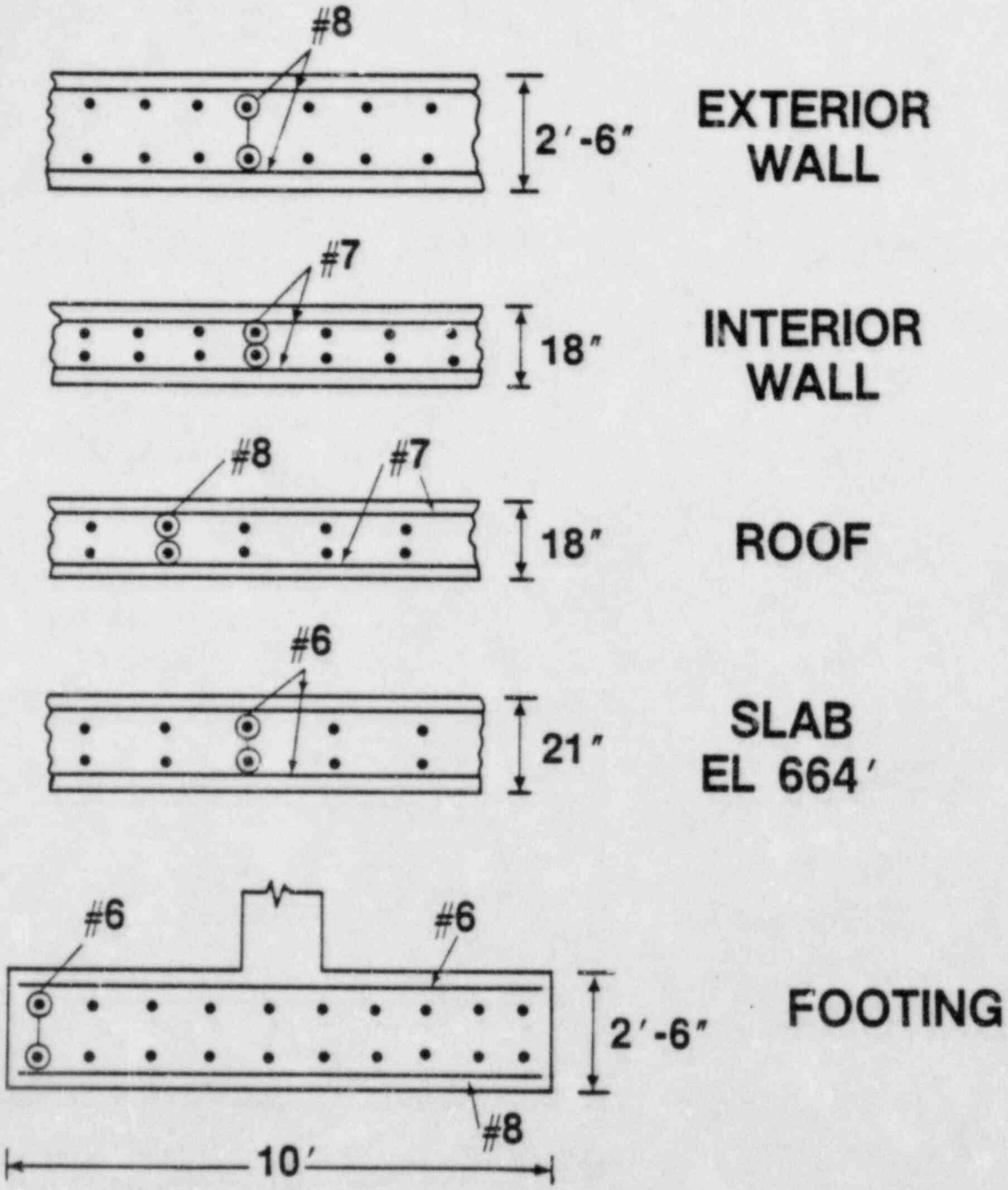
MIDLAND UNITS 1 AND 2
JULY 1983

G-3057-02

DIESEL GENERATOR BUILDING
SECTION B



DIESEL GENERATOR BUILDING
REINFORCEMENT



MIDLAND UNITS 1 AND 2
JULY 1983

25-G-3057-04

DIESEL GENERATOR BUILDING
MAJOR LOADS

- DEAD LOAD AND LIVE LOADS
- EARTHQUAKE
- TORNADO
- SETTLEMENT
- TEMPERATURE

DIESEL GENERATOR BUILDING
LOAD COMBINATIONS

- PSAR
- QUESTION 15
- ACI 349

CRITICAL LOAD COMBINATIONS

$$1.4\,(D + T) + 1.7\,L + 1.9\,E + T_0$$

$$D + T + L + W' + T_0$$

$$D + T + L + E' + T_0$$

DIESEL GENERATOR BUILDING
MATERIALS

- CONCRETE

  $f'_c = 4000$ PSI

  $f'_c = 5000$ PSI

- REINFORCEMENT

  GRADE 60

- STRUCTURAL STEEL A-36

- SOIL STIFFNESS

DIESEL GENERATOR BUILDING

DESIGN CRITERIA

- ACI 318 AND 349

  $f_s = 54$ KSI $= .9\ F_y$

  $\varepsilon_u = 0.003$

- AISC 1969

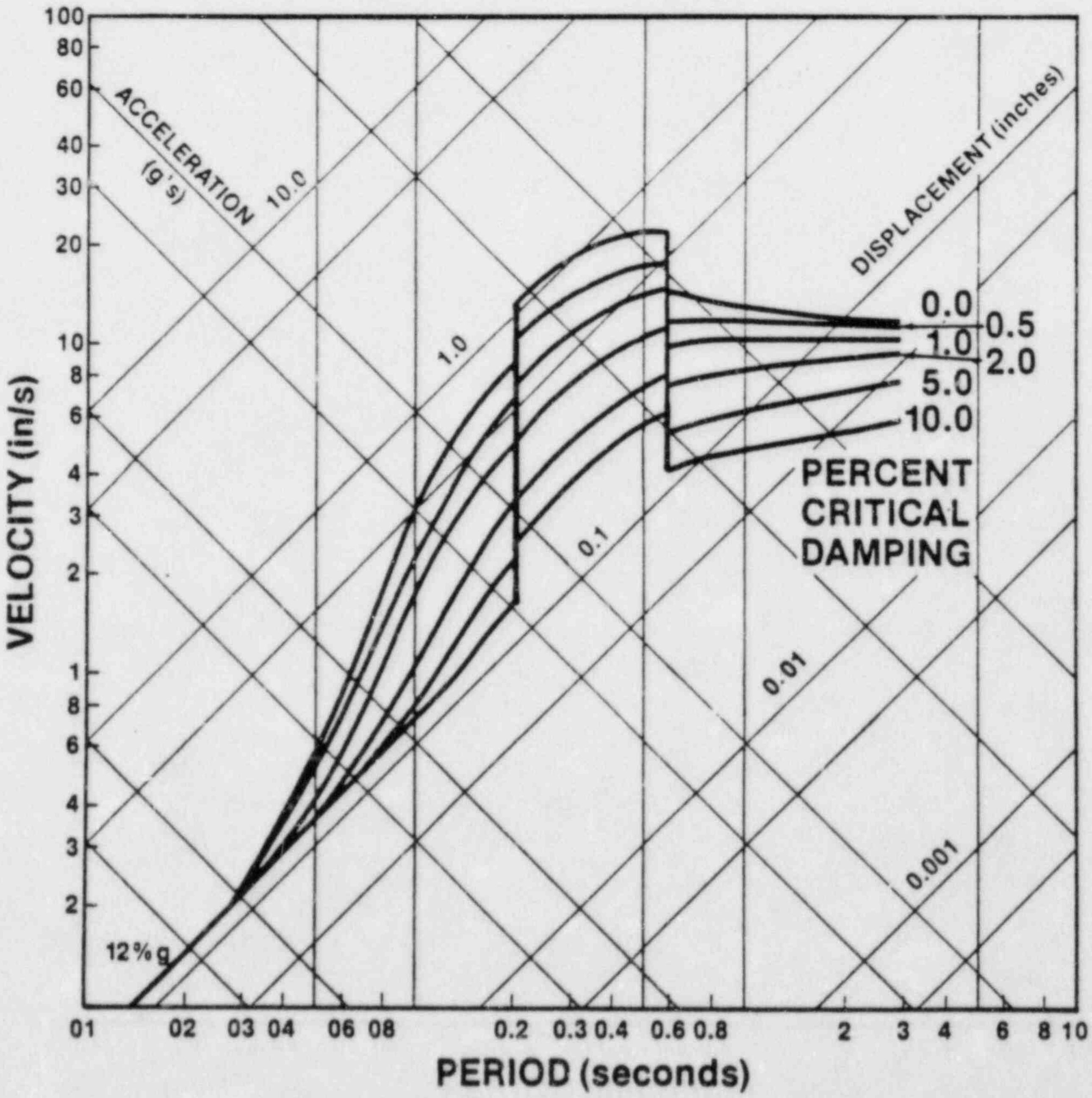
- BEARING

  4.67 KSF (STATIC)

  7KSF (STATIC AND DYNAMIC)

DIESEL GENERATOR BUILDING

HORIZONTAL DESIGN RESPONSE SPECTRA - SSE



MIDLAND UNITS 1 AND 2
JULY 1983

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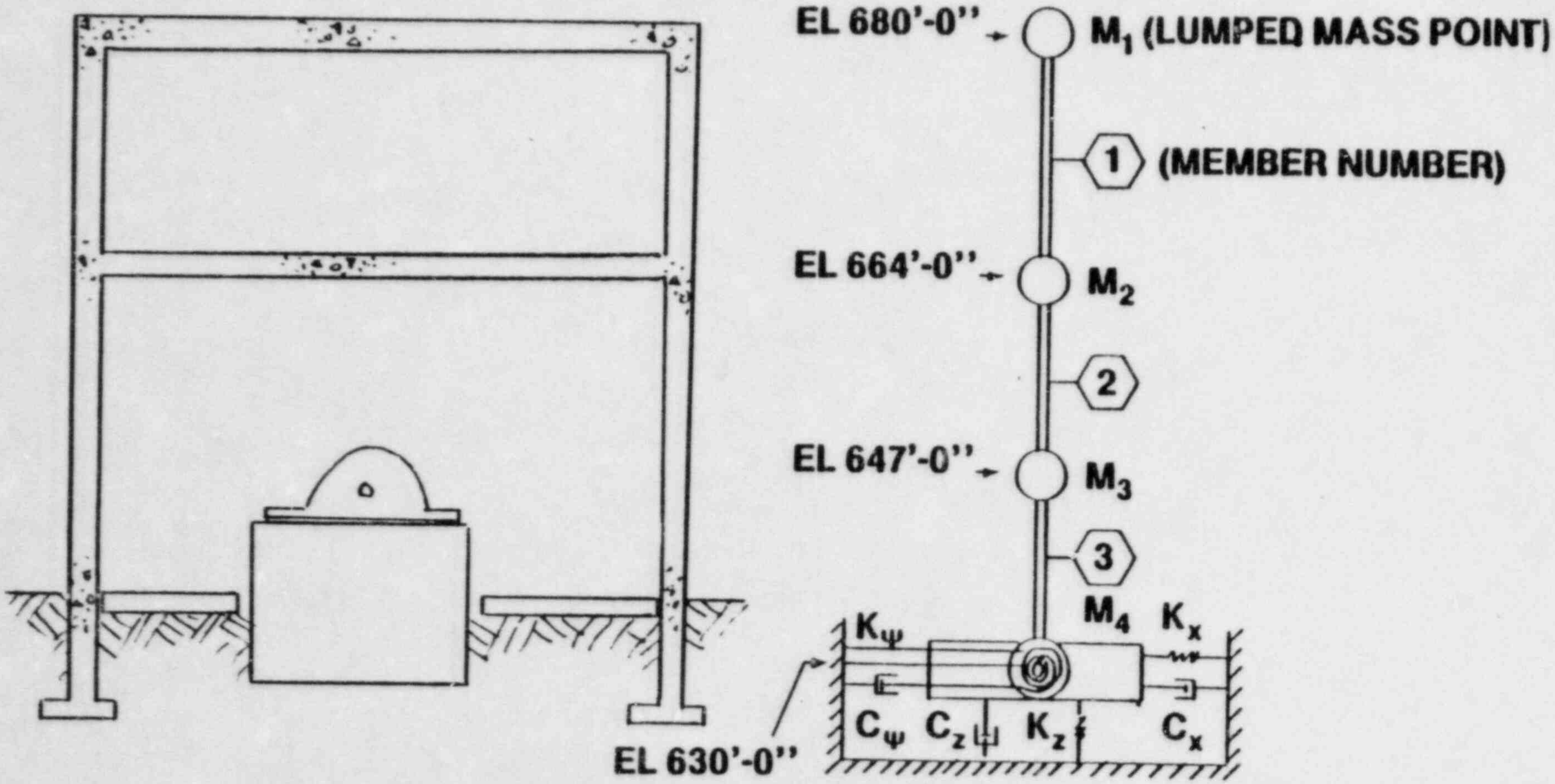
DIESEL GENERATOR BUILDING
SEISMIC MODEL



MIDLAND UNITS 1 AND 2
JULY 1983

25-G-3057-10

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DIESEL GENERATOR BUILDING
SEISMIC ANALYSIS

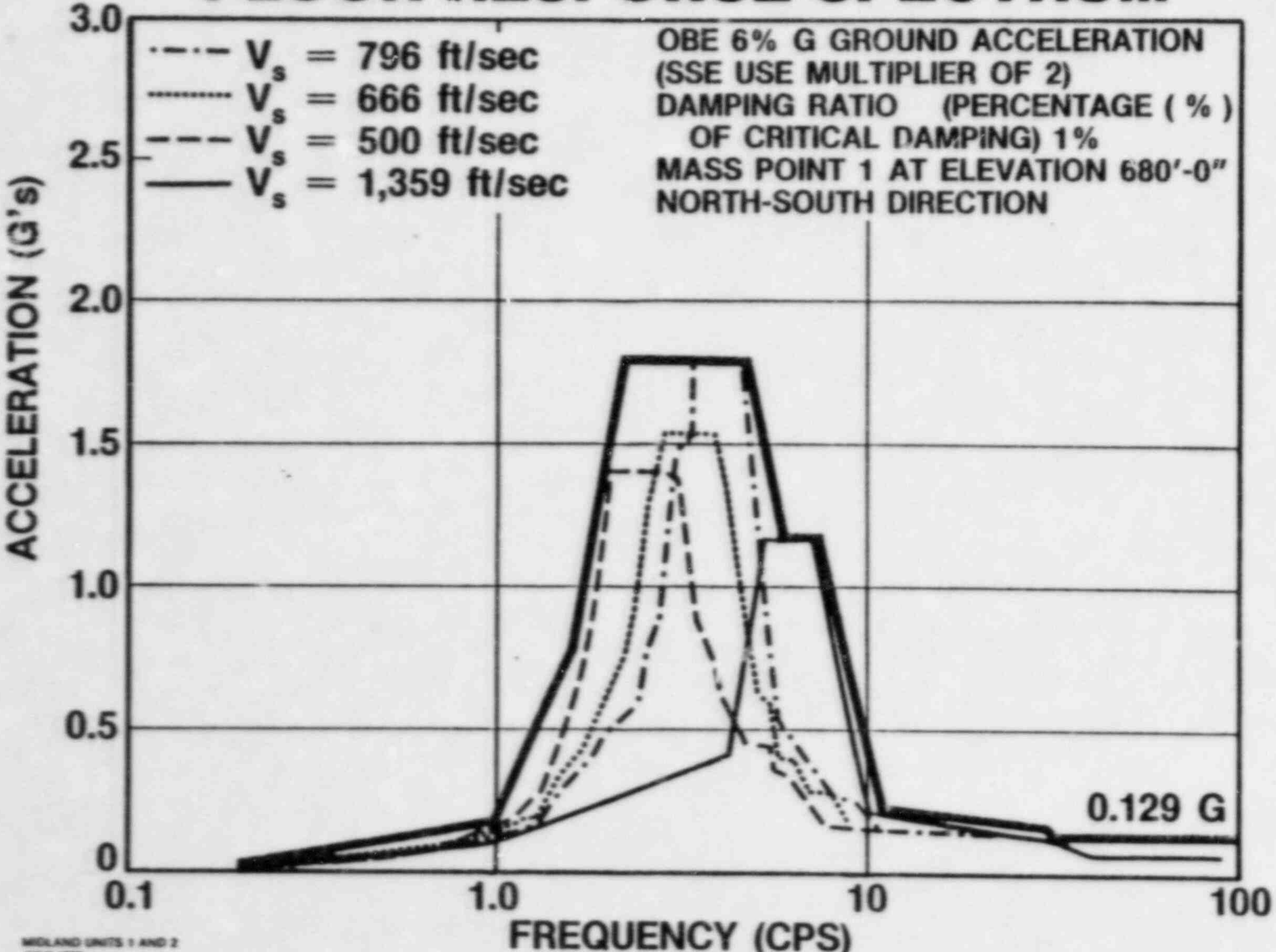
SOIL DYNAMIC PROPERTIES	ORIGINAL	SPECIAL 10 CFR 50.54	WEIGHTED AVERAGE	FSAR NOMINAL
V_S (FPS)	1,359	500	796	666
G (KSF)	7,750	971	2,275	1,593
μ	0.42	0.40	0.45	0.45
ρ (PCF)	135	125	115.6	115.6

DIESEL GENERATOR BUILDING
SEISMIC

ANALYSIS

- TIME-HISTORY
- RESPONSE SPECTRUM

DIESEL GENERATOR BUILDING
FLOOR RESPONSE SPECTRUM



MIDLAND UNITS 1 AND 2
JULY 1983

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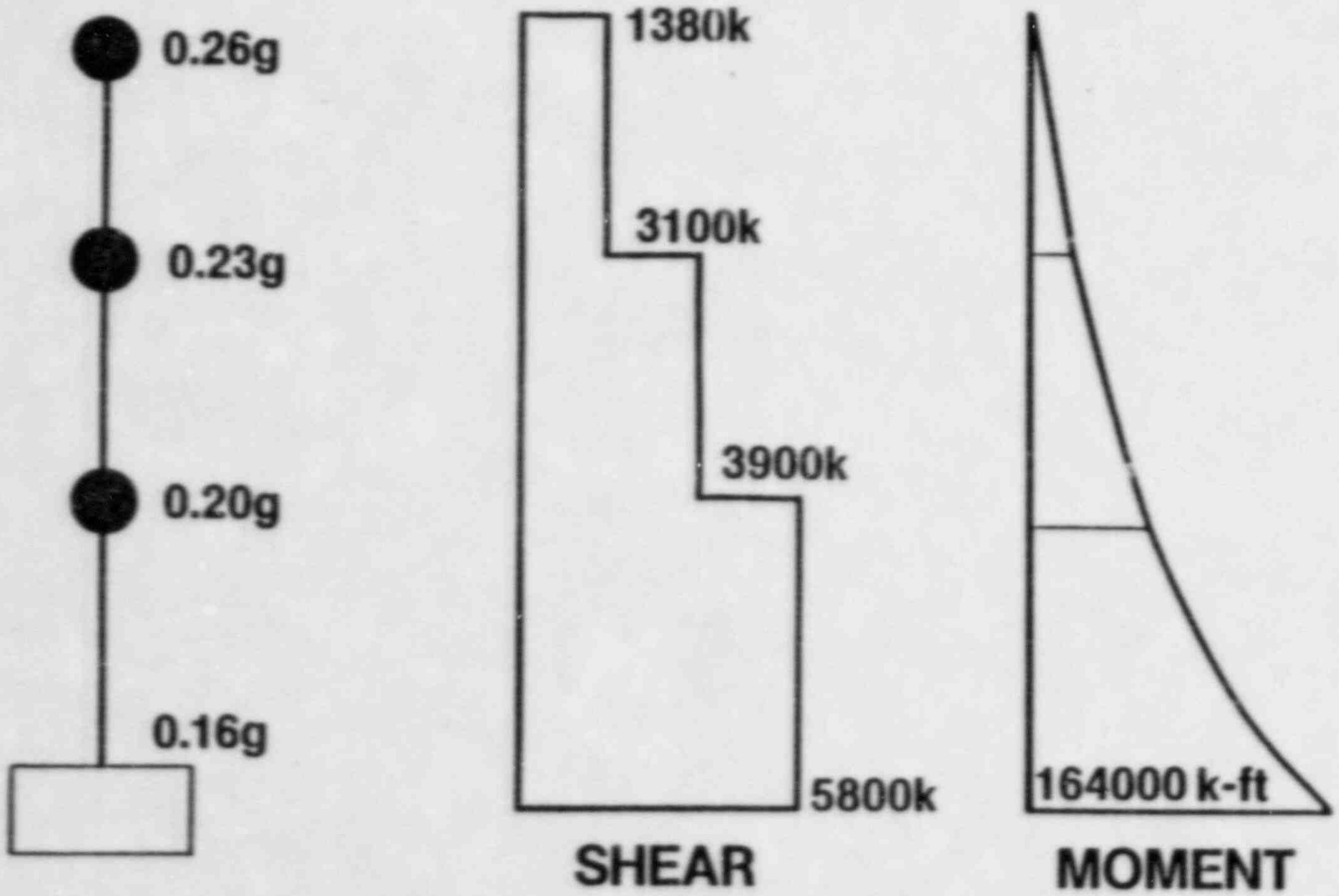
DIESEL GENERATOR BUILDING
SEISMIC ANALYSIS

