SMITH, CHARLES
Proj. 204

Andrew JIP- Phase II

Hurricane Andrew
Effects on Offshore Platforms
Phase II

Final Project Meeting
June 21-22, 1995

PMB Engineering, Inc.
San Francisco, California

Meeting Objectives

Andrew JIP- Phase II

- **Review Results of Study**
  - Weighting
  - Capacity Analysis
  - Calibration
- **Discuss Status of Calibration**
  - Joint Likelihood Functions
  - Conditional Likelihood Functions
- **Review Work Remaining**
  - Completion of Calibration
  - Documentation

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Meeting Agenda

Andrew JIP- Phase II

June 21, 1995 - 1 to 5 pm

1:00	Introduction and Overview	DKD
1:30	Calibration Status	CAC
1:45	Platform Selection	RKA
2:00	Weighting Procedure	RKA
2:30	Break	
2:45	Capacity Analysis Procedures	RWL
3:30	Hindcast Results	RWL
3:45	Capacity Analysis Results	RKA
4:30	Discussion	
5:00	Wrap-up	DKD

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Meeting Agenda (Cont.)

Andrew JIP- Phase II

June 22, 1995 - 8 to 12:30 pm

8:00	Introductory Remarks	DKD
8:10	Calibration Approach	RKA
9:00	Calibration Details	CAC
9:45	Break	
10:15	Calibration Results	RKA
11:00	Opinion - Bias Factors	CAC
11:30	Conclusions and Recommendations	DKD
11:45	Discussion	

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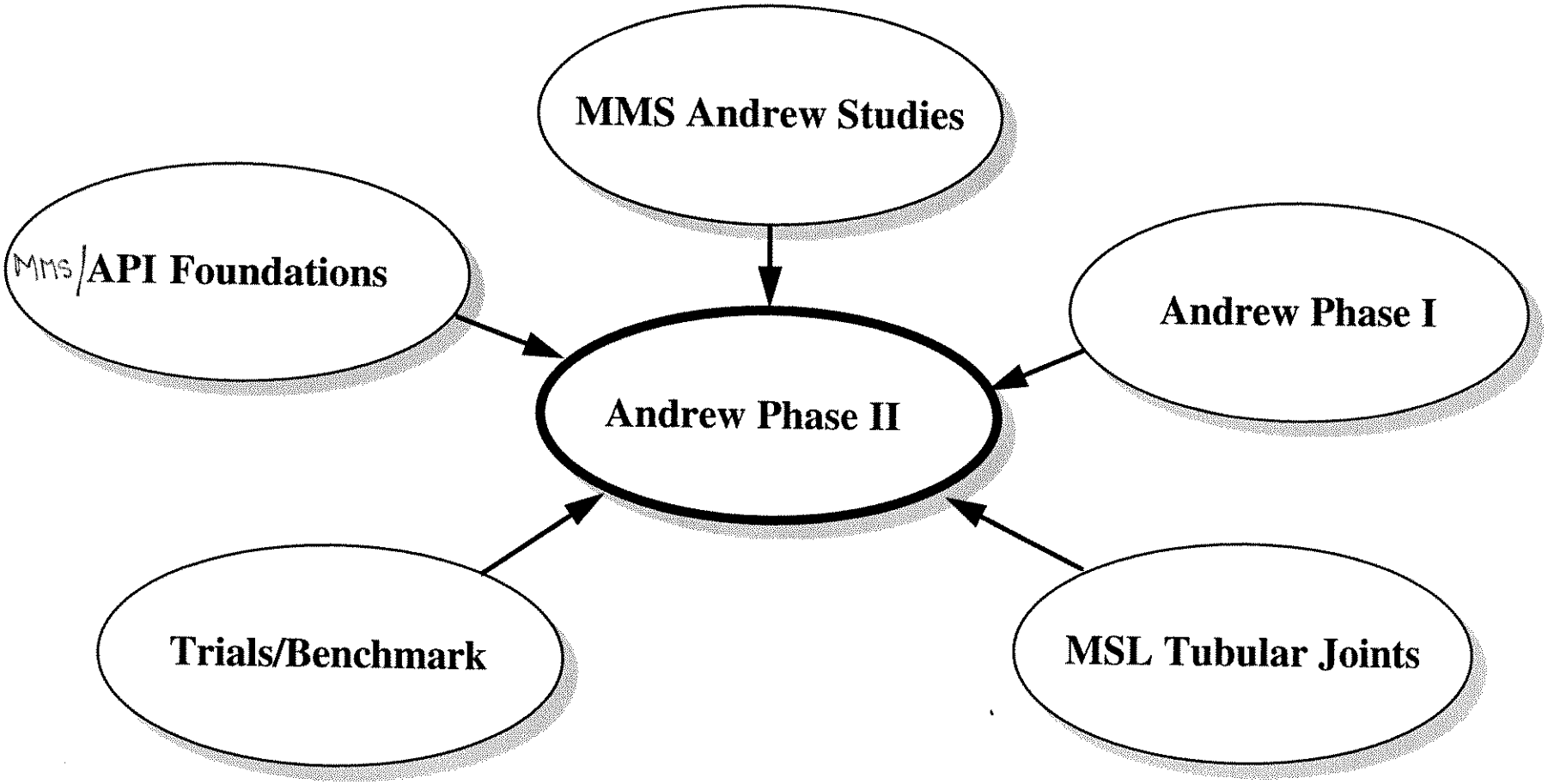
Andrew JIP Objectives I & II

Andrew JIP- Phase II

- **Utilize the Observations from the Hurricane to Validate and Improve Current Assessment Methodology**
  - **Compare Assessment Prediction and Observed Behavior**
  - **Develop Bias Factors to Quantify Degree of Conservatism**
  - **Improve Analytical Procedures**