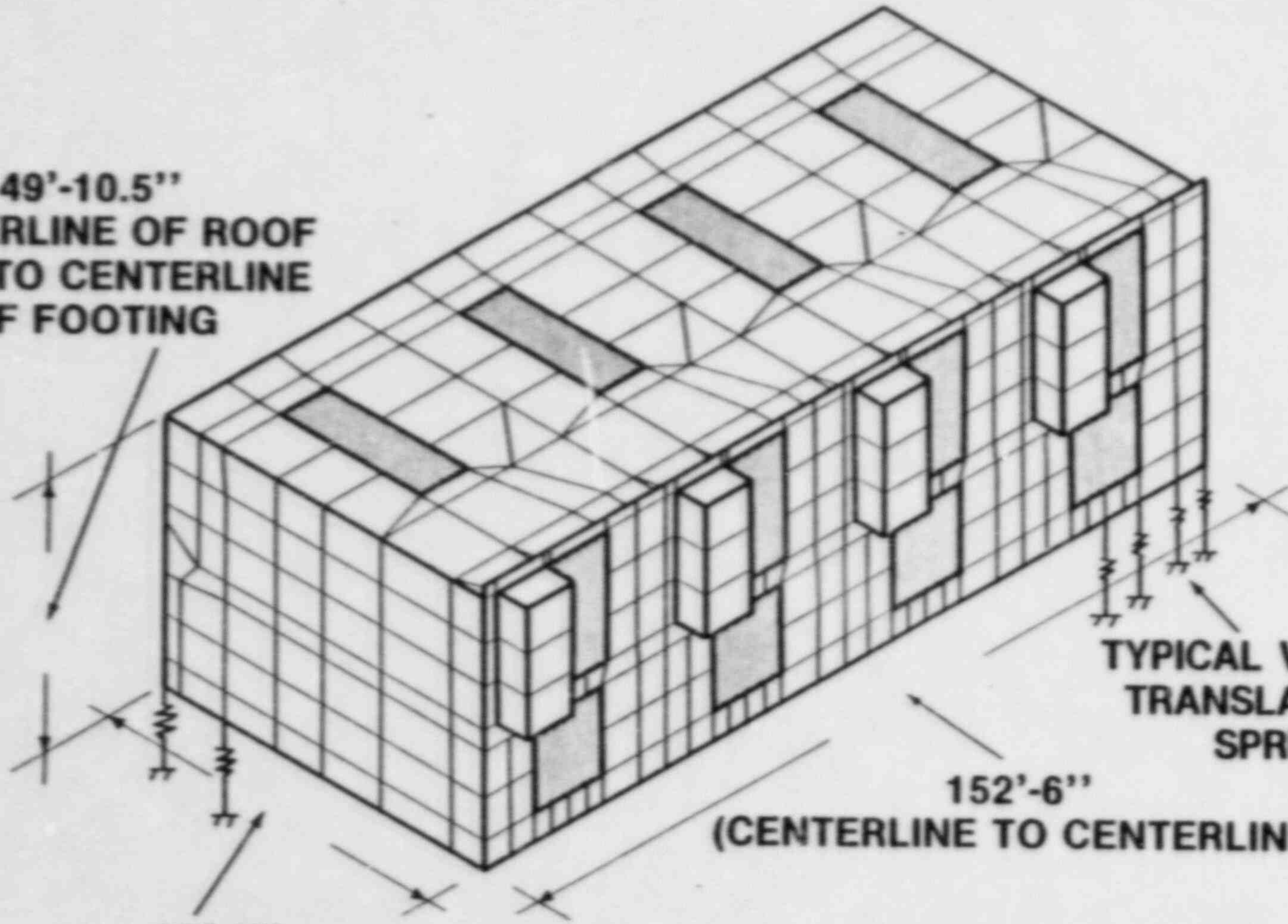
RESULTS



North-South Earthquake (SSE)

DIESEL GENERATOR BUILDING

FINITE ELEMENT MODEL



MIDLAND UNITS 1 AND 2
JULY 1982

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DIESEL GENERATOR BUILDING

FINITE ELEMENT ANALYSIS

PLATE ELEMENTS	901
BEAM ELEMENTS	141
BOUNDARY ELEMENTS	252
TOTAL	1,294
NODES	853

BSAP PROGRAM

LINEAR ELASTIC STATIC ANALYSIS

DIESEL GENERATOR BUILDING

FINITE ELEMENT ANALYSIS

- DEAD LOAD — GRAVITY
- LIVE LOAD — PRESSURE
- EARTHQUAKE — ACCELERATIONS
- TORNADO — PRESSURE, CONCENTRATED LOADS
- SETTLEMENT — SOIL SPRINGS

DIESEL GENERATOR BUILDING
FINITE ELEMENT ANALYSIS

- SOIL SPRINGS (BOUNDARY ELEMENTS)

  No Settlements (Approximately 16,000 KSF/Ft)

  Short Term Loading (Seismic)

  Long Term Loading (Settlement)

DIESEL GENERATOR BUILDING
SETTLEMENT

MEASURED/PREDICTED	NW	SE	ERROR BAND
A) 3/78 - 8/78	1.19″	1.99″	± 1/8″
B) 8/78 - 1/79	0.77″	2.21″	± 1/8″
C) 1/79 - 8/79	1.50″	3.24″	± (1/8 + 0.1)
D) 9/79 - 12/2025	1.33″	1.89″	± 0.2″
	4.78″	9.33″	

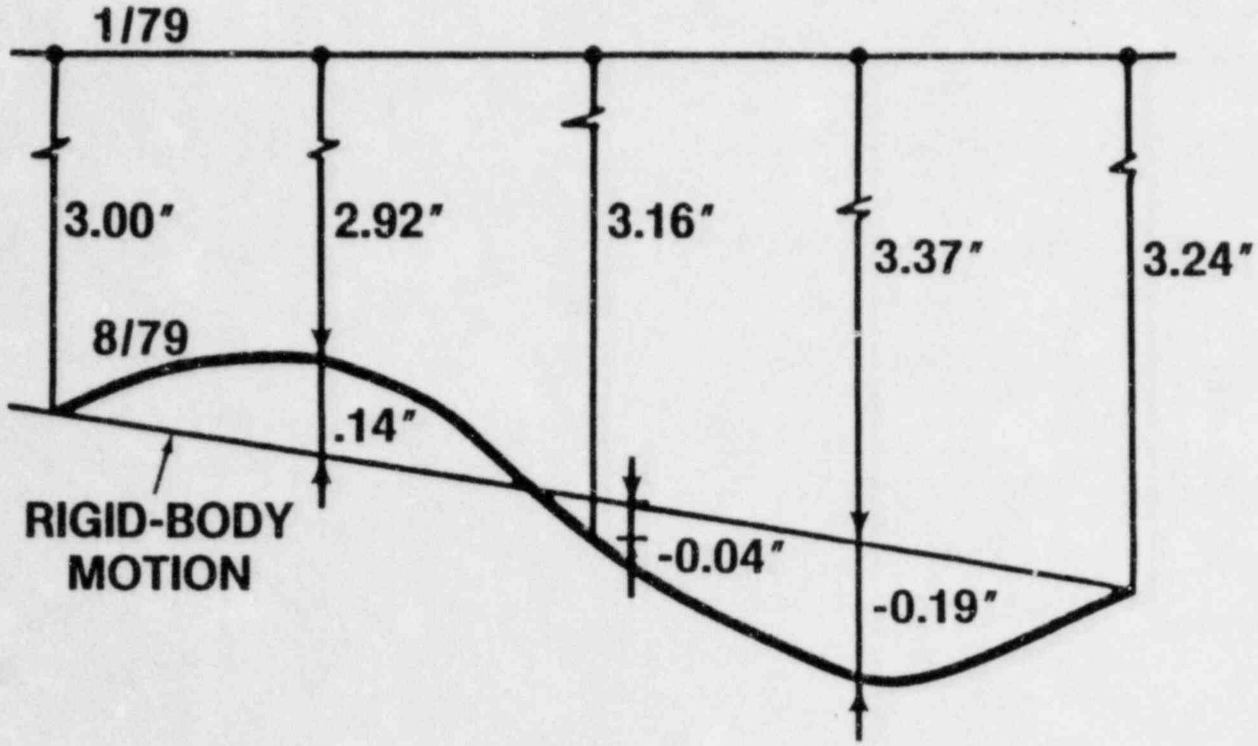
DIESEL GENERATOR BUILDING
ERROR IN SETTLEMENT VALUES

- PRECISION OF SURVEY INSTRUMENTS
- READING AND RECORDING ERRORS
- SYSTEMATIC ERRORS

  (SCRIBE MARK ⟶ MARKER
  SUBSTITUTED MARKER ⟶ MARKER)
- EXTRAPOLATION ERRORS

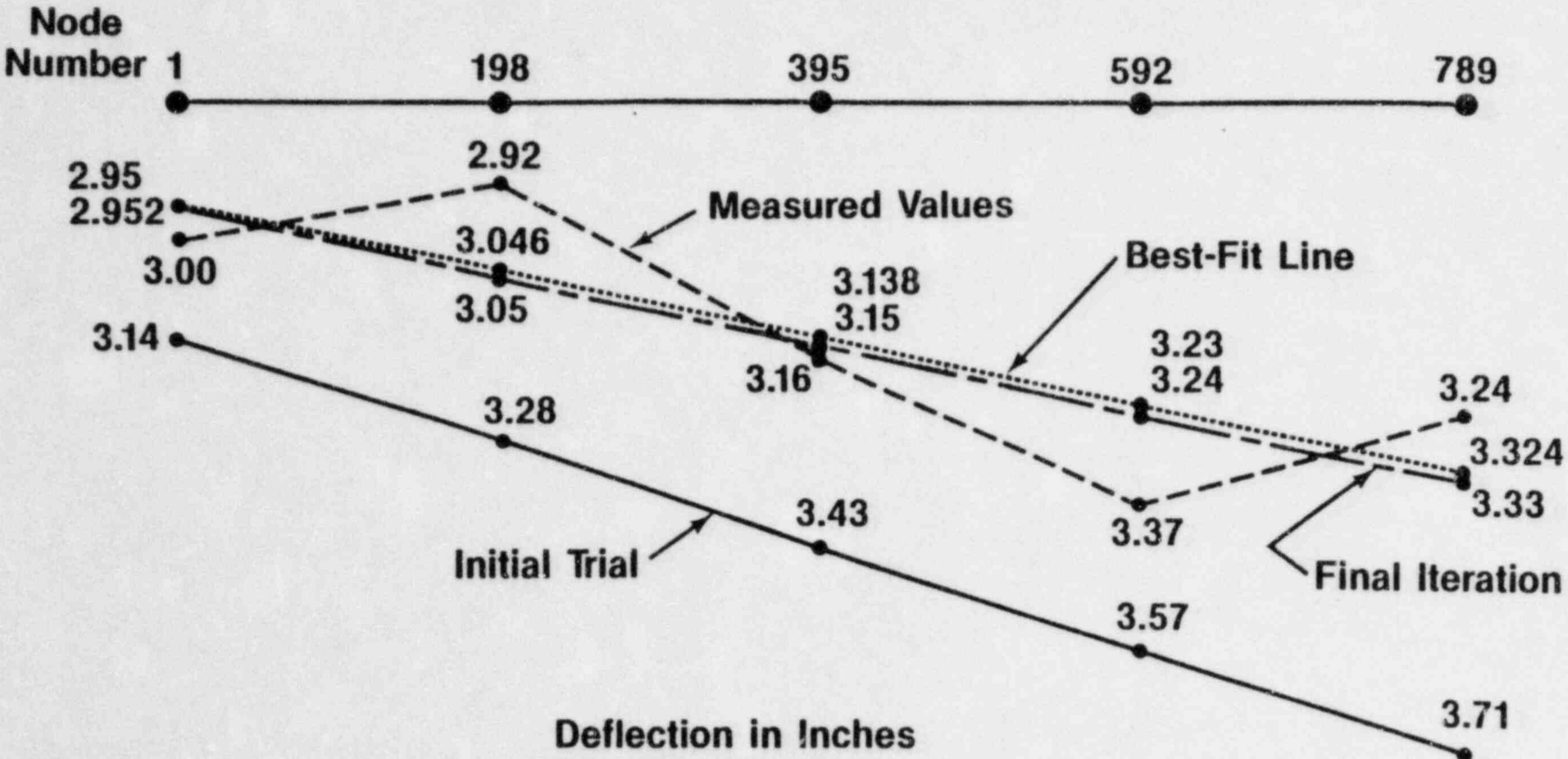
TOTAL ERROR = ± (1/8 + 0.1″)

DIESEL GENERATOR BUILDING
MEASURED SETTLEMENT ALONG SOUTH WALL



DIESEL GENERATOR BUILDING

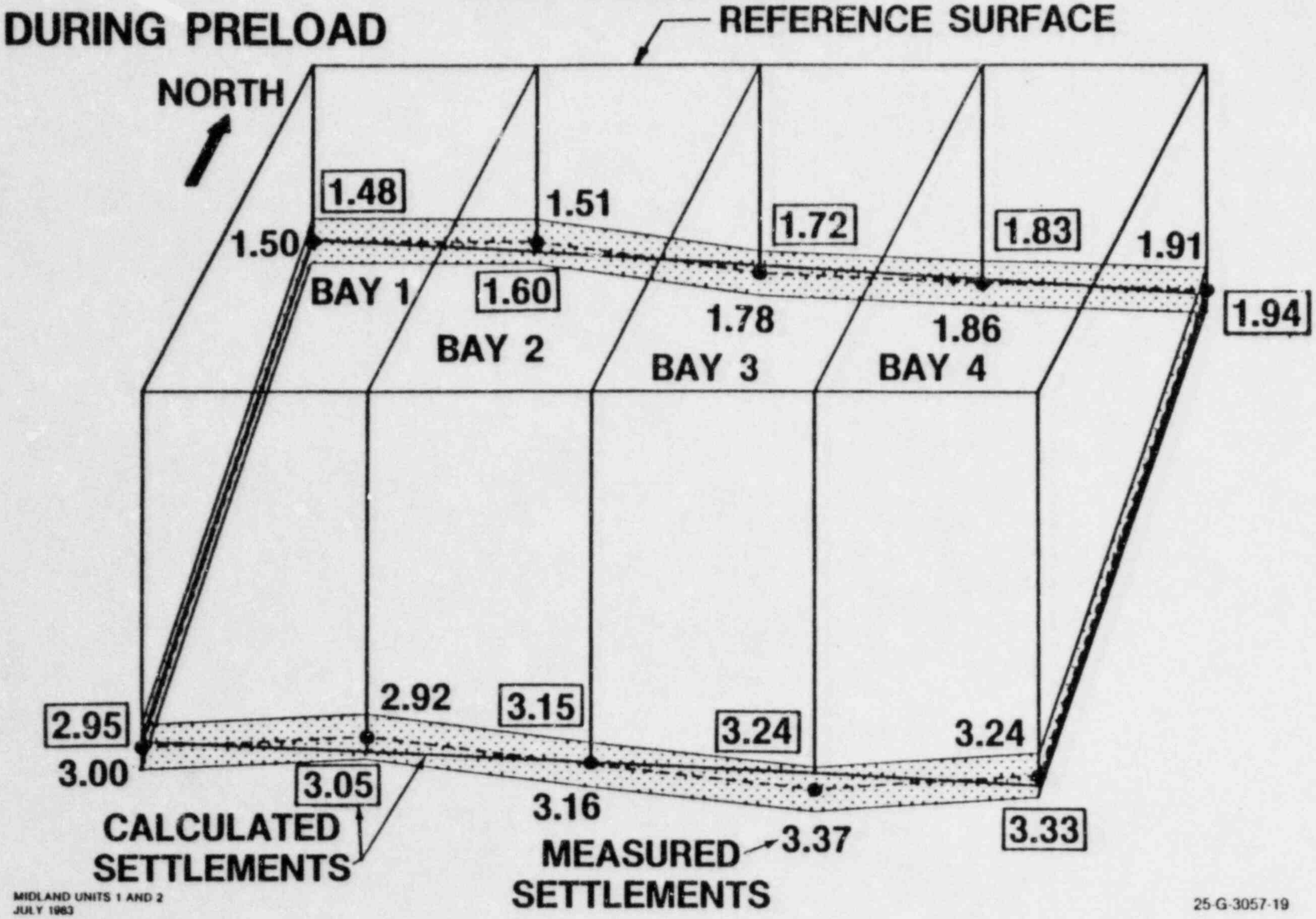
SOUTH WALL SETTLEMENT — SURCHARGE CONDITION



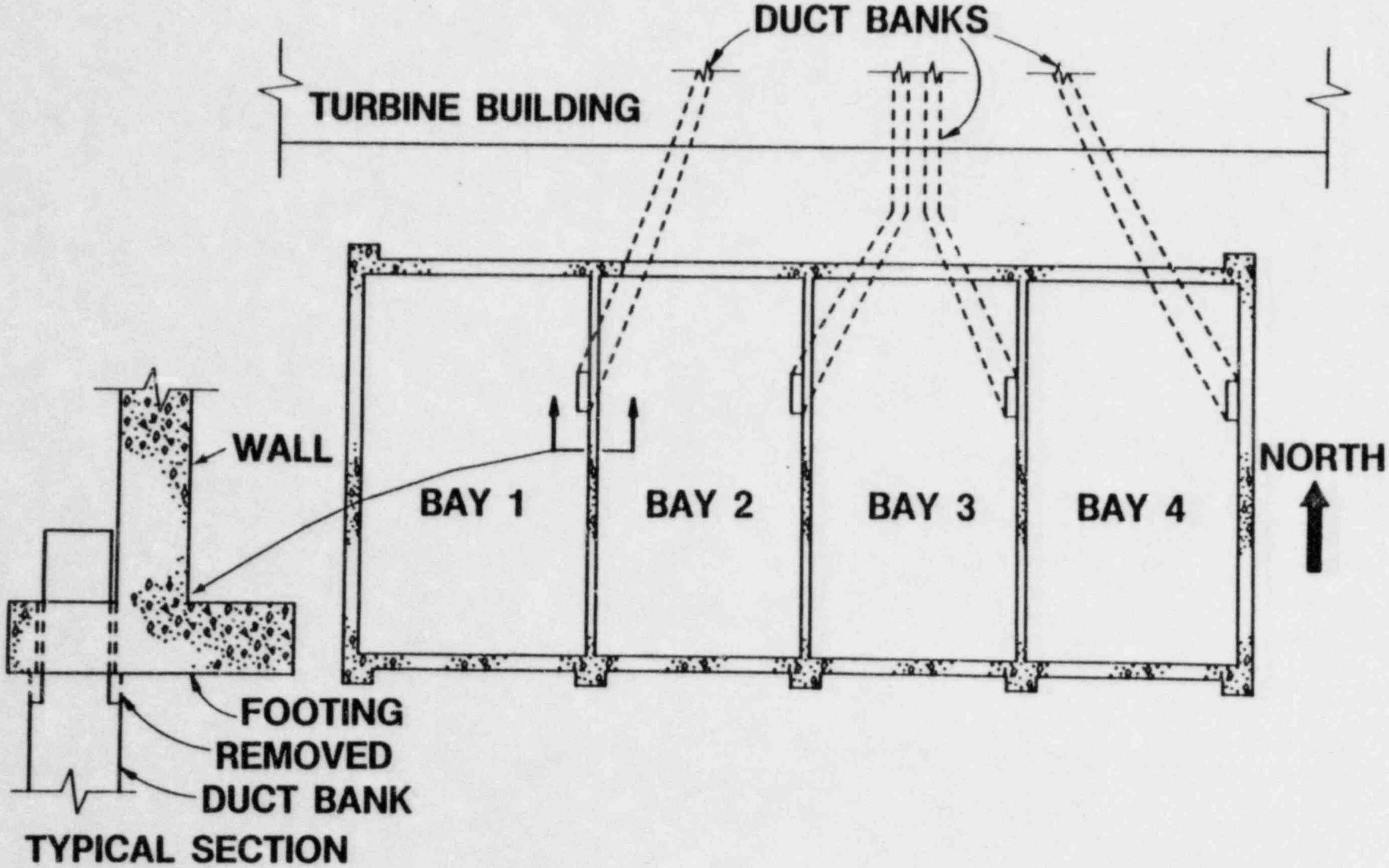
Deflection in Inches
View Looking North

$$K_{i+1} = K_i \frac{\Delta_I}{\Delta_{BF}}$$

DIESEL GENERATOR BUILDING
SETTLEMENT



DIESEL GENERATOR BUILDING
DUCT BANK LAYOUT



MIDLAND UNITS 1 AND 2
JULY 1983

27-G-3057-26

DIESEL GENERATOR BUILDING
ANALYSIS

- **CONCRETE WALLS AND SLABS**

  Axial Load + Moment — OPTCON

  (Thermal Gradient)