Andrew Phase II Heredity

Andrew JIP- Phase II



rka/June 1995

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Andrew Phase I - Results

Andrew JIP- Phase II

- Database of Platforms Affected by Andrew
- Ultimate Capacity Analysis Procedures
- Procedure and Software for Failure Probability Evaluation
- Bayesian Updating Procedure
- Established a Global Bias Factor of 1.20 in the Ratio of Predicted Ultimate Capacity to Expected Loads
- Example Application
- Input to the API TG on Platform Assessment

Andrew Phase I -Key Conclusions

Andrew JIP- Phase II

- Low Joint Strength Predicted / but not observed in the field
- Low Foundation Capacity Predicted / Also more observed
- Global Bias Factor ≥ 1.2
- 15 to 20 % Conservative (Mean)
- Unexpected Survivals Have Greatest Impact
- Damage Cases More Informative

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Andrew Phase I - Recommendations

Andrew JIP- Phase II

- **Develop Updated Capacity Analysis Procedures**
  - **– Joint Strength and Stiffness Effect**
  - **– Pushover Load Pattern Application**
  - **– Modeling of Brace Elements**
  - **– Foundation Capacity**
- **Investigate More Directly Component Damage**
- **Develop Multiple Bias Factors**
- **Develop a Weighting Procedure**
- **Investigate Additional Platforms in Different Categories**

API/MMS Foundation Study

Andrew JIP- Phase II

- **Developed Foundation Bias Factors Using Behavior During Andrew**
  - **No Observed Foundation Damage to Jacket Platforms**
  - **Several Possible Interpretations Investigated**
  - **Bias in Lateral Capacity to Load Ratio (Bfl) 1.3** – STATIC
  - **Bias in Axial Capacity to Load Ratio (Bfa) 1.7**
  - **Effect of Including Damaged Caissons Presented** THREE CAISSONS AND 9 PLATFORMS USED IN PHASE II
- **Identified Factors Influencing Bias Factors**
  - **Foundation Lateral Capacity**
  - **Foundation Axial Capacity**

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Andrew Phase II - Objectives

Andrew JIP- Phase II

- Update Modeling and Analysis Recipe
  - Joint Strength and Stiffness
  - Braces
  - Wave Profile
  - Conductors
  - Foundation
- Capacity Analysis of Platforms
- Weighting Approach - Sensitivity Analysis
- Calibration Approach for Multiple Bias Factors
- Determine Multiple Bias Factors
- Example Application of Bias Factors

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Weighting Procedure

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Participants

Andrew JIP- Phase II

PHASE I	PHASE II
AMOCO	AMOCO
BP	
Chevron	Chevron
Exxon	Exxon
HSE	
MMS	MMS
Mobil	Mobil
Phillips	Phillips
Shell	Shell
Texaco	
Trunkline	
UNOCAL	UNOCAL

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Project Team

Andrew JIP- Phase II

- **PMB Engineering**
  - **Dan Dolan**
  - **Dick Litton**
  - ***Rajiv Aggarwal***
- **Consultants**

– **Prof. Allin Cornell**	**Calibration**
– **Prof. Fred Moses**	**Weighting Approach**
– **MSL Engineering, UK**	**Tubular Joint Information**
» **Dr. Adrian Dier**	

Input to Project

Andrew JIP- Phase II

❑ Chevron	Platforms Data and Soil Reports
❑ MSL Engineering	Strength and Stiffness for Joints
❑ Oceanweather	Hindcast Data
❑ Risk Engineering Inc.	Clarifications to RELACS
❑ Shell	Platform Data
❑ Trunkline	Soil Reports

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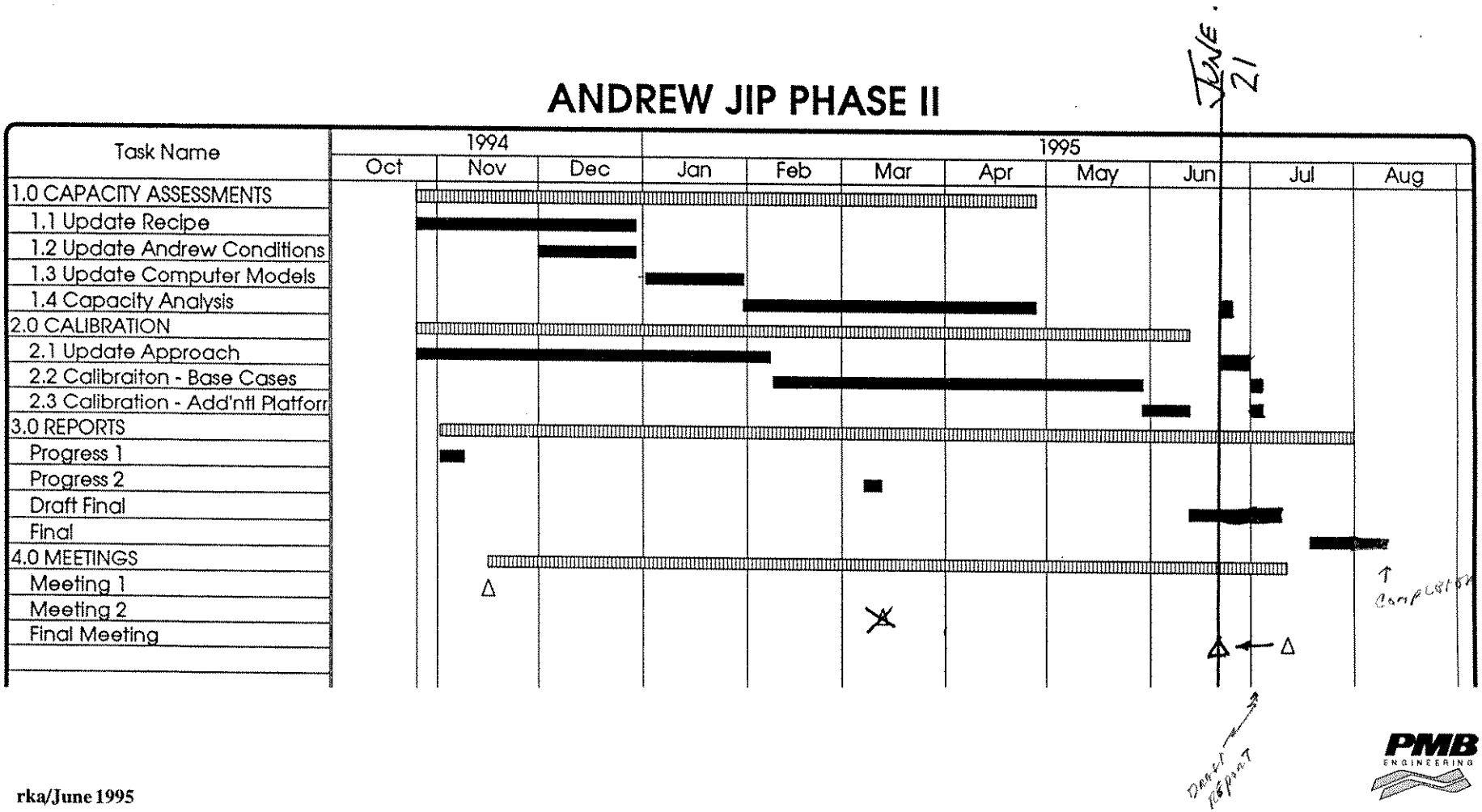
Project Schedule

Andrew JIP- Phase II



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Calibration Status

Objective

a.) From experience from Andrew look at trends on loads

2.) Andrew I — Load — capacity

Likely mode of failure

Global $\frac{CAP}{LOAD} = 1.2$

Foundations — Higher
Structure — Lower

Look at platform as a system problem

Couple models in failure

3.) Andrew II

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Platform Selection

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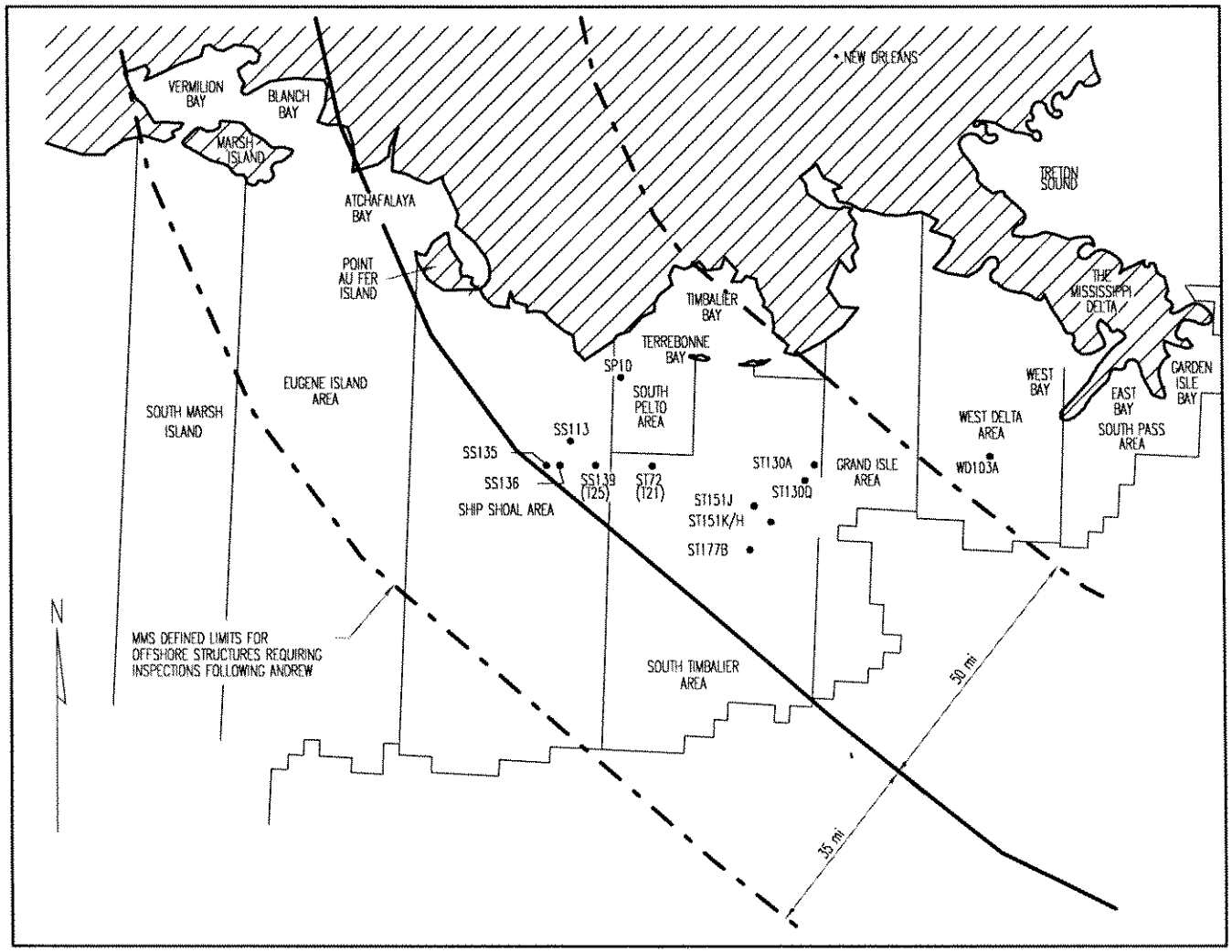
Andrew Storm Track