  Out of Plane Shear

- **SPREAD FOOTING**

  Bending and Shear

  Bearing Pressure

DIESEL GENERATOR BUILDING

MAXIMUM STRESSES IN REINFORCEMENT (KSI)

LOCATION	STRESS	ALLOWABLE	LOADING
South Shield Wall in Bay 2	47	54	(D + T + L + E′ + To)
South Wall	34	54	1.4 (D + T) + 1.7 (L) + 1.9 (E)
Footing	37	54	1.4 (D + T) + 1.7 (L) + 1.9 (E)
Slab @ 664′	34	54	1.4 (D) + 1.7(L)
Roof Slab	45	54	$(D + W_T)$

2r

DIESEL GENERATOR BUILDING

TYPICAL STRESSES IN REINFORCEMENT (KSI)

	MIDLAND POSITION		ACI 349	
LOCATION	STRESS	LOADING	STRESS	LOADING
Exterior Wall	14	FSAR Tornado	15	Tornado
Interior Wall	11	FSAR Tornado	16	Tornado
Roof Slab	45	FSAR Tornado	45	Tornado
Slab @ El 664′	34	Dead & Live	34	Dead & Live
Footing	35	FSAR Tornado	37	Seismic

DIESEL GENERATOR BUILDING

CONCRETE STRESSES (PSI)

TYPE	LOCATION	LOADING	STRESS	ALLOWABLE
Flexural Compression	Roof	Tornado	1560	3400
Shear (Out-of-Plane)	Exterior Wall	Tornado	45	126
Shear	Slab @ 664′	Dead & Live	79	126
Shear	Roof Slab	Tornado	36	141
Shear	Footing	Dead & Live	47	126

DIESEL GENERATOR BUILDING
STRUCTURAL REANALYSIS

CONCLUSION

- **DGB MEETS ACI 318 AND ACI 349 CODES**
- **CONSERVATISM**
  - Elastic Analysis
  - Peak Stress
  - Tornado