Andrew JIP- Phase II



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Platforms Selected

Andrew JIP- Phase II

- **Steel Jacket Platforms -- Andrew Phase I**
  - **ST151K** — **No Damage**
  - **ST130Q** — **No Damage**
  - **ST177B** — **Damaged**
  - **SS139 (T25)** — **Damaged**
  - **ST151H** — **Failed**
  - **ST130A** — **Failed**
  - **ST72 (T21)** — **Failed**
- **Other Steel Jacket Platforms**
  - 8 Legs **WD103A** — **No Damage**
  - 8 Legs **ST151J** — **Damaged**

Platforms Selected - Issues

Andrew JIP- Phase II

- Caison Platforms - API/MMS Foundation Study
  - SPelto 10 — Damaged (lean 12 degrees)
  - SS135 — Damaged (lean 15 degrees)
  - SS136 — Damaged (lean 30 degrees)
- Provides Observed Foundation Damage Cases
- Considered Effect of Caissons on Foundation Lateral Capacity Bias Factor Only - Sensitivity

Weighting Procedure

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Weighting Evaluation

Andrew JIP- Phase II

PHASE I - 13 PLATFORMS

- Larger Number of Platforms Experienced Andrew
- Case Studies Limited Due to Time and Information Required to Complete Assessment
- Number of Platforms Selected Under Different Categories (Survival, Damage, Failed) not in Proportion to the Affected Platforms
- Use Results of Phase I in this Evaluation
- Sensitivity Analysis to Determine the Likely Shift in Bias Factor

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Weighting Approach

Andrew JIP- Phase II

- Identify Number of Platforms Under Different Categories from a Review of the MMS Database
- Screen Platforms Based on Installation Date and Significant Wave Height During Andrew
- Use the 1992 Oceanweather Hindcast Data
- Use Likelihood Functions Developed in the Andrew Phase I
- Develop Combined Likelihood Functions
- Perform Sensitivity Analysis

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OVERVIEW OF PLATFORMS SURVIVED/DAMAGED/FAILED

Operator	Platforms Survived	Platforms Damaged & Failed
Andrew Observations:		
JIP Participants		
Amoco	30	1
Chevron	143	12
Exxon	72	-
Mobil	22	1
Phillips	7	-
Shell	39	-
Unocal	25	1
Total Participants Platforms	338	15
Other Operators	310	13
Total Platforms	648	28
Phase I Sample:		
Platforms Considered	6	7
%ge of Total Platforms	1%	25%

Platforms Affected by Andrew

Andrew JIP- Phase II

	Total (includes non-participants)	Used in Phase I JIP	Based on Proportional Sampling
Survival Cases	648	6	162
Damage Cases	14	3	3
Failure Cases	14	4	4

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Possible Number of Platforms in Different "Survival" Categories

Andrew JIP- Phase II

	Total (based on 1st cut)	Assumed for Sensitivity Analysis	Representative Platform - Type
Unexpected Survivals	**34**	**8**	**ST130Q**
Expected Survivals	**147**	**37**	**WD90A**
Sure Survivals	**467**	**117**	**MC397**

Most Likely Unexpected Survival Cases (ST130Q types) Total 34

Likley Expected Survival Cases (WD90A types) Total 147

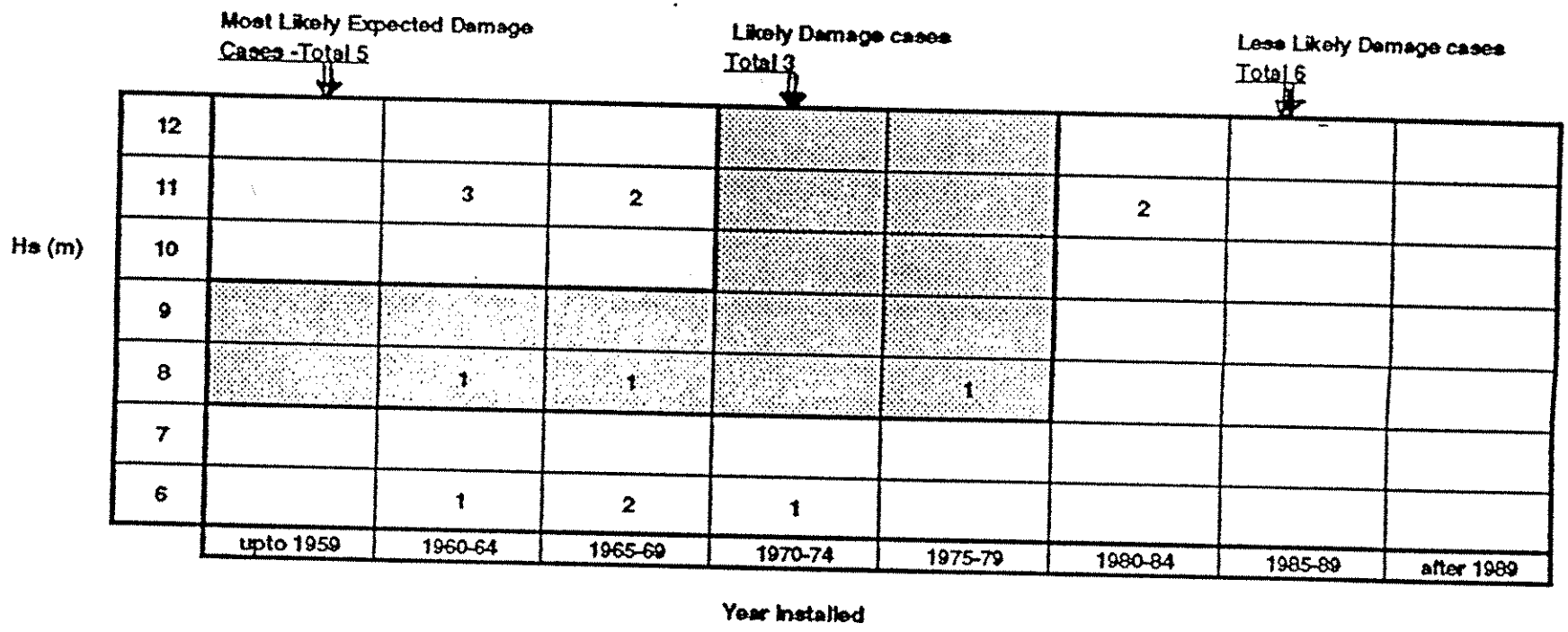
Likely Sure Survival Cases (MC397 types) Total 467

Hs (m)	upto 1959	1960-64	1965-69	1970-74	1975-79	1980-84	1985-89	after 1989
12				3	2		2	3
11		10	16	2	8	2	5	5
10			8	4	8	7	4	6
9	1	3	11	6	5	9	6	4
8	7	18	42	22	5	25	10	4
7	16	20	29	25	42	37	23	13
6	35	20	17	32	12	28	15	8

Year Installed

a) PLATFORMS SURVIVING ANDREW

Platforms Classification According to Significant Wave Height During Andrew and Platform Age



b) PLATFORMS DAMAGED DURING ANDREW

Platforms Classification According to Significant Wave Height During Andrew and Platform Age

Most Likely Expected Failure Cases -Total 7

Likely Failure cases Total 3

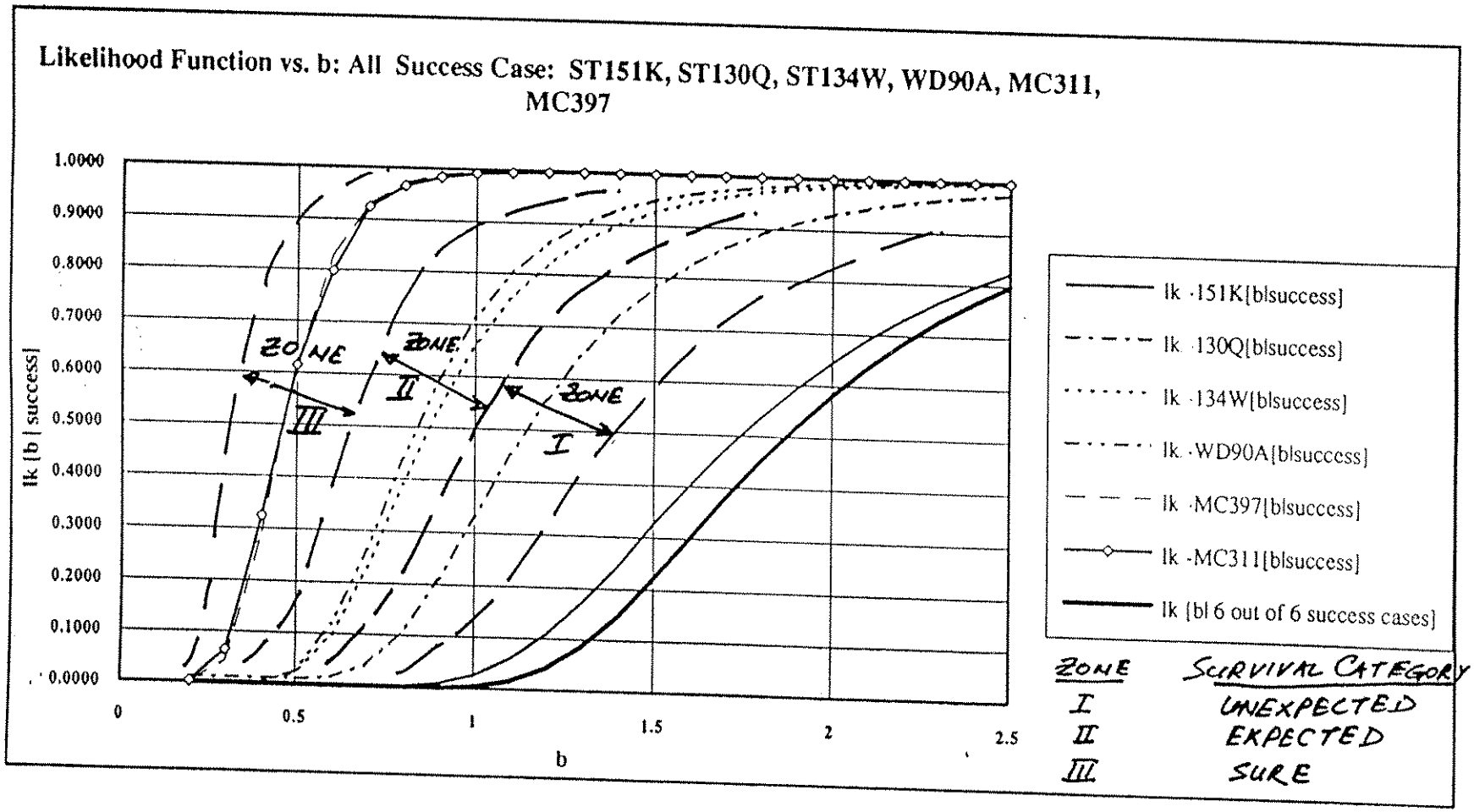
Less Likely Failure cases Total 4

Hs (m)	upto 1959	1960-64	1965-69	1970-74	1975-79	1980-84	1985-89	after 1989
12								
11	1	3	2					
10		1						
9								
8		1	2					
7								
6	2	1	1					