DIESEL GENERATOR BUILDING

- ADDITIONAL ANALYSIS
- MONITORING
  - Settlement
  - Cracks
- CRACK REPAIR

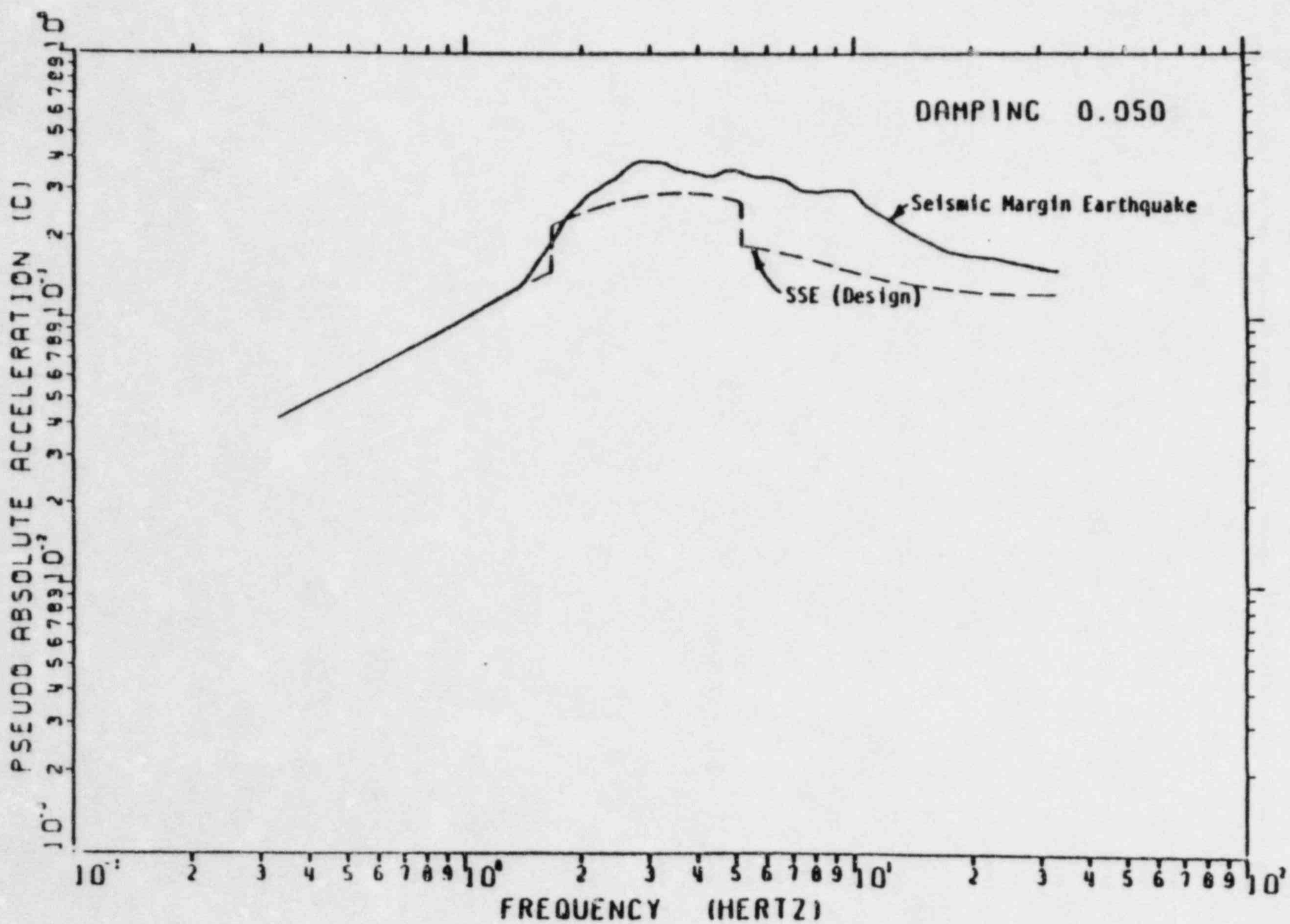


FIGURE I-2-4. COMPARISON OF SME AND FSAR (SSE) TOP OF FILL RESPONSE SPECTRA

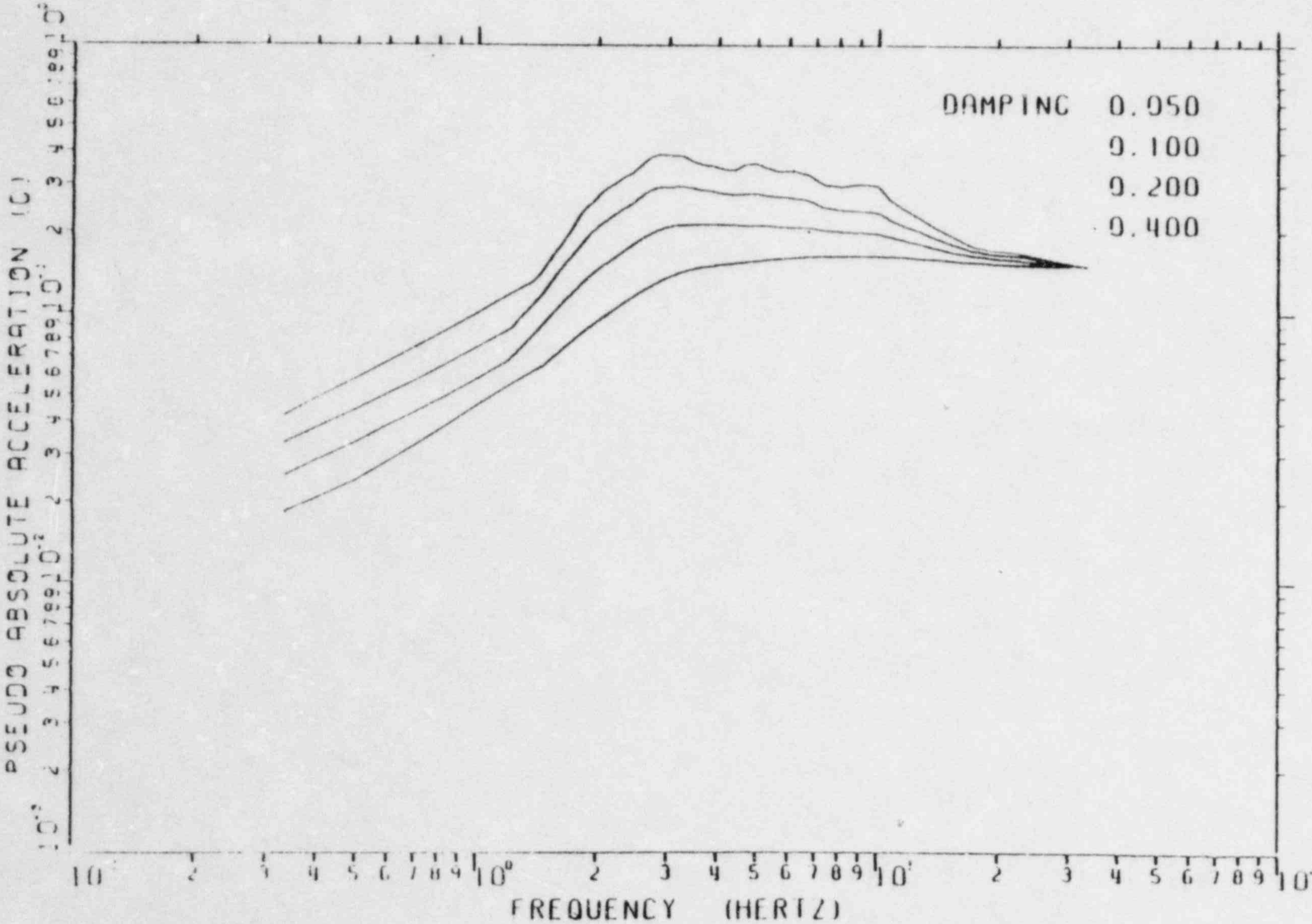


FIGURE I-2-2. SEISMIC MARGIN EARTHQUAKE TOP OF FILL ENVELOPE RESPONSE SPECTRA

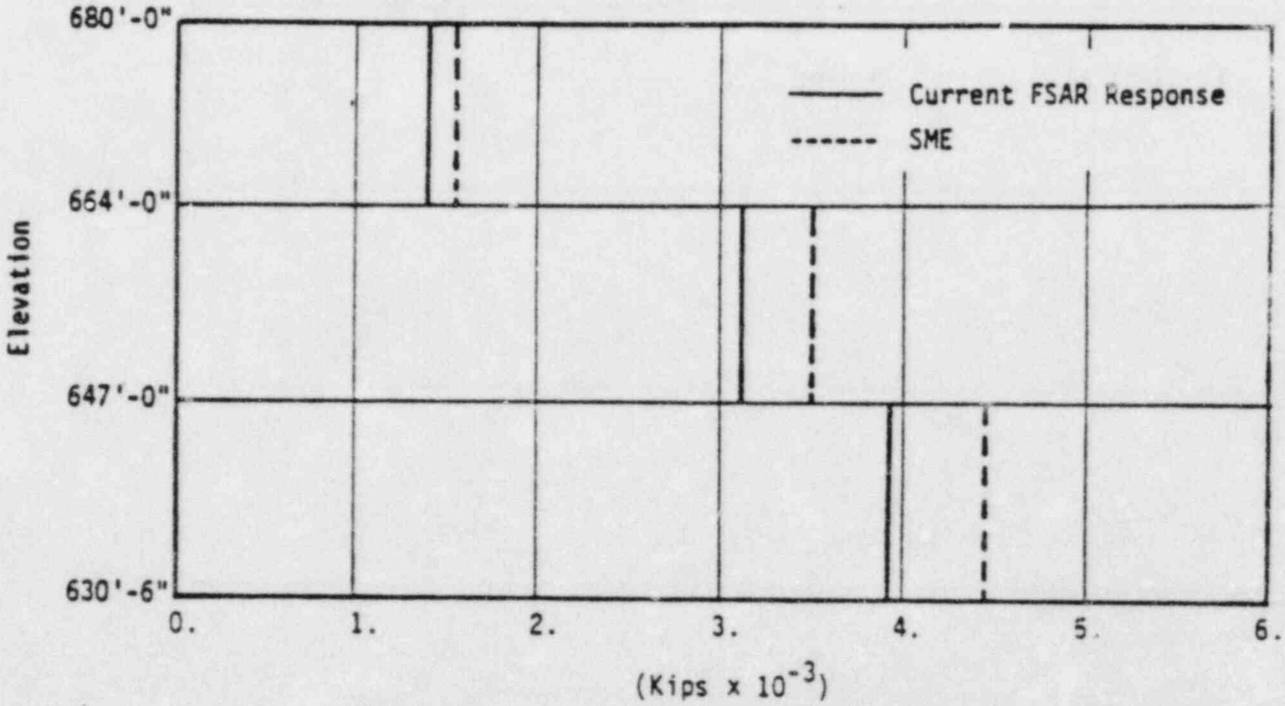


FIGURE V-3-9. DIESEL GENERATOR BUILDING N-S SHEAR COMPARISON

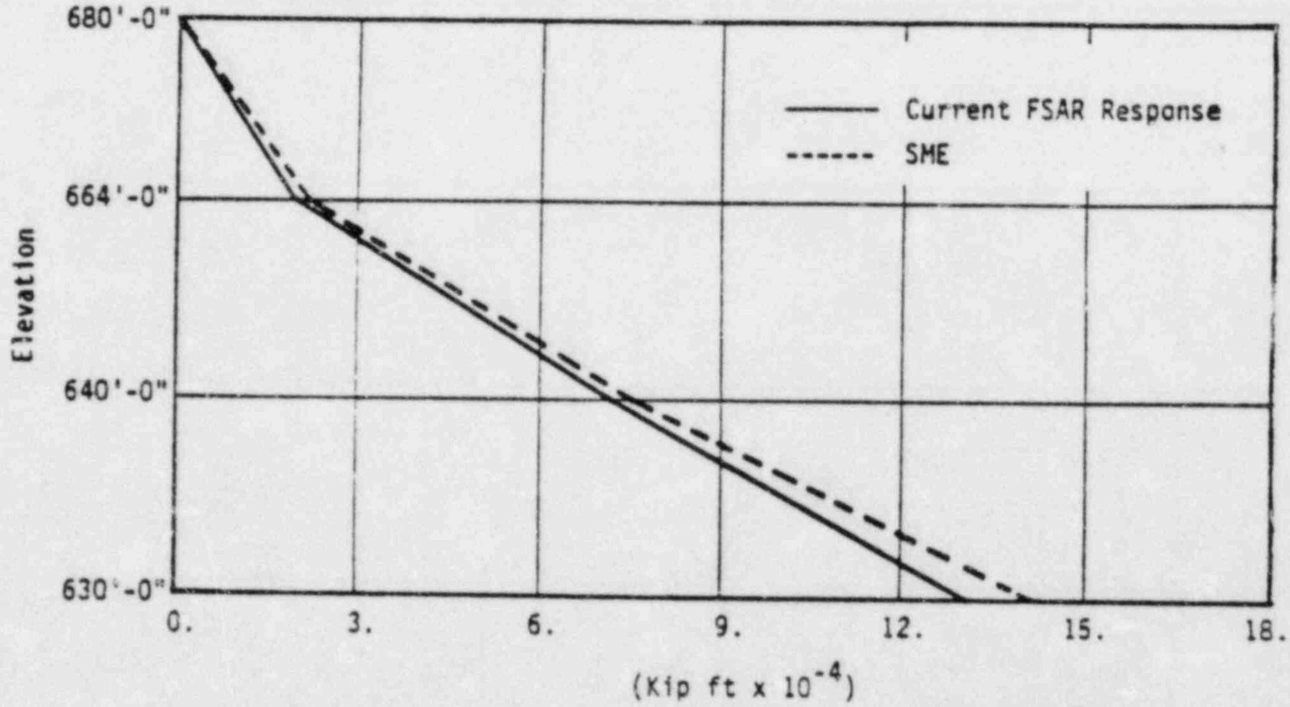


FIGURE V-3-8. DIESEL GENERATOR BUILDING MOMENT ABOUT N-S AXIS COMPARISON

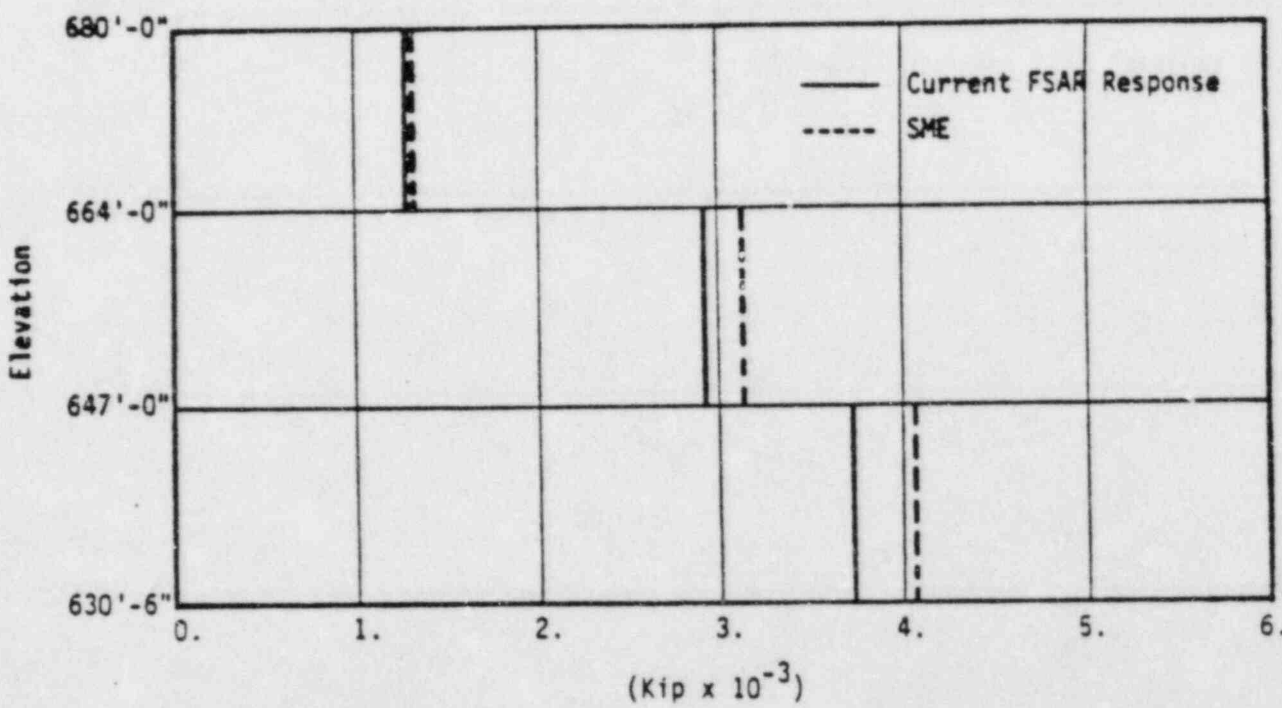


FIGURE V-3-7. DIESEL GENERATOR BUILDING E-W SHEAR COMPARISON

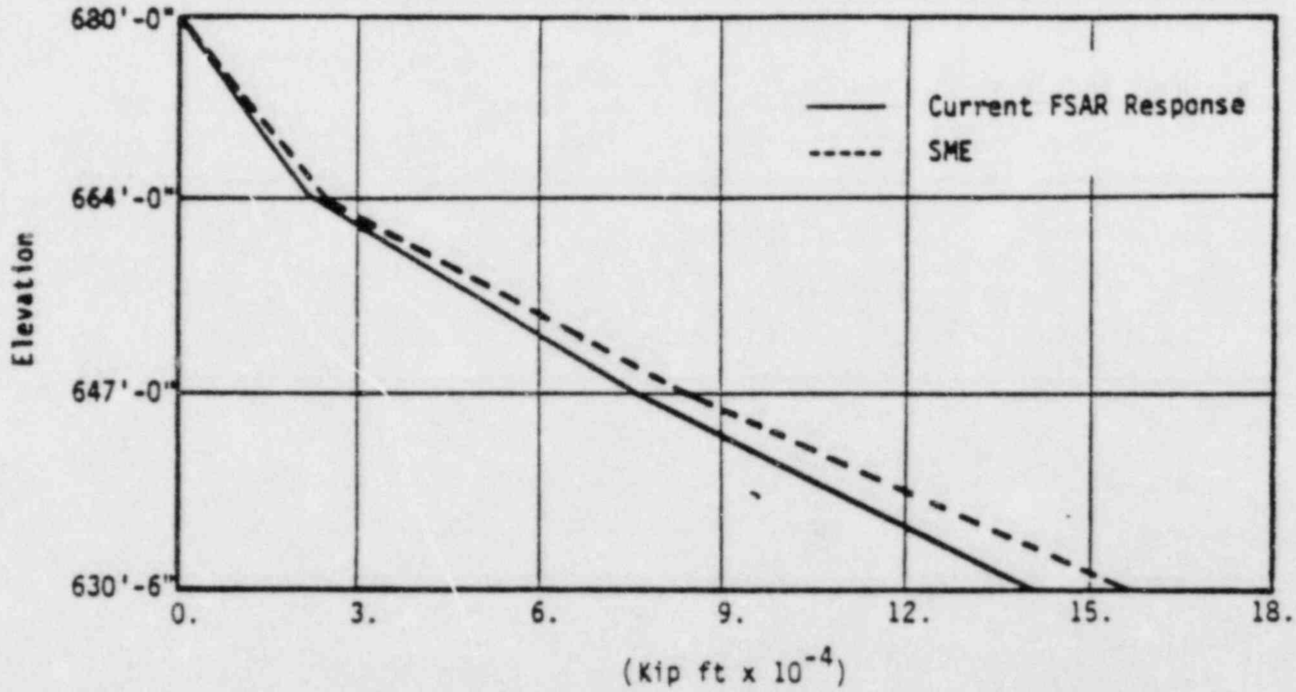


FIGURE V-3-6. DIESEL GENERATOR BUILDING MOMENT ABOUT E-W AXIS COMPARISON

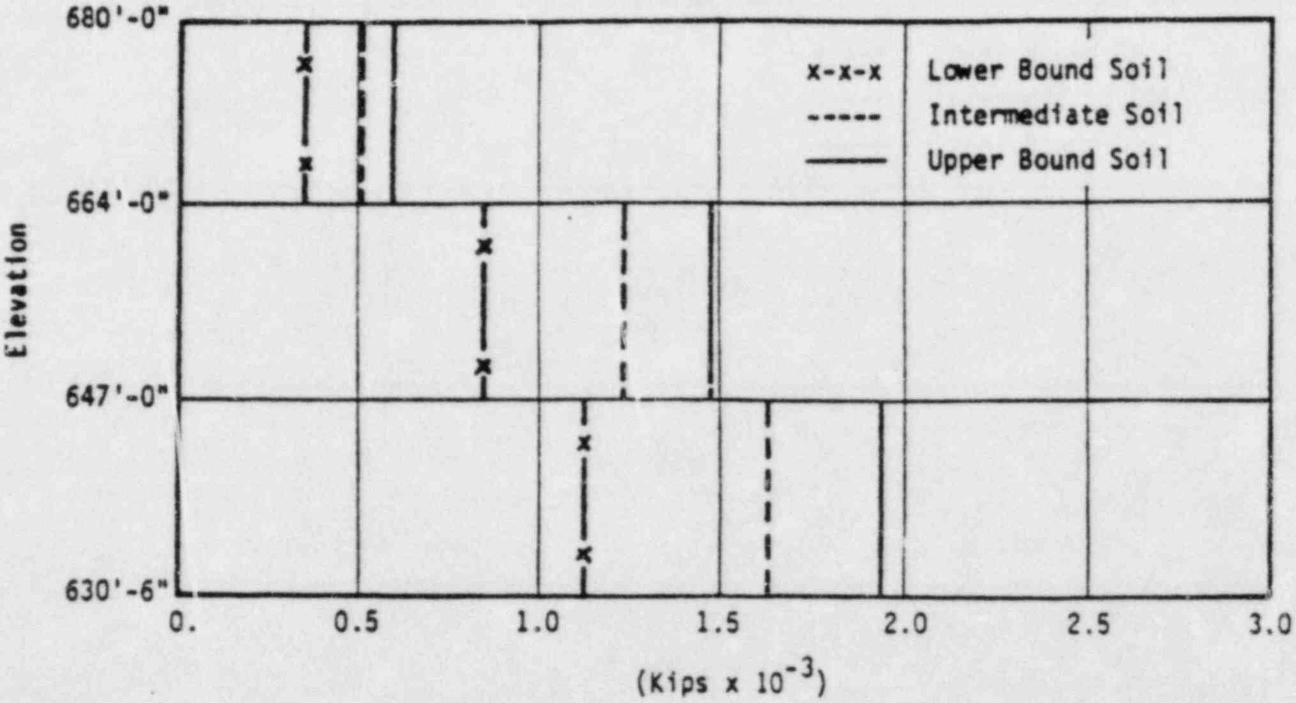


FIGURE V-3-5. DIESEL GENERATOR BUILDING AXIAL FORCE

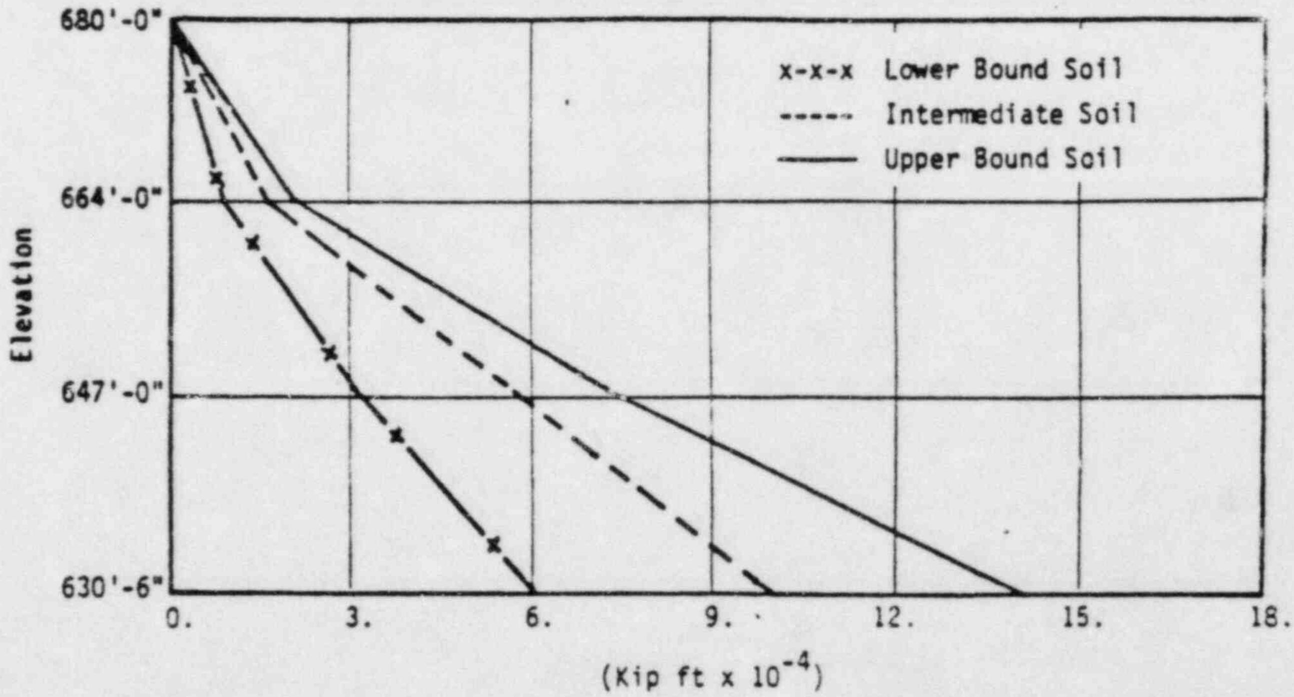


FIGURE V-3-3. DIESEL GENERATOR BUILDING MOMENT ABOUT N-S AXIS

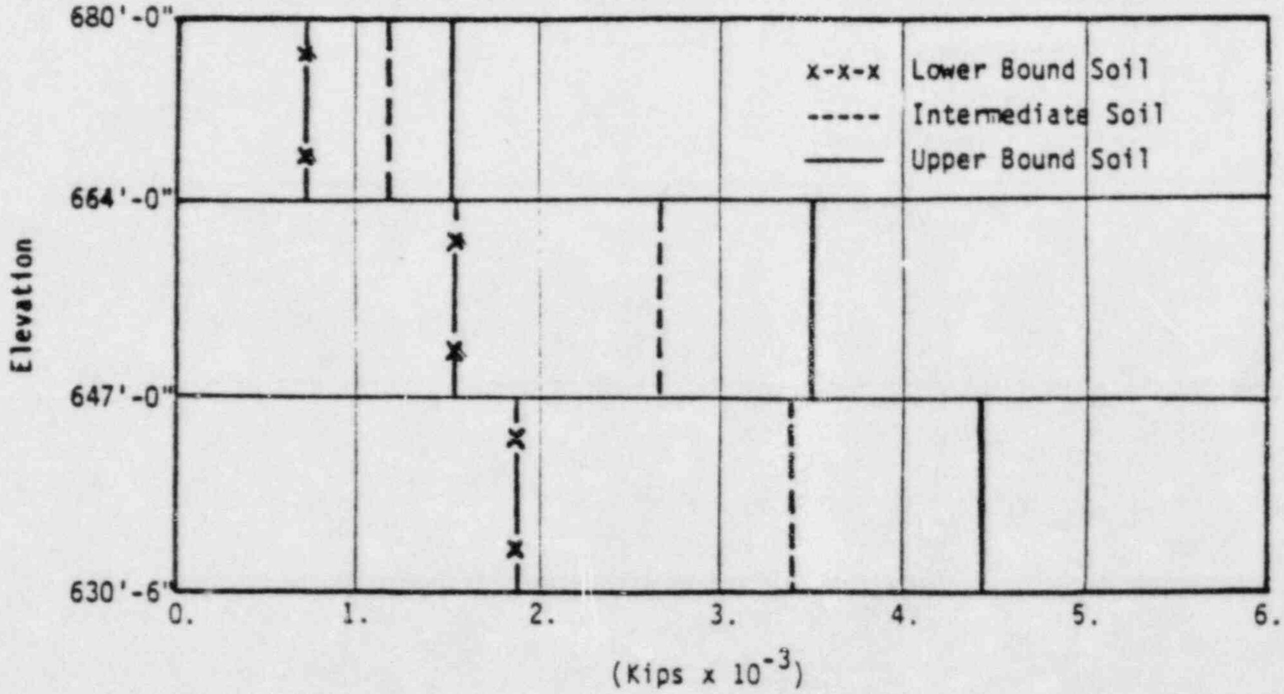


FIGURE V-3-1. DIESEL GENERATOR BUILDING N-S SHEAR

Elevation	Material	Properties	Moduli
634			
628			
	Fill	W_s = 120 pcf ν = 0.42 V_s = 570 fps	G_{max} = 1.2 x 10^6 psf G_{ms} = 1.87 x 10^6 psf G_{SME} = 0.75 x 10^6 psf
615			
	Fill	W_s = 120 pcf ν = 0.42 V_s = 850 fps	G_{max} = 2.7 x 10^6 psf G_{ms} = 3.28 x 10^6 psf G_{SME} = 1.7 x 10^6 psf
596			
	Glacial Till	W_s = 135 pcf ν = 0.42 V_s = 2300 fps	G_{max} = 22.2 x 10^6 psf G_{SME} = 17.3 x 10^6 psf
463			
	Glacial Till	W_s = 135 pcf ν = 0.42 V_s = 3000 fps	G_{max} = 37.8 x 10^6 psf G_{SME} = 32.5 x 10^6 psf
363			
	Dense Cohesionless Material	W_s = 135 pcf ν = 0.34 V_s = 3000 fps	G_{max} = 37.8 x 10^6 psf G_{SME} = 40.3 x 10^6 psf
263			
	Bedrock	W_s = 1[illegible]0 pcf ν = 0.33	V_s = 5000 fps

FIGURE V-1-4. UPPER BOUND LAYERED SOIL PROFILE BASED ON STIFF SITE DATA

Elevation	Material	Properties		Moduli	
634					
628					
	Fill	W_s = 120 pcf		G_{max} = 0.9 x 10^6 psf	
		ν = 0.42		G_{ms} = 1.40 x 10^6 psf	
		V_s = 490 fps		G_{SME} = 0.30 x 10^6 psf	
615					
	Fill	W_s = 120 pcf		G_{max} = 2.0 x 10^6 psf	
		ν = 0.42		G_{ms} = 2.50 x 10^6 psf	
		V_s = 730 fps		G_{SME} = 0.70 x 10^6 psf	
603					
	Fill	W_s = 120 pcf		G_{max} = 2.7 x 10^6 psf	
		ν = 0.42		G_{ms} = 3.16 x 10^6 psf	
		V_s = 850 fps		G_{SME} = 0.85 x 10^6 psf	
596					
	Glacial Till	W_s = 135		G_{max} = 7.0 x 10^6 psf	
		ν = 0.47			
		V_s = 1290 fps		G_{SME} = 1.2 x 10^6 psf	
550					
	Glacial Till	W_s = 135 pcf		G_{max} = 12 x 10^6 psf	
		ν = 0.47			
		V_s = 1690 fps		G_{SME} = 2.5 x 10^6 psf	
410					
	Dense Cohesionless Material	W_s = 135 pcf	V_s = 2540 fps	G_{max} = 27 x 10^6 psf	Elevation 410
		ν = 0.34		G_{SME} = 10.7 x 10^6 psf	
			V_s = 2970 fps	G_{max} = 37 x 10^6 psf	Elevation 260
				G_{SME} = 15.1 x 10^6 psf	
260					
	Bedrock	W_s = 150 pcf	V_s = 5000		
		ν = 0.33			

FIGURE V-1-3. LOWER BOUND LAYERED SOIL PROFILE BASED ON SOFT SITE DATA

Elevation	Material			
634				
628	Fill	W_s = 120 pcf ν = 0.42 V_s = 490 fps		G_{max} = 0.9 x 10^6 psf G_{ms} = 1.40 x 10^6 psf G_{SME} = 0.30 x 10^6 psf
615	Fill	W_s = 120 pcf ν = 0.42 V_s = 730 fps		G_{max} = 2.0 x 10^6 psf G_{ms} = 2.50 x 10^6 psf G_{SME} = 0.70 x 10^6 psf
603	Fill	W_s = 120 pcf ν = 0.42 V_s = 850 fps		G_{max} = 2.7 x 10^6 psf G_{ms} = 3.16 x 10^6 psf G_{SME} = 0.85 x 10^6 psf
596	Glacial Till	W_s = 135 ν = 0.47 V_s = 1290 fps		G_{max} = 7.0 x 10^6 psf G_{SME} = 1.2 x 10^6 psf
550	Glacial Till	W_s = 135 pcf ν = 0.47 V_s = 1690 fps		G_{max} = 12 x 10^6 psf G_{SME} = 2.5 x 10^6 psf
410	Dense Cohesionless Material	W_s = 135 pcf ν = 0.34	V_s = 2540 fps	G_{max} = 27 x 10^6 psf, G_{SME} = 10.7 x 10^6 psf } Elevation 410
			V_s = 2970 fps	G_{max} = 37 x 10^6 psf, G_{SME} = 15.1 x 10^6 psf } Elevation 260
260	Bedrock	W_s = 150 pcf ν = 0.33	V_s = 5000	

FIGURE V-1-3. LOWER BOUND LAYERED SOIL PROFILE BASED ON SOFT SITE DATA

Enclosure 4

August 24, 1983

MIDLAND PLANT UNITS 1 AND 2
DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

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MIDLAND PLANT UNITS 1 AND 2

DIESEL GENERATOR BUILDING

EXECUTIVE SUMMARY

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

MIDLAND PLANT UNITS 1 AND 2
DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

I. BACKGROUND

A. GENERAL

A construction permit for Midland Plant Units 1 and 2 was issued by the Atomic Energy Commission on December 15, 1972. Soils-related problems were first identified in July 1978 when the settlement monitoring program detected excessive settlement of the diesel generator building (DGB). The DGB has a shallow foundation and is located at the southern end of the main power block as shown in the site plan (Figure ES-1). The building had settled more than was predicted for this stage of construction. Shortly thereafter, the applicant verbally reported the matter to the NRC site inspector, and formally reported it under 10 CFR 50.55(e) in September 1978.

B. LAYOUT

The DGB is a two-story, reinforced-concrete structure with three crosswalls that divide the structure into four cells; each cell contains a diesel generator unit. The building is supported on continuous footings that are founded at el 628' and rests on fill that extends down to approximately el 603'. Plan dimensions of the DGB are approximately 155' x 70' with a total internal height of approximately 44 feet as shown in Figure ES-2. Each diesel generator rests on a 6'-6"-thick, reinforced-concrete pedestal that is not structurally connected to the building foundation.

C. ORIGINAL DESIGN

1. Philosophies

The DGB is a Seismic Category I, safety-related structure designed to protect the diesel generators and associated equipment and to protect this equipment from extreme environmental conditions such as seismic events and tornado and wind loads. As a result of these requirements, a box-type, reinforced-concrete structure with thick walls and roof was chosen. The building is supported by strip or continuous footings. The diesel generators, supported on separate foundations, isolate the building from any potential vibration problem.

2. Structural Systems

In general, conventional and standard calculations were used to analyze and design the various components of the structural system. Computer analysis using the finite-element method was used in some cases such as the settlement monitoring program detected settlements of 3.5 inches at the point of greatest settlement, compared to the design predictions of 3 inches for the 40 years of expected plant operation. It appeared that the building was settling due to the consolidation of the underlying fill and was being partially supported along the north portion by four electrical duct banks acting as vertical piers resting on the natural soil below the fill. Shortly thereafter, the applicant verbally reported the matter to the NRC site inspector, and formally reported it under 10 CFR 50.55(e) in September 1978.

Construction of the DGB was voluntarily stopped in August 1978 and a soil boring program was initiated to determine the quality of the backfill under the foundation. Drs. R.B. Peck and A.J. Hendron, Jr. were retained as consultants to advise on the selection and the execution of any remedial action.

The exploration program confirmed that the fill did not meet the specified compaction requirements and that it consisted of both cohesive soil and granular soil. Lean concrete was also used locally as backfill. The fill ranged from very soft to very stiff for cohesive soil and from very loose to dense for granular soil. At the time of the exploration, the groundwater level ranged from el 616' to el 622', and the cooling pond, located about 275 feet south of the building, had a water level at approximately el 622'.

On the basis of the consultants' recommendations and after a review of various alternatives, it was decided to surcharge the DGB and the surrounding area to accelerate settlement and consolidate the fill material. During November 1978, the duct banks (see Figure ES-2A) entering the DGB were isolated from the building so additional settlement due to surcharging and the additional deadweight of the structure to be constructed would not overstress these areas. Construction of the building was also resumed in November 1978 with the remainder of the concrete work on the building being essentially completed by the end of March 1979. Before the surcharge program began in January 1979, the utilities entering the DGB were isolated from the DGB so that settlement during surcharging would not overstress these areas. The utilities were reconnected after the surcharge program was completed in August 1979.

III. <u>REMEDIAL PROGRAM</u>

A. SURCHARGE PROGRAM

The purpose of the surcharge was to accelerate the settlement so that future settlement under the operating loads would be within tolerable limits. Furthermore, this procedure would permit a reliable estimate of the future settlement. Before the surcharge was placed, soil instrumentation was installed (see Table ES-1). The instrumentation was directed at monitoring settlement and pore water pressure in the fill.

building showed a maximum settlement of about 0.1 inch. This is less than the range of 0.2 to 0.5 inch, which was predicted on the basis of the previously mentioned straight-line extrapolation.

Following the start of dewatering activities in September 1980 up to December 31, 1981, the building settled 0.4 to 0.5 inch (see Figure ES-8) primarily due to lowering the groundwater table from approximately el 620' to el 595'. Between December 31, 1981, and June 1983, the building settled an additional 0.3 inch primarily due to further lowering of the groundwater table to approximately el 587'. As shown in Figure ES-6, these settlements display relatively steep slopes on the settlement-versus-log-time plot. However, when these data are compared with the observed settlements of the two Borros anchors BA-8 and BA-53 (see Figure ES-9) embedded in the natural soil below the structures, it is seen that most of the observed settlement of the building was due to deep settlement of the underlying natural soil caused by dewatering. When the uniform, deep-seated settlement of the natural soil (below el 603') due to dewatering is subtracted from the total building settlement, the resulting backfill settlement-versus-log-time plot (see Figure ES-10) displays a slope less than the one used for secondary consolidation settlement prediction. Therefore, the predictions of secondary consolidation settlement given in Figure ES-7 are conservative. Furthermore, any future dewatering settlements should be small because future drawdown would exceed the present magnitude by only small amounts.