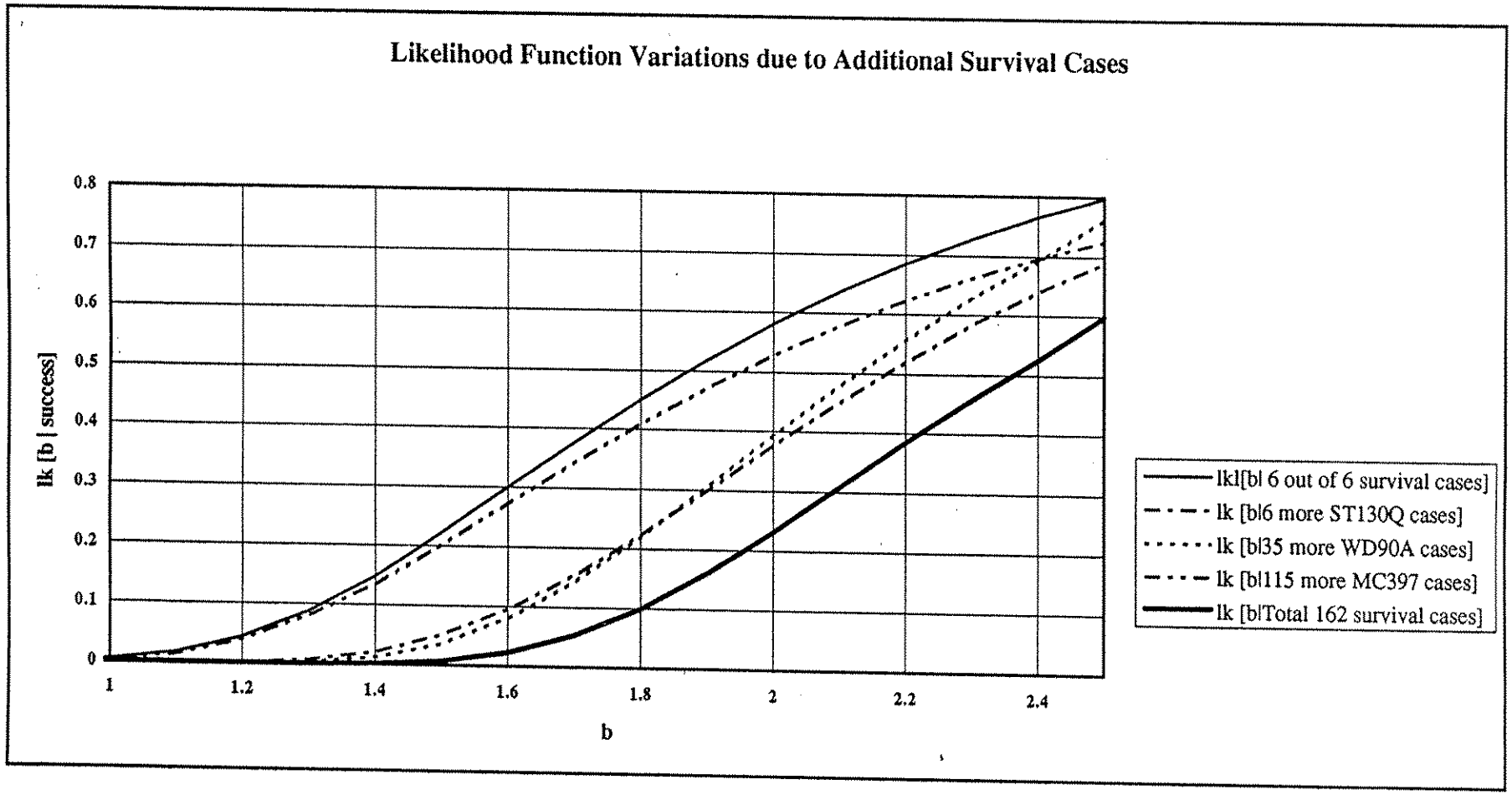
Year Installed

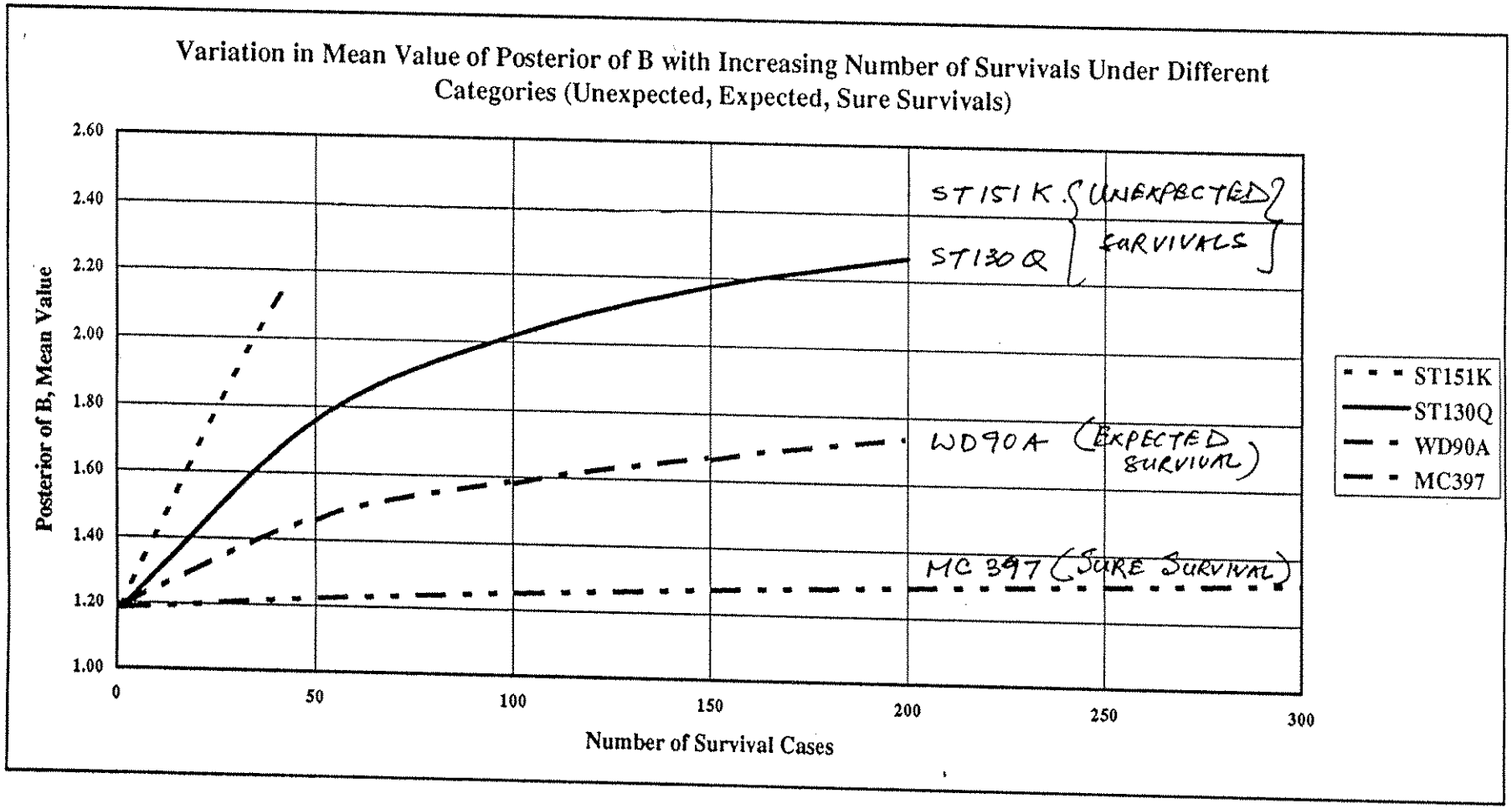
c) PLATFORMS FAILED DURING ANDREW

Platforms Classification According to Significant Wave Height During Andrew and Platform Age



Likelihood Functions - Success Cases (ANDREW JIP- PHASE I)


Likelihood Function Variations due to Additional Survival Cases
lk [b | success]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
b
lkl[bl 6 out of 6 survival cases]
lk [bl6 more ST130Q cases]
lk [bl35 more WD90A cases]
lk [bl115 more MC397 cases]
lk [blTotal 162 survival cases]


Variation in Mean Value of Posterior of B with Increasing Number of Survivals Under Different Categories (Unexpected, Expected, Sure Survivals)
Posterior of B, Mean Value
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0
50
100
150
200
250
300
Number of Survival Cases
ST151K (UNEXPECTED SURVIVALS
ST130Q