Concern about liquefaction of the loose sand portions of the backfill is eliminated by permanent groundwater lowering. The settlement of the unsaturated sand because of ground shaking caused by earthquakes (shakedown settlement) was calculated on the basis of the approach described by Silver and Seed (Reference 2) and the recommendations on multidirectional shaking by Pyke, Seed, and Chan (Reference 3). The estimated shakedown settlement is approximately 1/4 to 1/2 inch for ground acceleration up to 0.19 g. The north side of the building will settle the maximum of 1/4 to 1/2 inch during the 0.19 g earthquake, whereas the south side will settle a negligible amount because there is a smaller thickness of sand under the south side of the DGB. Thus, the building will tend to rotate slightly toward the north during seismic shaking. To date, it has tended to rotate south during static settlement under the surcharge load due to the higher percentage of clay under the south side of the building.

surface to el 615' and by a value of 850 ft/sec from el 615' to el 600'. These numbers were used to determine the shear wave velocity value used in the seismic analysis of the DGB.

E. SURCHARGE EFFECTIVENESS

Figure ES-12 presents a comparison between the pressures that existed during surcharge and those expected during the operating life of the structure. This comparison shows that at all depths in the fill, the pressures that existed during surcharge exceeded those that are expected while the structure is operational. Furthermore, all settlement-versus-log-time plots show that secondary consolidation has been reached. Therefore, the settlements predicted on the assumption that the surcharge remains in place for 40 years (see Figure ES-7) are conservative based on the fact that all loads added after surcharge removal, including those due to permanent dewatering, will be less than the surcharge loading at all depths.

F. SETTLEMENT MONITORING

The settlement of the diesel generator building will be monitored during plant operation. Survey measurements will be taken at least every 90 days during the first year of plant operation. Survey frequency for subsequent years will be established after evaluating measurements taken during the first year. Allowable total settlements, which are based on the predicted values, have been established for each of the settlement markers on the structure and pedestals. If 80% of the allowable settlement (settlement action limit) is reached, survey frequency will be increased to at least once every 60 days and an engineering evaluation will be performed. If the allowable settlements are exceeded, the plant will be shut down until the structure's safety can be established.

IV. STRUCTURAL REANALYSIS

A structural reanalysis was performed on the DGB to determine the settlement and surcharging effects on the building.

A. DESIGN CRITERIA

The DGB is predominately made from 4,000 psi concrete (except the roof slab, which is 5,000 psi concrete) reinforced with Grade 60 steel bars. The building was originally designed for the ACI code allowables.

The load combinations employed for the original analysis and design of the DGB are provided in FSAR Subsection 3.8.6.3. The original FSAR load combinations did not contain a settlement effects term (T). Four additional load combinations were the boundary condition. Figure ES-13 illustrates an isometric view of the finite-element model.

2. Load Representation

The dead load is represented in the finite-element model by the acceleration due to gravity. The live load is represented by pressures applied to plate elements modeling the floors. Wind loads are represented by pressures on plate elements and concentrated nodal loads. Seismic loads are represented by accelerations and settlement effects are represented by the soil springs explained below.

3. Soils Springs

a) Short-Term Load Analysis

The overall translational soil impedances from the dynamic model are used to calculate soil springs in the finite-element analysis for short-term loads (i.e., wind, tornado, and seismic).

b) Analysis Without Settlement Effects

The analytical model for dead load and live load case without settlement effects was constructed by using large values for the soil springs.

c) Analysis for Settlement Effects

For long-term loadings with settlement effects, the structural reanalysis addresses four distinct time periods. A unique set of measured or estimated settlement values that corresponds to each of the following periods are used:

1) March 28, 1978, to August 15, 1978

The first scribe mark was placed on the structure on March 28, 1978. August 15, 1978, represents the closest survey date before halting DGB construction. The structure was partially completed to 26 feet (el 656'-6") above the top of the foundation. A long-hand analysis was used for calculating stresses.

2) August 15, 1978, to January 5, 1979

The duct banks were separated from the structure, and DGB construction activities resumed during this period. January 5, 1979, is the last survey date before the start of surcharge activities.

4. Analysis of Survey Data

An analysis of the survey data reveals that the data are not accurate enough to reflect the exact changes in the structural shape due to the settlement.

The results of a review of this survey data can be summarized as follows:

a) The difference between consecutive measurements at a building location reveals both positive and negative values. The negative values indicate that the structure moved up or a potential inaccuracy in measurement existed. Because the structure cannot easily move up against its own weight, it is likely that a negative value indicates an inaccuracy in measurement.

b) Review of relative displacements of the north and south walls show that the data vary irregularly. It cannot be concluded from these data that the structure developed differential settlement in the period considered.

c) Angle Variation Analysis

During the settlement period considered, random changes in algebraic sign exists for the vertical angle formed by three markers along the south wall of the DGB. Therefore, it can be concluded that the settlement of the structure during this period was mainly rigid body motion.

d) Warpage Analysis

The warpage across the structure was found to vary with time between positive and negative values. It can be concluded that the survey data are not sufficiently accurate to prove that the structure has developed differential settlement (warpage) across the corners.

Summarizing, the survey data analysis concludes that the existing data were not accurate enough for direct use in structural analysis and need to be modified, error bands were established to be between 0.125 inch and 0.225 inch for the four settlement periods. By smoothing the settlement vs time curves to compensate for the survey inaccuracies, the data reflect that the structure was experiencing mainly rigid body motion in the period during which settlement was measured.

junction of the south wall and the interior wall separating bays 3 and 4. Soil spring values were then linearly varied in the north as well as the east-west directions so that they returned to their original 40-year value within a distance of approximately 15 feet from the zero spring. It can be concluded from this analysis that the DGB can successfully span the assumed soft soil spot introduced without significantly increasing the stress levels.

E. EFFECTS OF CONCRETE CRACKS

A set of electrical duct banks located beneath the building foundation initially acted to restrain the even movement of the structure during fill settlement. A systematic crack pattern was observed in walls resting on the duct banks. Cracks in walls that do not rest on duct banks are attributable to the effect of restrained volume changes during curing and drying of the concrete. Cracks were first mapped after the duct banks were separated from the DGB and prior to surcharge placement. Another crack mapping of the DGB was performed after surcharge removal to acertain the effect of surcharge.

The concrete cracks within the DGB were formally addressed in the response to Question 29 of the NRC Requests Regarding Plant Fill. In this response, the cause and significance of the concrete cracks in all structures were presented. Subsequently, during the NRC structural technical audit of April 1981, further discussion was held concerning the effects of the cracks and the additional stresses resulting from the concrete cracks. To evaluate the additional stresses associated with the concrete cracking, a number of analytical approaches have been used and the results forwarded to the NRC in the response to Question 40 of the NRC Requests Regarding Plant Fill. These results indicated that because these stresses are strain-induced secondary stresses, they do not affect the ultimate strength capacity of the cracked member.

In response to an NRC request for a nonlinear, finite-element analysis to evaluate the effects of cracks on the integrity of the DGB, an additional computer analysis of the DGB was performed. This analysis was performed using a finite-element program, Automated Dynamic Incremental Nonlinear Analysis (ADINA), which is a three-dimensional, nonlinear program capable of considering concrete crushing, cracking, crack widening, and reinforcement yielding. The east wall of the DGB was selected for the ADINA analysis. A crack was modeled into the east wall, and the ADINA analysis was performed for two governing load combinations. The analysis indicated that the effect of concrete cracks was localized and minor in nature. The results of this ADINA analysis were submitted to the NRC, followed by meetings with the NRC staff to discuss these results.

the load distributions to the individual walls. The shear walls and diaphragms were evaluated for seismic loads combined with loads due to normal operating conditions predicted by static analyses.

Capacities for the shear walls were developed in accordance with the ultimate strength design provisions contained in ACI 349-80. Shear walls were checked for their ability to resist in-plane shears and overturning moments. Margin factors were determined for the selected walls based on comparisons of the loads due to seismic and normal operating conditions and the code ultimate strength capacities. The selected walls were found to be governed by overturning moment. The lowest code margin calculated was found to be 1.8. The SME must be increased by at least a factor of 2.2 before the code margin for any wall would be exceeded.

Diaphragm capacities were determined using ACI 349-80 criteria developed for shear walls. The diaphragms evaluated were found to be governed by shear. The lowest code margin for the diaphragms was found to be 2.0. For any diaphragm to reach code capacity, the SME must be increased by a factor of 2.1.

Code margins for the selected structural elements were all conservatively based on minimum specified material strengths and maximum seismic load cases. Reductions in loads to account for inelastic energy dissipation were not used for the DGB. All code margins were determined to be greater than unity. Before code capacity is reached for any DGB element investigated, the SME must be increased by 2.1. It can, therefore, be concluded that the DGB has more than sufficient structural capacity to resist the SME based on code criteria and significantly higher capacity before failure is expected.

V. CONCLUSIONS

The original design of the DGB, based on its overall geometry and layout, produced a structure with a great deal of reserve strength. The settlements during early stages of construction and during the surcharge program did not cause any unusual distress or significant loss of structural strength. The remedial program of surcharging the area with 20 feet of sand has caused the fill to now be under secondary consolidation. Future settlement can be conservatively predicted and will not be excessive. It has been shown through the soil exploration program that the fill material under the DGB does have sufficient reserve in bearing capacity to resist all the imposed loads with the proper safety factor. This area of the site is being permanently dewatered to eliminate any potential for liquefaction that could occur in the sand backfill below the DGB during a seismic event.

REFERENCES

1. H.B. Seed, "Soil Liquefaction and Cyclic Mobility Evaluation for Level Ground During Earthquakes," Journal of the Geotechnical Engineering Division, Proceedings of the American Society of Civil Engineers, Vol 105, No. GT2 (February 1979), Pages 201 through 255

2. M.L. Silver and H.B. Seed, The Behavior of Sands Under Seismic Loading Conditions, Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, California, December 1969

3. R. Pyke, B. Seed, and K.C. Chan, "Settlements of Sands under Multidirectional Shaking," Journal of Geotechnical Engineering Division, GT4, April 1975, Pages 379 through 397

TABLE ES-2

LOADS AND LOAD COMBINATIONS FOR CONCRETE STRUCTURES OTHER THAN THE CONTAINMENT BUILDING FROM THE FSAR AND QUESTION 15 OF RESPONSES TO NRC REQUESTS REGARDING PLANT FILL

Responses to NRC Requests Regarding Plant Fill, Question 15

a. Service Load Condition

$U = 1.05D + 1.28L + 1.05T$ (1)

$U = 1.4D + 1.4T$ (2)

b. Severe Environmental Condition

$U = 1.0D + 1.0L + 1.0W + 1.0T$ (3)

$U = 1.0D + 1.0L + 1.0E + 1.0T$ (4)

FSAR Subsection 3.8.6.3

a. Normal Load Condition

$U = 1.4D + 1.7L$ (5)

b. Severe Environmental Condition

$U = 1.25 (D + L + H_O + E) + 1.0T_O$ (6)

$U = 1.25 (D + L + H_O + W) + 1.0T_O$ (7)

$U = 0.9D + 1.25 (H_O + E) + 1.0T_O$ (8)

$U = 0.9D + 1.25 (H_O + W) + 1.0T_O$ (9)

c. Shear Walls and Moment Resisting Frames

$U = 1.4 (D + L + E) + 1.0T_O + 1.25H_O$ (10)

$U = 0.9D + 1.25E + 1.0T_O + 1.25H_O$ (11)

d. Structural Elements Carrying Mainly Earthquake Forces, Such as Equipment Supports

$U = 1.0D + 1.0L + 1.8E + 1.0T_O + 1.25H_O$ (12)

TABLE ES-3

LOADS AND LOAD COMBINATIONS FOR

COMPARISON ANALYSIS REQUESTED IN

QUESTION 26 OF NRC REQUESTS

REGARDING PLANT FILL

ACI 349 as Supplemented by Regulatory Guide 1.142

a. Normal Load Condition

$U = 1.4 (D + T) + 1.7L + 1.7R_O$

$U = 0.75 [1.4 (D + T) + 1.7L + 1.7T_O + 1.7R_O]$

b. Severe Environmental Condition

$U = 1.4 (D + T) + 1.4F + 1.7L + 1.7H + 1.9E_O + 1.7R_O$

$U = 1.4 (D + T) + 1.4F + 1.7L + 1.7H + 1.7W + 1.7R_O$

$U = 0.75 [1.4 (D + T) + 1.4F + 1.7L + 1.7H + 1.9E_O + 1.7T_O + 1.7R_O]$

$U = 0.75 [1.4 (D + T) + 1.4F + 1.7L + 1.7H + 1.7W + 1.7T_O + 1.7R_O]$

c. Extreme Environmental Conditions

$U = (D + T) + F + L + H + T_O + R_O + W_T$

$U = (D + T) + F + L + H + T_O + R_O + E_{SS}$

d. Abnormal Load Conditions

$U = (D + T) + F + L + H + T_A + R_A + 1.5P_A$

$U = (D + T) + F + L + H + T_A + R_A + 1.25P_A + 1.0(Y_R + Y_J + Y_M) + 1.25E_O$

$U = (D + T) + F + L + H + T_A + R_A + 1.0P_A + 1.0(Y_R + Y_J + Y_M) + 1.0E_{SS}$

where

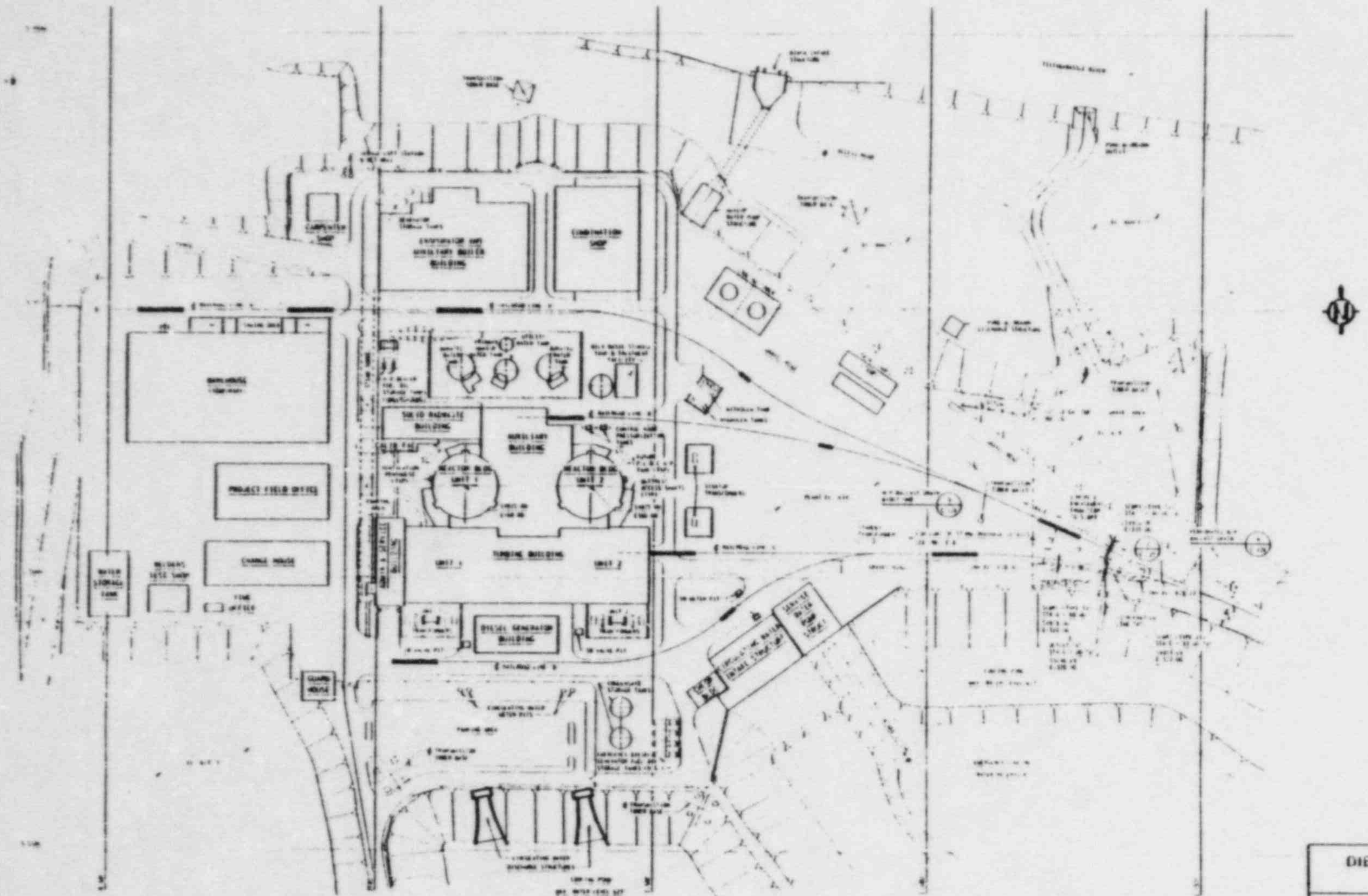
Normal loads are those loads encountered during normal plant operation and shutdown, and include:

T = settlement loads

Table ES-3 (continued)

Y_J = jet impingement load on a structure generated by a postulated break

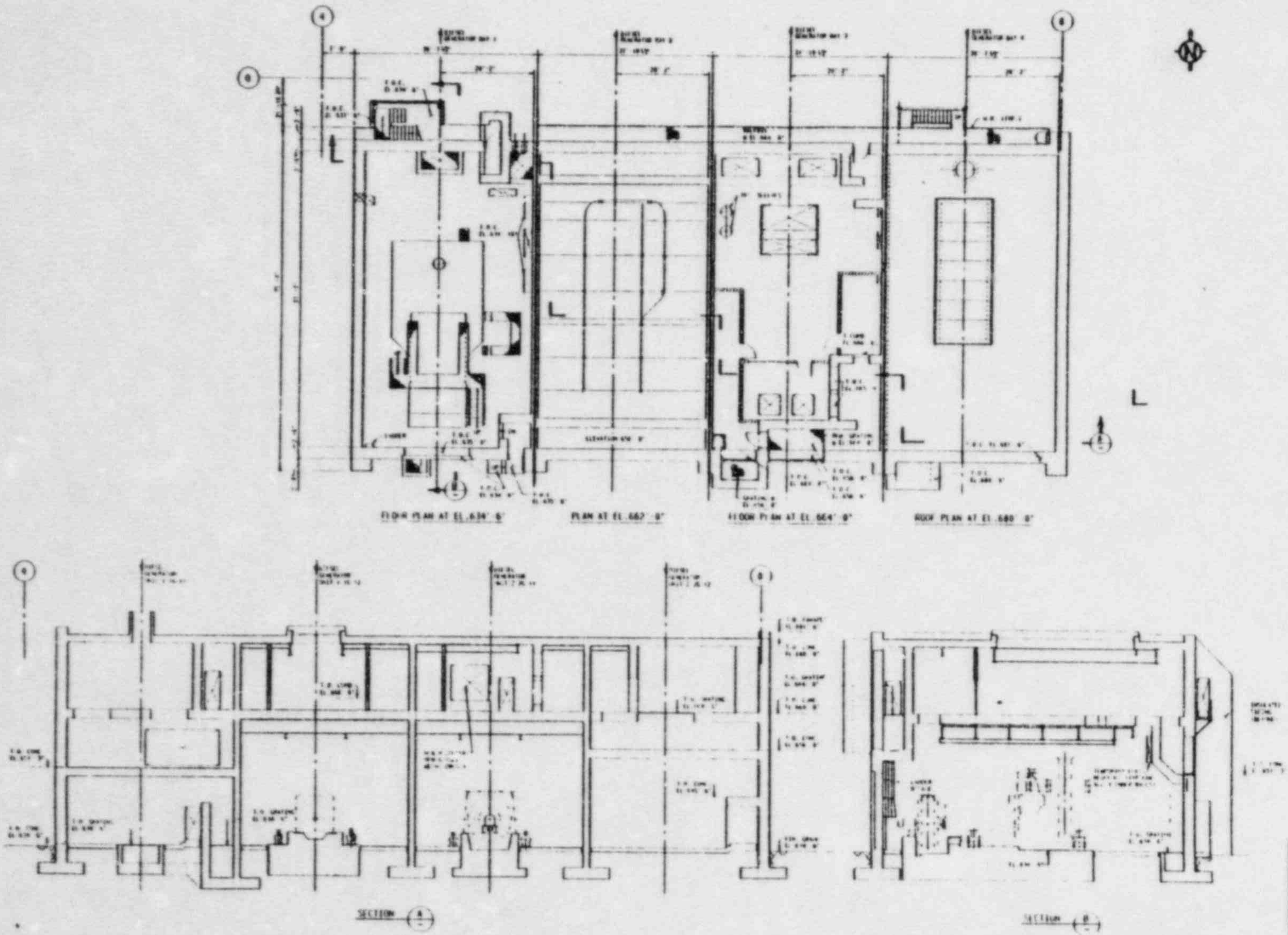
Y_M = missile impact load on a structure generated by or during a postulated break, such as pipe whipping



DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

SITE PLAN OF MIDLAND
UNITS 1 AND 2 POWER PLANT

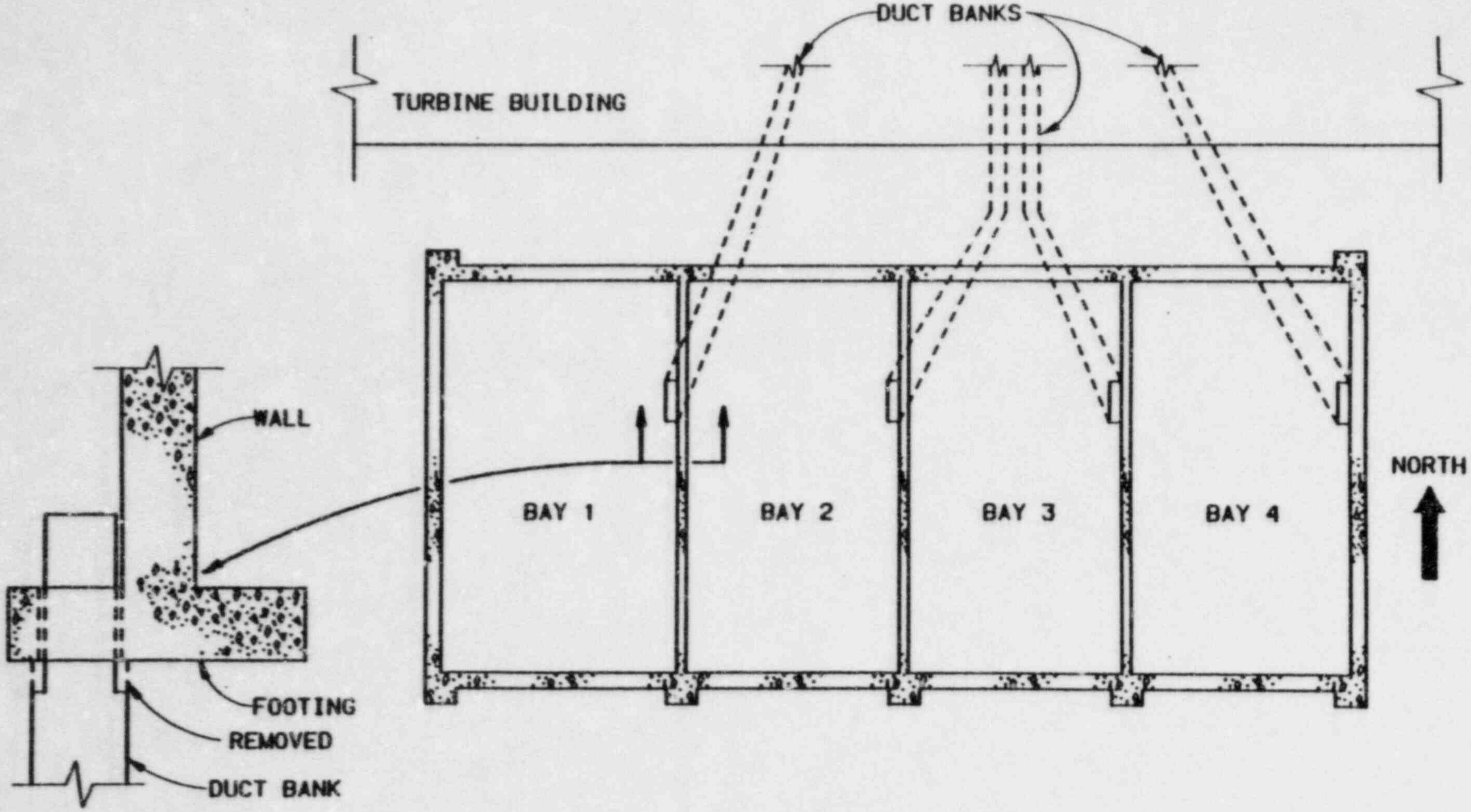
FIGURE ES-1



DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

PLAN VIEW AND SECTIONS

FIGURE ES-2

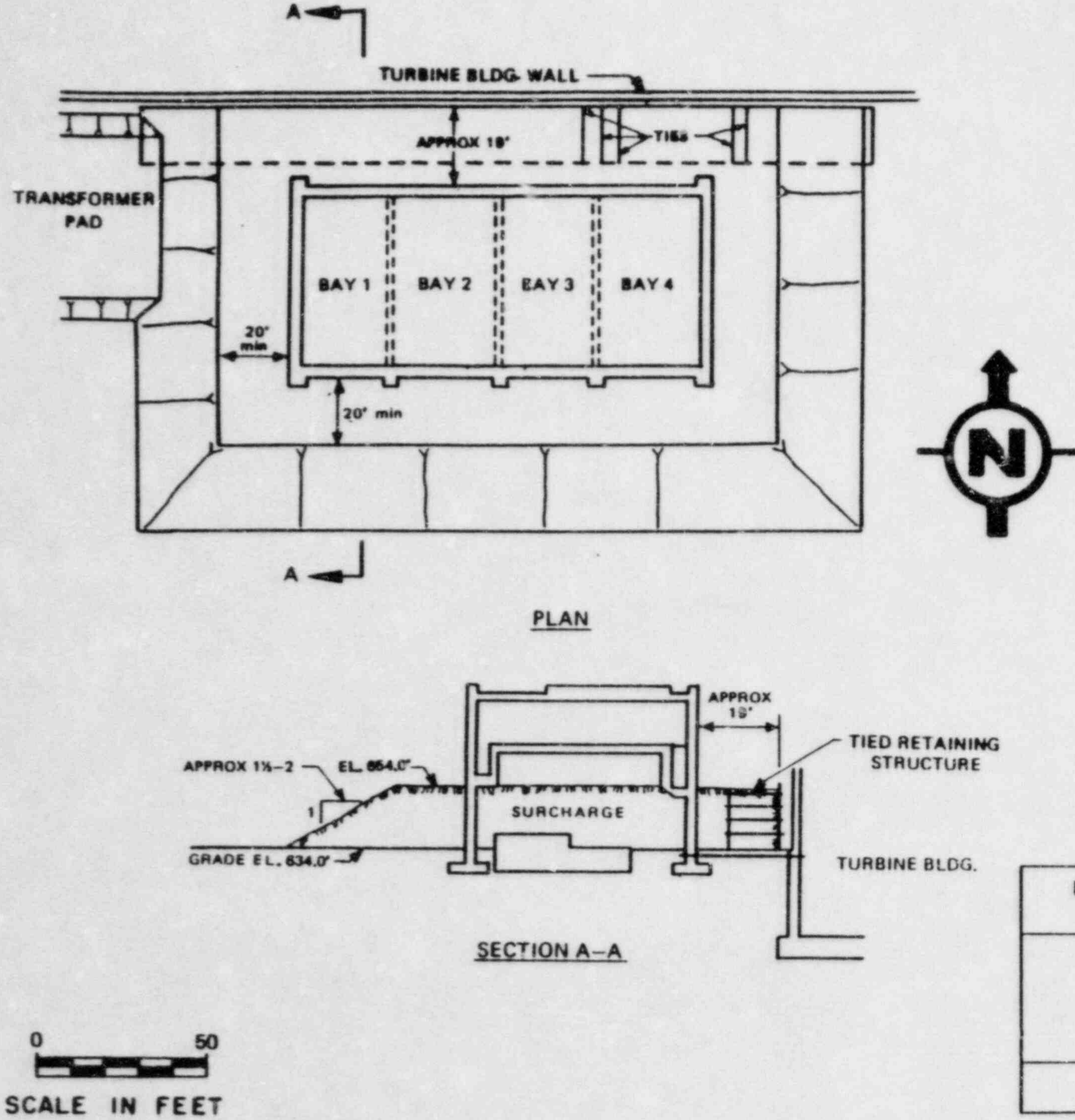


TYPICAL SECTION

DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

DUCT BANK LAYOUT

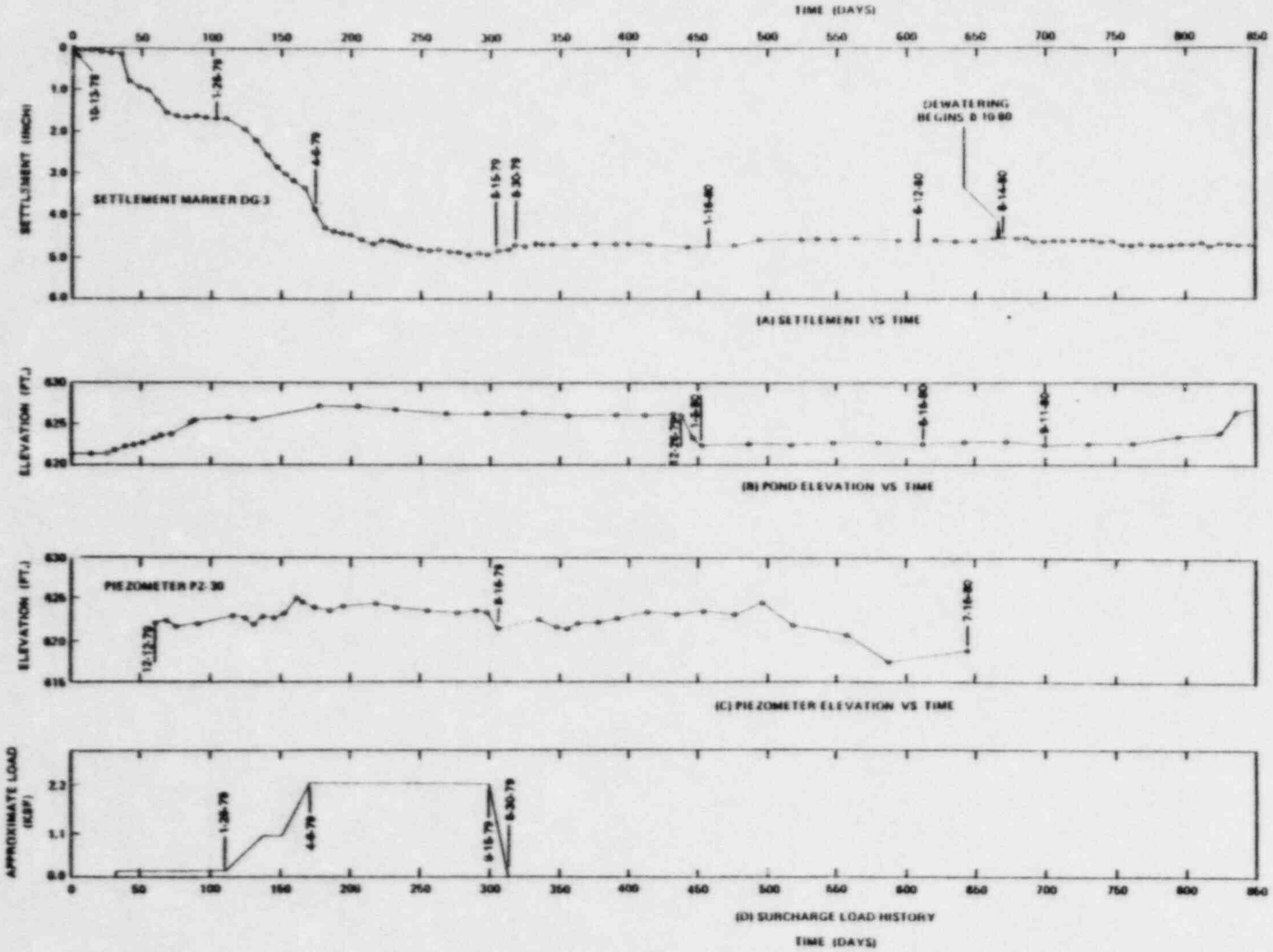
FIGURE ES-2A



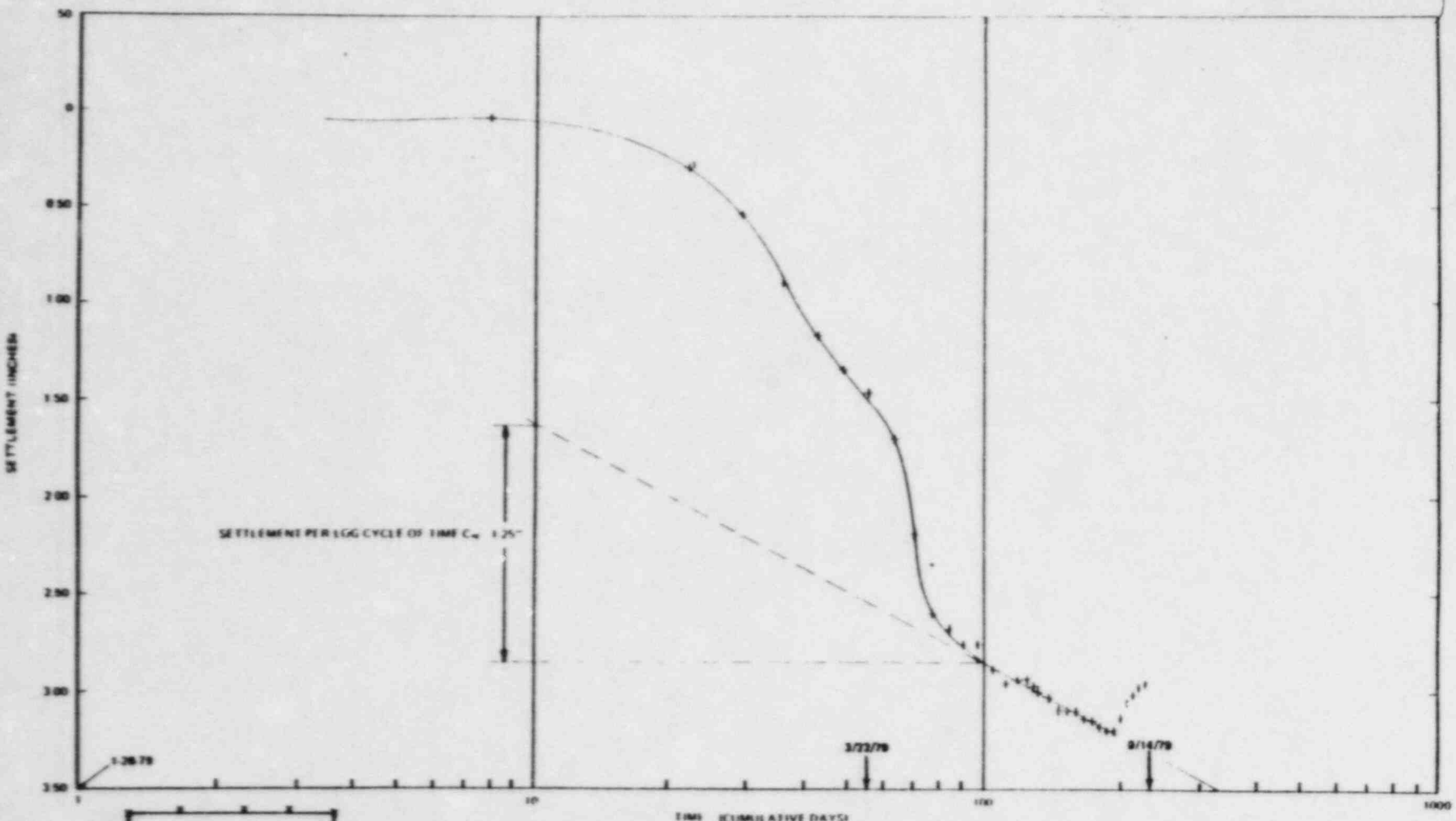
DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

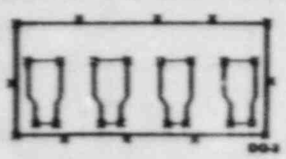
GENERAL LAYOUT OF
SURCHARGE LOAD

FIGURE ES-3



DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY
TYPICAL SETTLEMENT, COOLING POND LEVEL, PIEZOMETER LEVEL AND SURCHARGE LOAD HISTORY
FIGURE ES-4





SETTLEMENT MARKER LOCATION PLAN
DIESEL GENERATOR BUILDING
(NOT TO SCALE)

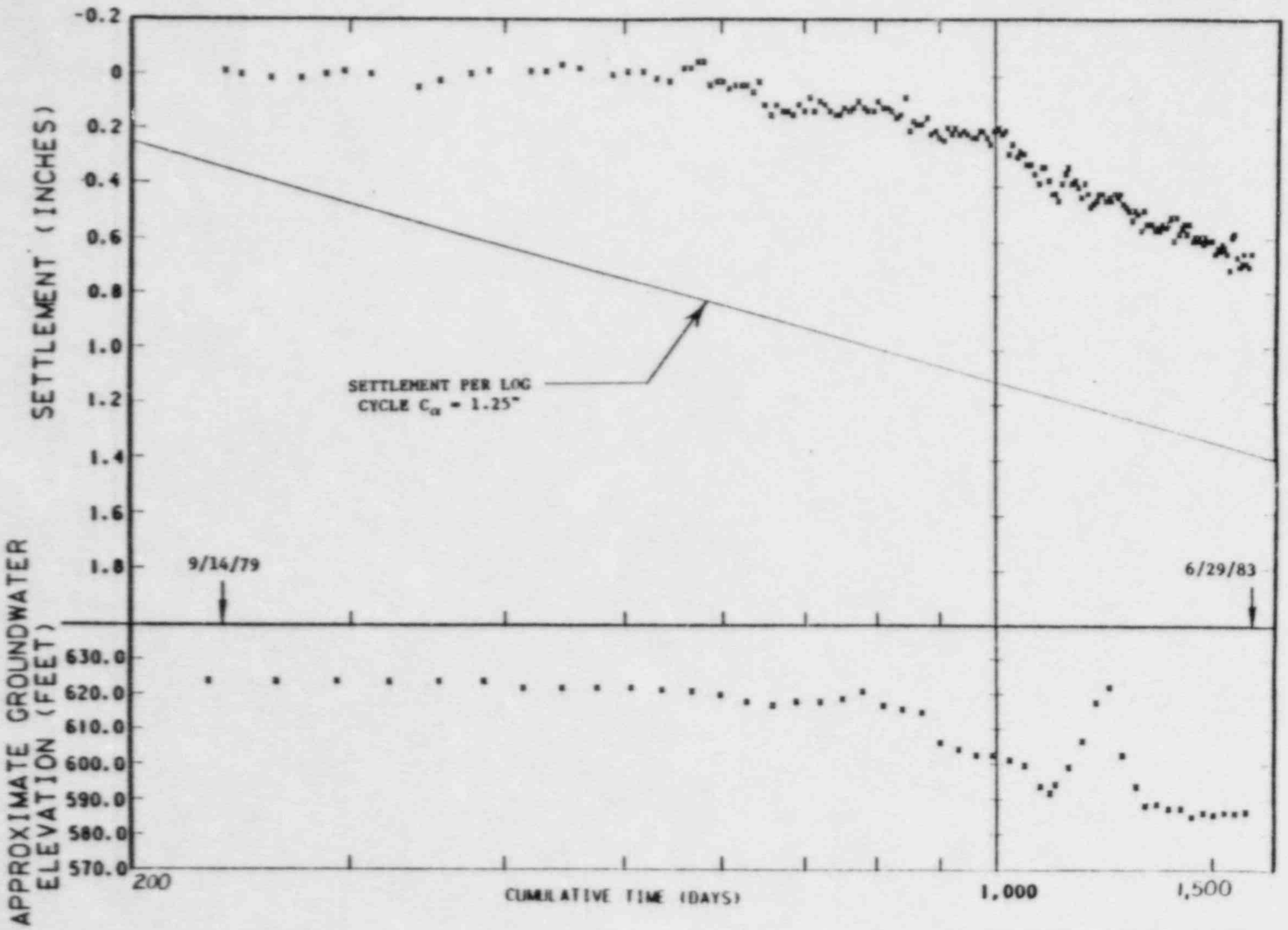
NOTE

The permanent marker could not be monitored from 3-22-79 to 9-14-79 due to surcharge. Temporary markers at elevation 664'-6" were used during this period to estimate the settlement of the permanent marker. On 9-14-79 the settlement was again based directly upon the permanent marker.

DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

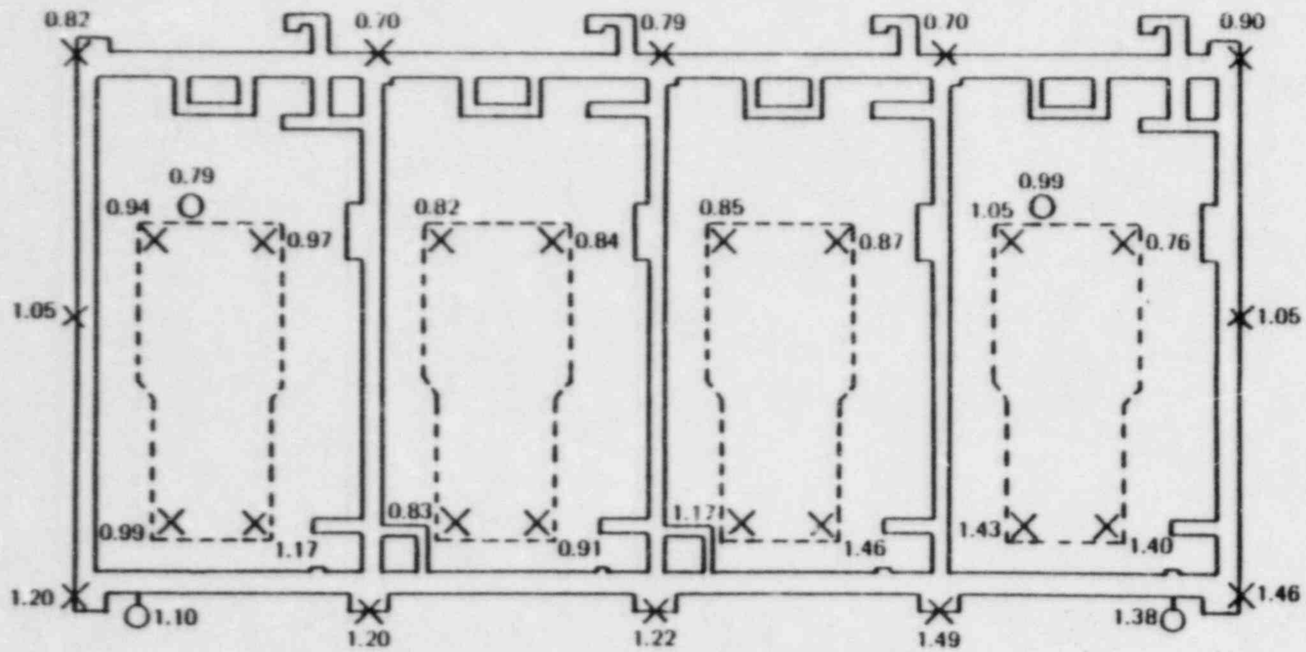
SETTLEMENT VS. LOGARITHM OF TIME FROM 1/26/79 TO 9/14/79
MARKER DG-3

FIGURE ES-5



DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY
SETTLEMENT VS. LOGARITHM OF TIME SINCE 9/14/79 MARKER DG-3
FIGURE ES-6

DIESEL GENERATOR BUILDING



LEGEND

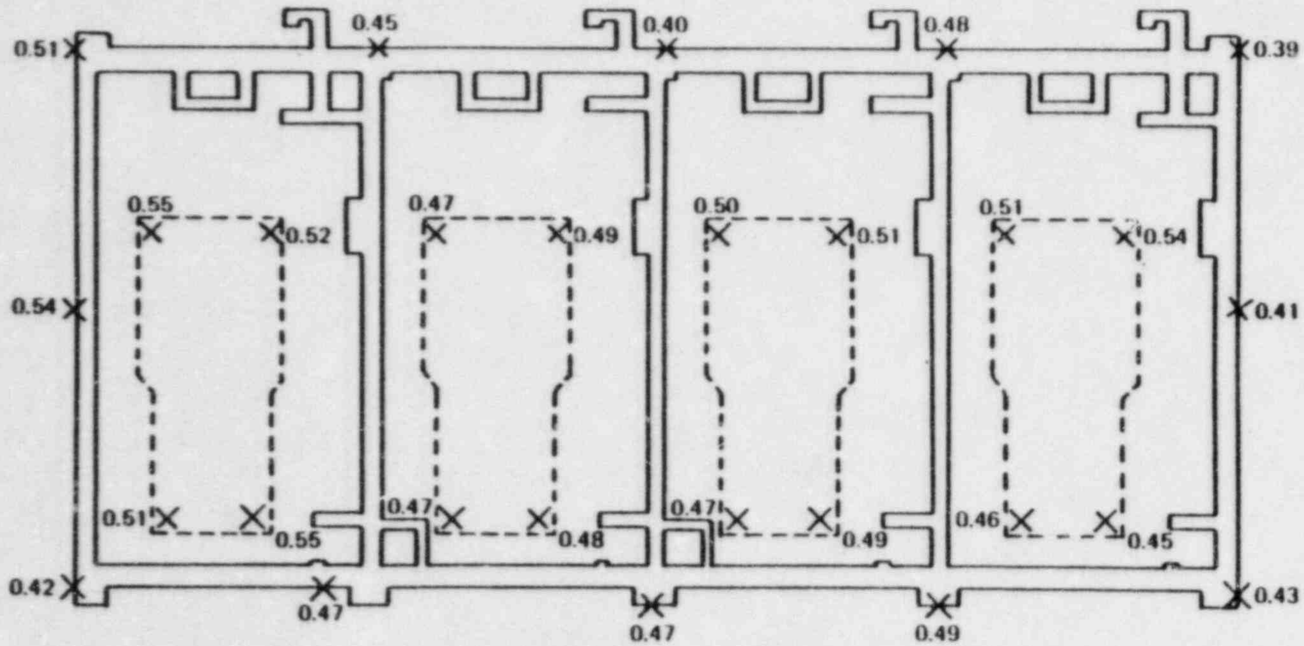
○ —— DEEP BORROS ANCHOR

× —— BUILDING / PEDESTAL SETTLEMENT MARKER

1.20 —— SETTLEMENT IN INCHES

DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY
ESTIMATED SECONDARY COMPRESSION SETTLEMENTS FROM 12/31/81 TO 12/31/2025 ASSUMING SURCHARGE REMAINS
FIGURE ES-7

DIESEL GENERATOR BUILDING

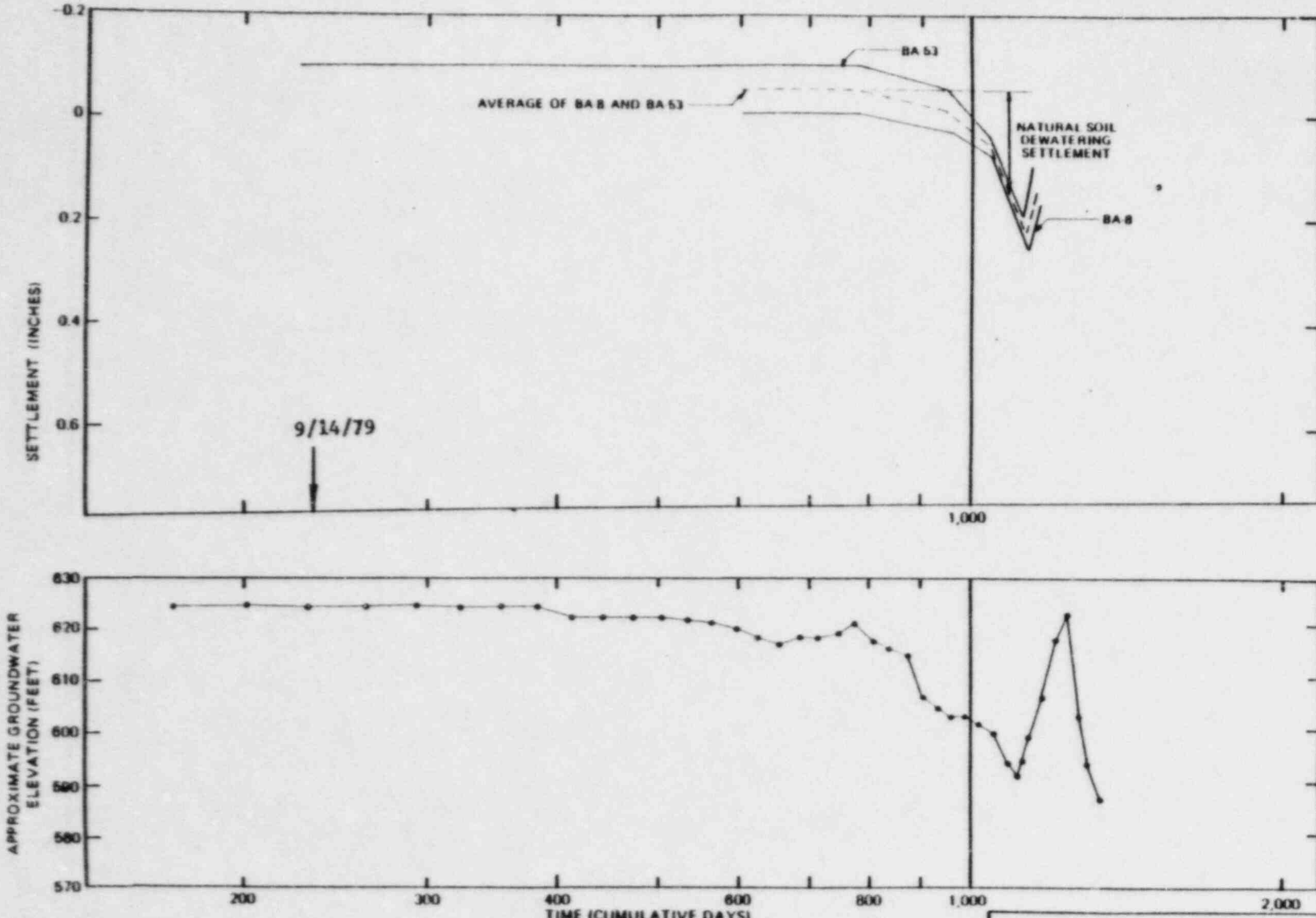


LEGEND

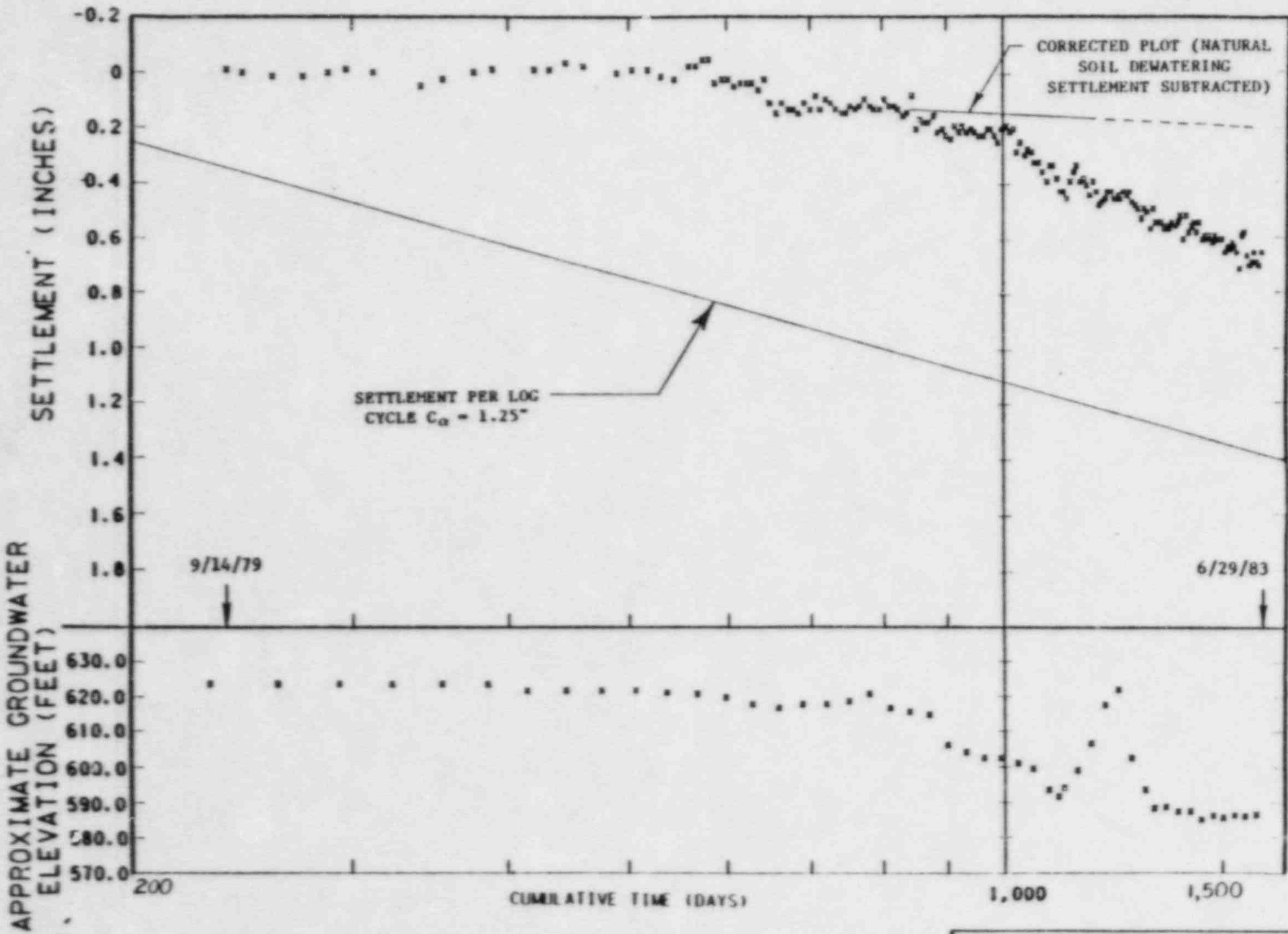
X ——— BUILDING / PEDESTAL SETTLEMENT MARKER

0.42 ——— MEASURED SETTLEMENT BETWEEN 9/14/79 AND 12/31/81.

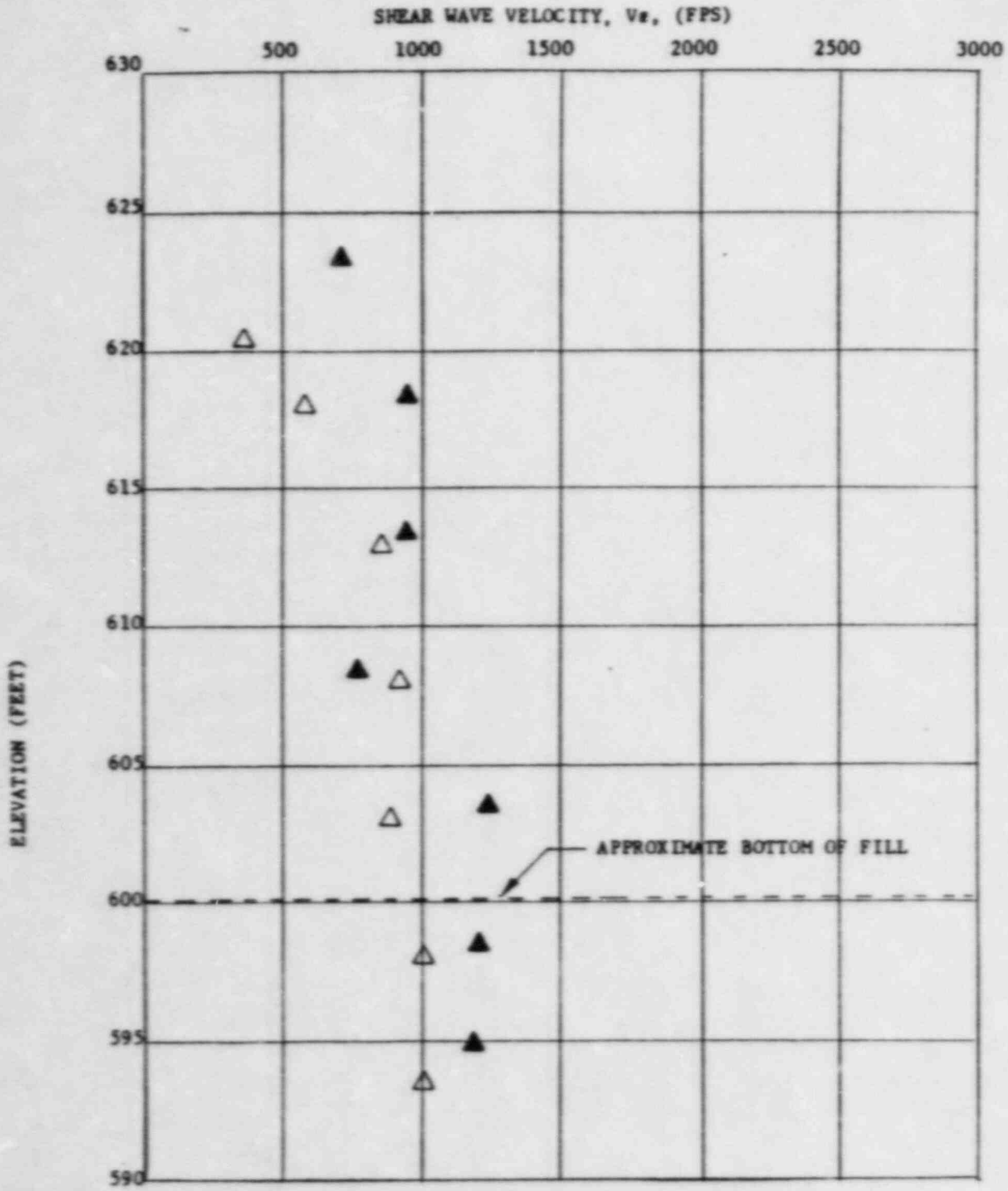
DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY
MEASURED SETTLEMENT FROM 9/14/79 TO 12/31/81
FIGURE ES-8



DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY
AVERAGE SETTLEMENT AFTER SURCHARGE REMOVAL BA-8 AND BA-53
FIGURE ES-9

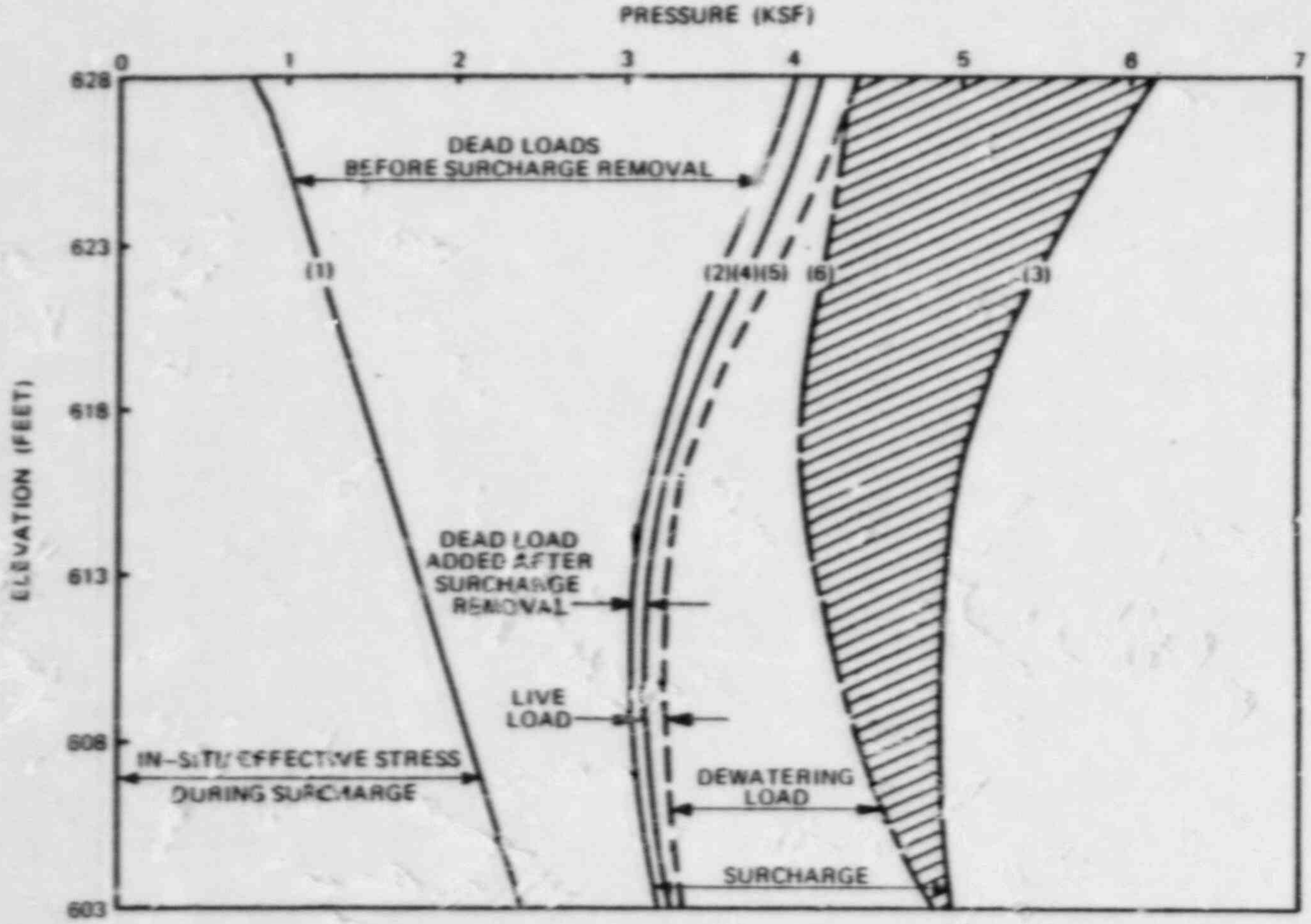


DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY
SETTLEMENT VS. LOGARITHM OF TIME SINCE 9/14/79 SHOWING CORRECTED SLOPE MARKER DG-3
FIGURE ES-10



NOTE:
Open and closed symbols represent tests at different locations.

DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY
SHEAR WAVE VELOCITY PROFILE
FIGURE ES-11



EXPLANATIONS

(1) In-situ effective overburden pressure (GWT at 627).