WD90A (EXPECTED SURVIVAL)
MC397 (SURE SURVIVAL)
ST151K
ST130Q
WD90A
MC397

Posterior of "B - Effect of Including Additional Platforms

Andrew JIP- Phase II

	Mean (B)	COV (B)
Case I: Andrew I-13 cases	1.19	0.10
Case II: Case I + 6 more ST130Q types	1.29	0.09
Case III: Case I + 35 more WD90A types	1.35	0.08
Case IV: Case I +115 more MC397 types	1.20	0.09
Case V: Case I + 156 more Survival cases	1.40	0.08

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Capacity Analysis Procedures

CAP

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Modeling and Analysis Recipe

Andrew JIP- Phase II

- Conductor Resistance
- Wave Force Profile
- Brace Modeling
- Foundations – SHEAR STRENGTH OF THE SOIL
- Joint Modeling

REMOVED F.S. ON ALL FACTORS
USED 42 KSI YIELD ON STEEL

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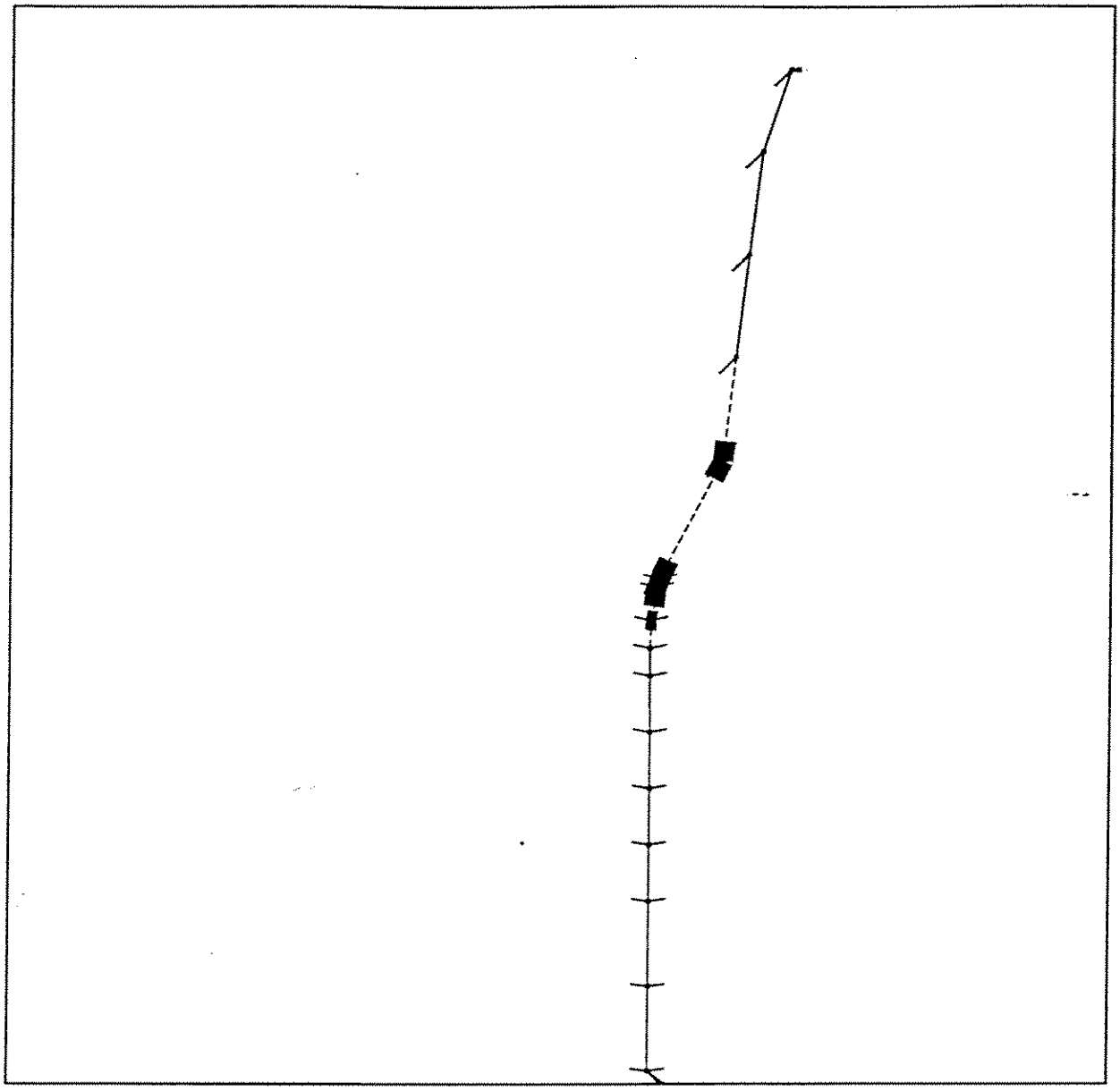
Conductor Resistance