(2) Total effective pressure before surcharge removal due to In-situ effective overburden pressure and structural dead loads present during surcharge.

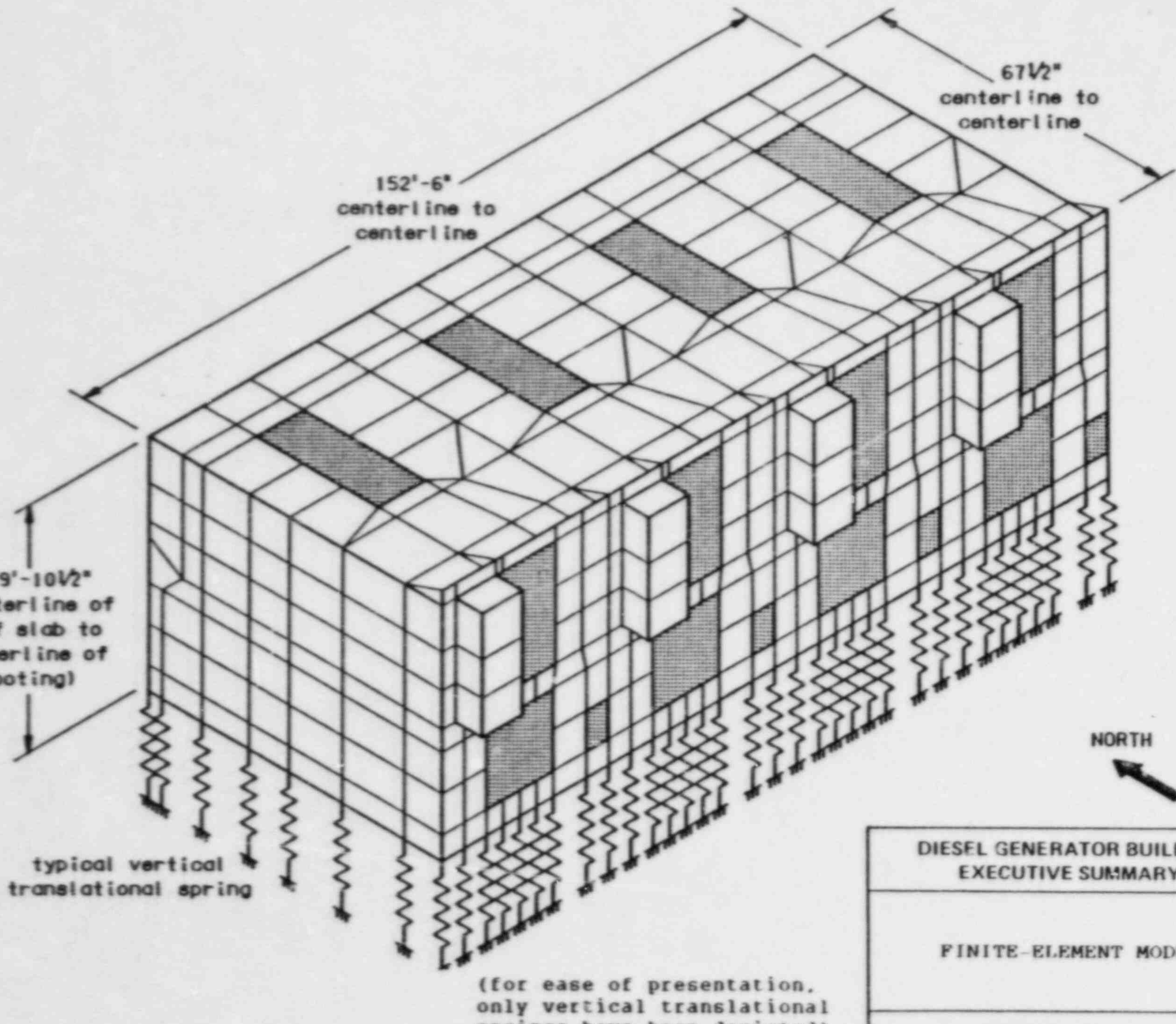
(3) Total effective pressure at the end of surcharge due to In-situ effective overburden pressure, structural dead loads, and surcharge loads.

(4) Total effective pressure due to In-situ effective overburden pressure and total structural dead loads (loads present during surcharge plus dead loads added after surcharge removal).

(5) Total effective pressure due to In-situ effective overburden pressure, total structural dead loads, and expected live loads.

(6) Total effective pressure during the life of plant operation due to In-situ effective overburden pressure, structural dead loads, dewatering loads, and expected live loads.

DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY
COMPARISON OF EFFECTIVE STRESS BEFORE AND AFTER SURCHARGE SOUTHWEST CORNER
FIGURE ES-12

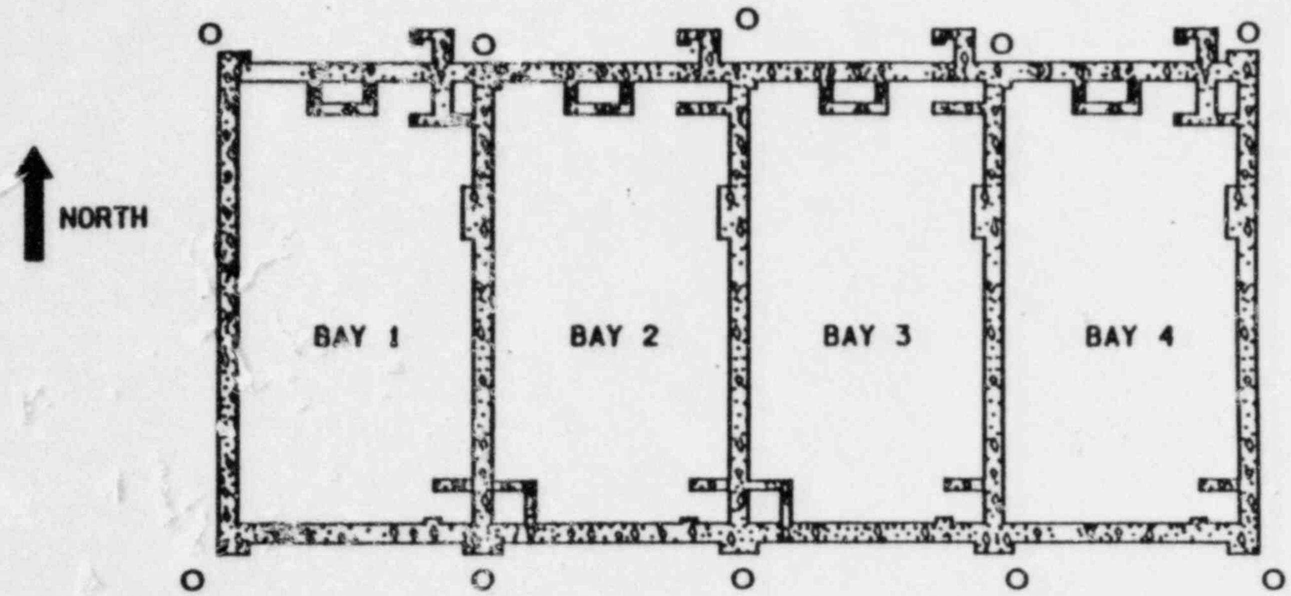


DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

FINITE-ELEMENT MODEL

FIGURE ES-13

LINE A	1.19	1.02	0.90	0.85	0.76
LINE B	0.77	1.09	1.54	1.98	2.41
LINE C	1.50	1.51	1.78	1.86	1.91
LINE D	1.33	1.15	1.19	1.18	1.29
TOTAL	4.79	4.77	5.41	5.67	6.37



LINE A	1.67	1.42	1.28	1.44	1.99
LINE B	1.14	1.12	1.46	1.92	2.21
LINE C	3.00	2.92	3.16	3.37	3.24
LINE D	1.62	1.67	1.69	1.98	1.89
TOTAL	7.43	7.13	7.59	8.71	9.33

LEGEND

O —— DIESEL GENERATOR BUILDING SETTLEMENT MARKER

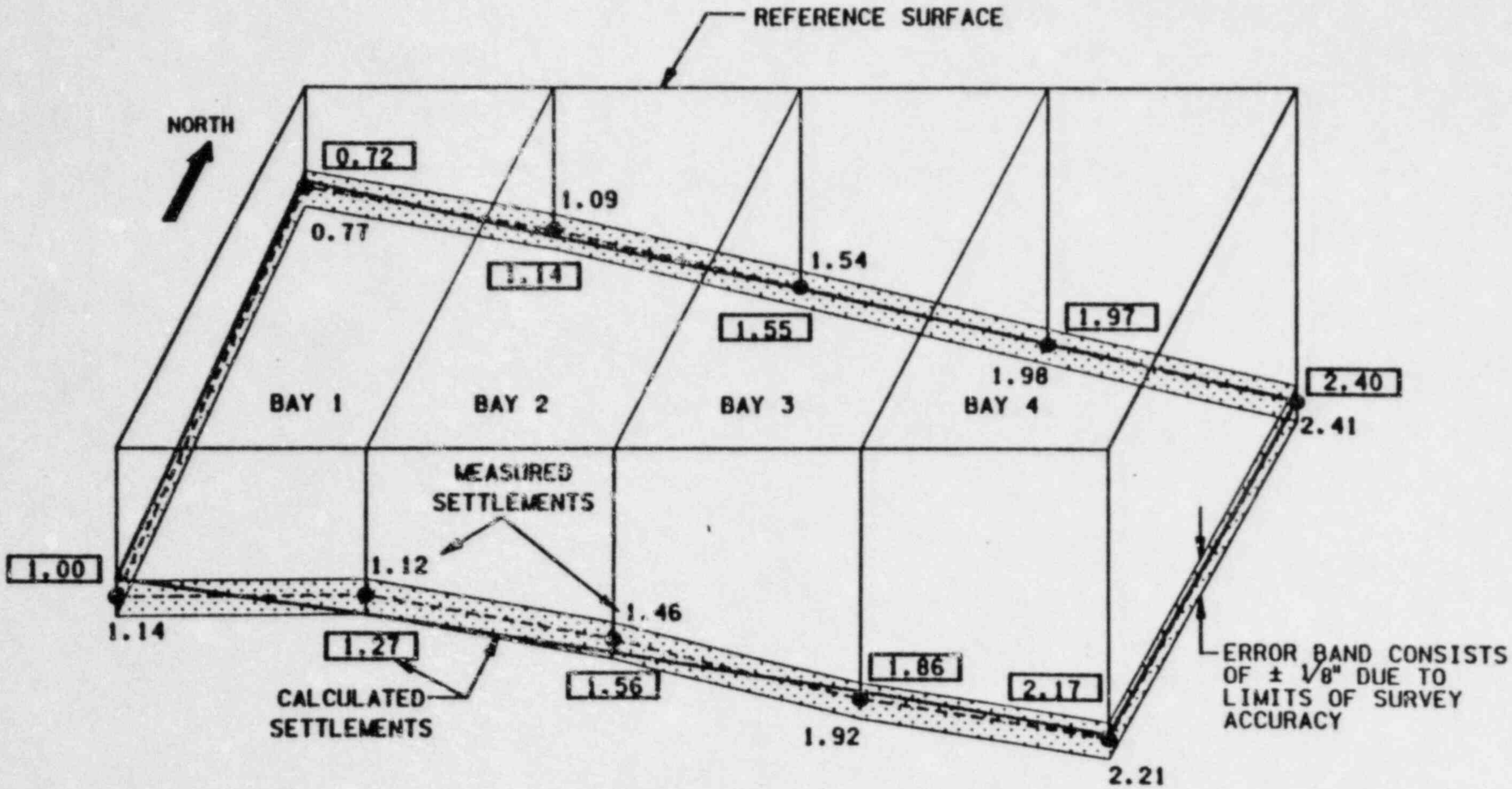
SETTLEMENT IN INCHES FOR

PRE-SURCHARGE PERIOD (3/78-8/78)............LINE A
PRE-SURCHARGE PERIOD (8/78-1/79)............LINE B
SURCHARGE PERIOD (1/79-8/79) ....LINE C
POST SURCHARGE PERIOD (9/79-12/2025) ....LINE D
ASSUMING SURCHARGE REMAINS IN PLACE

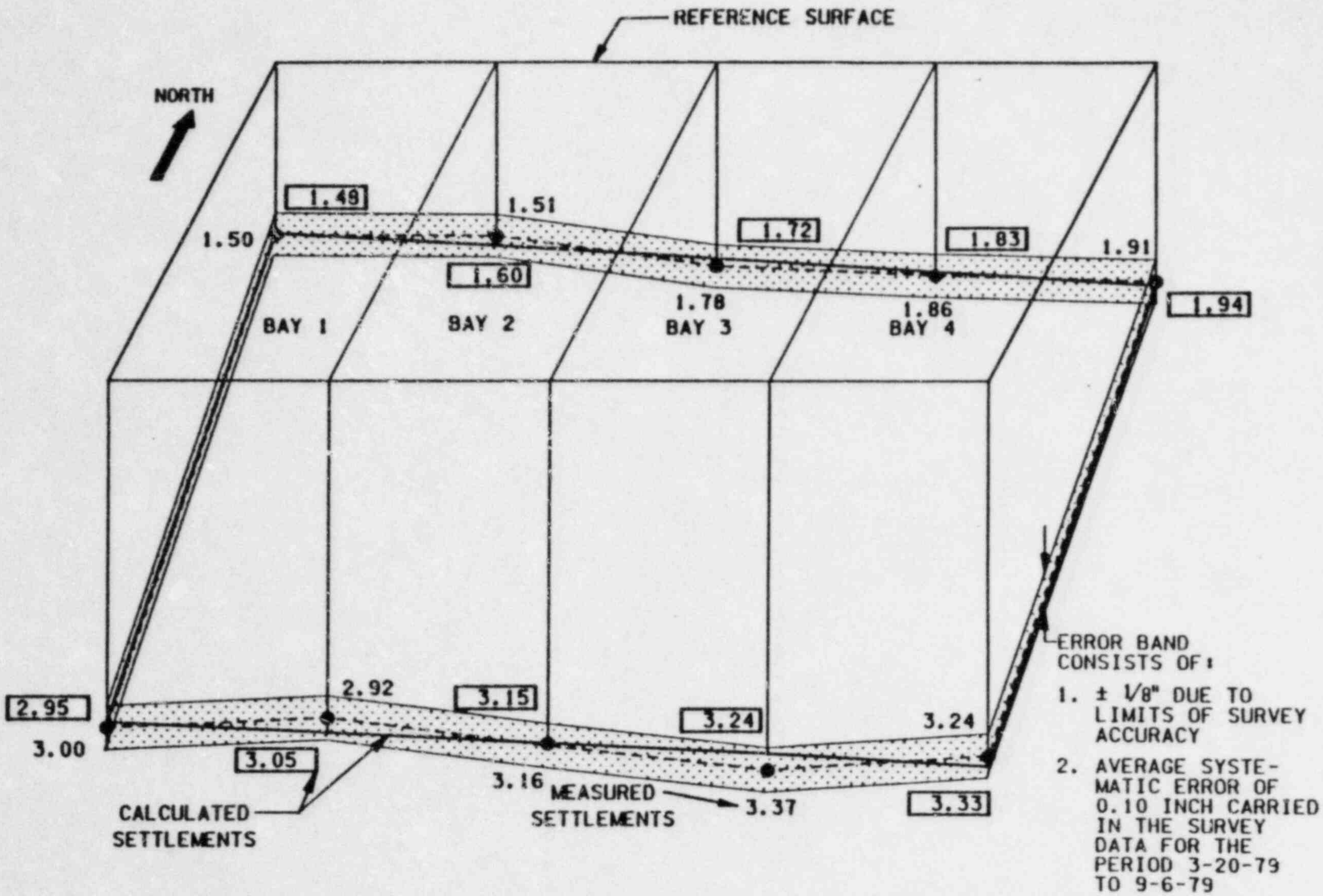
DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

SUMMARY OF ACTUAL AND ESTIMATED SETTLEMENTS

FIGURE ES-14



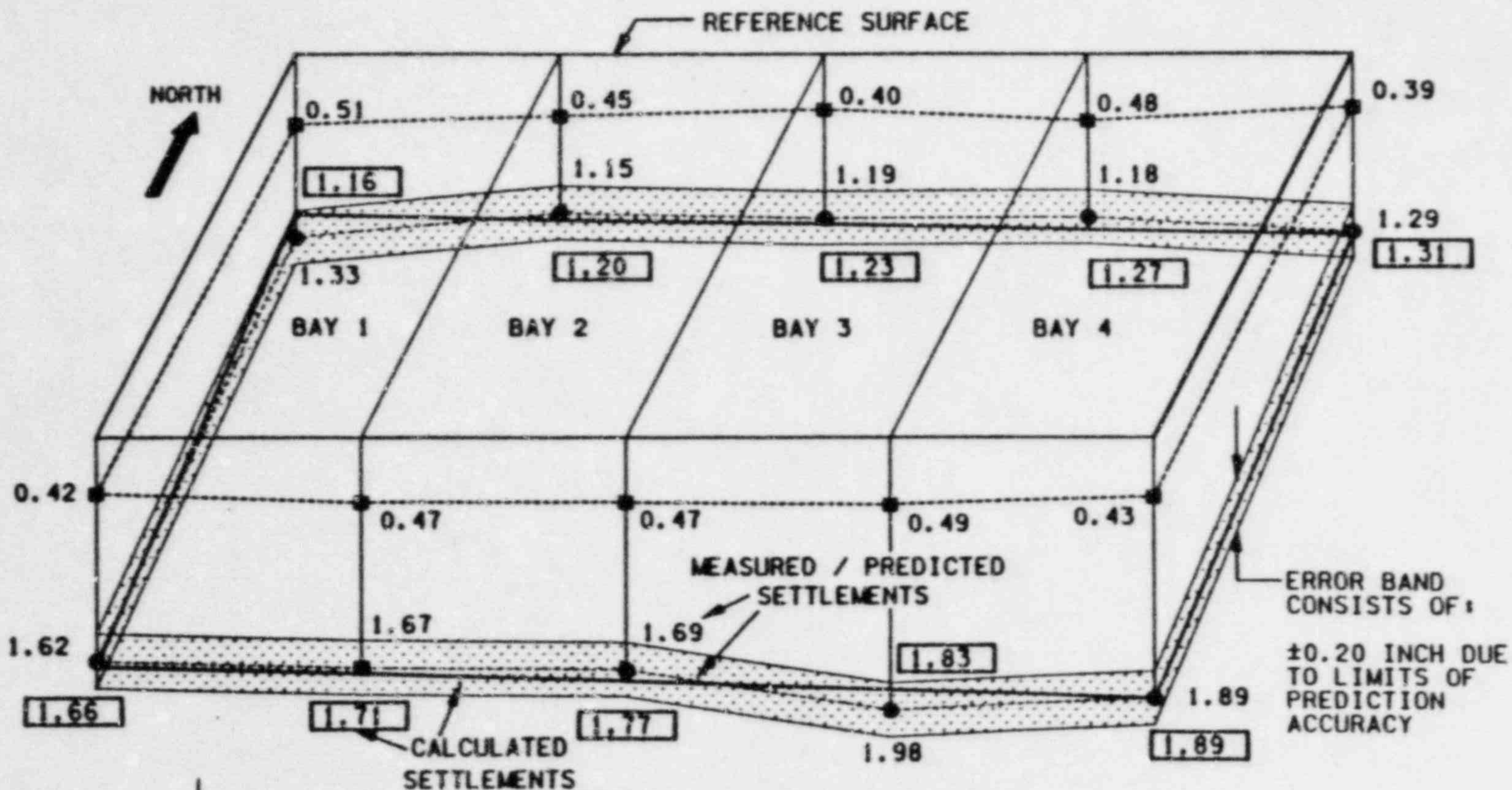
DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY
COMPARISON OF SETTLEMENT VALUES PRE-SURCHARGE PERIOD AUGUST 1978 - JANUARY 1979
FIGURE ES-15



DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY

COMPARISON OF SETTLEMENT VALUES
SURCHARGE PERIOD
JANUARY 1979 - AUGUST 1979

FIGURE ES-16



ACTUAL MEASURED SETTLEMENT FROM SEPT.14, 1979 TO DEC.31, 1981. THESE INCLUDE EFFECT OF DEWATERING TO APPROXIMATELY EL. 595', AND REPRESENT MOVEMENT OF THE STRUCTURE DUE TO SETTLEMENT OF THE FILL AND NATURAL SOIL BELOW.

ACTUAL MEASURED SETTLEMENTS FROM SEPT.14, 1979 TO DEC.31, 1981 PLUS ESTIMATED SECONDARY COMPRESSION SETTLEMENT FROM DEC.31, 1981 TO DEC.31, 2025 ASSUMING SURCHARGE REMAINS IN PLACE.

DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

COMPARISON OF SETTLEMENT VALUES
POST-SURCHARGE PERIOD
SEPTEMBER 1979 - DECEMBER 2025

FIGURE ES-17