Andrew JIP- Phase II

- Not Considered in Phase I
- Phase II Study Results
  - Important If Guided at Mudline
  - Important If Foundation Failure Mode
- One Platform Guided at Mudline

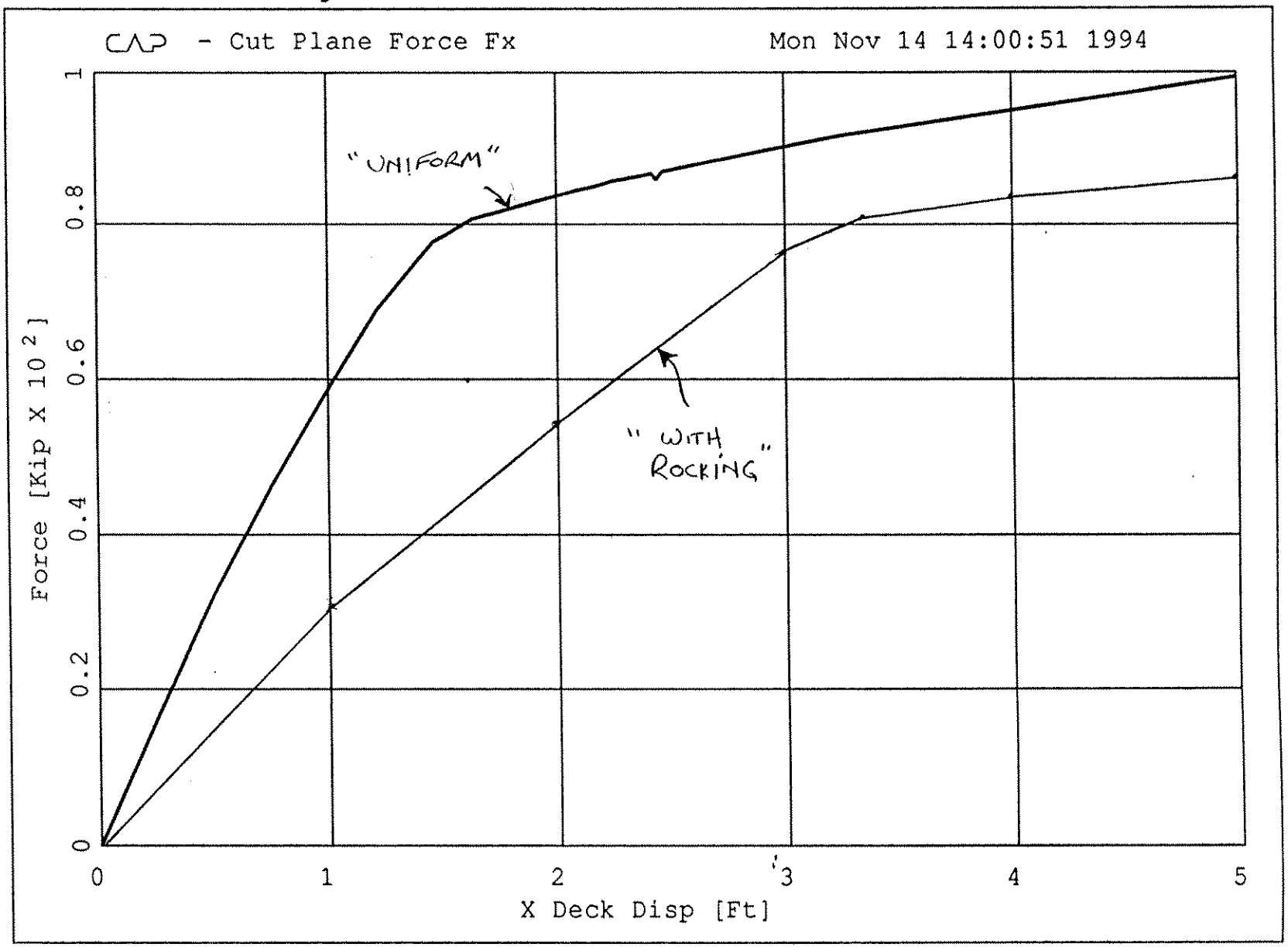
Project: ST151K Model: Conductor Version: 2 Mon Nov 14 14:21:45 1994 *



CAP z ↑ → x Variable Displacement: step 35

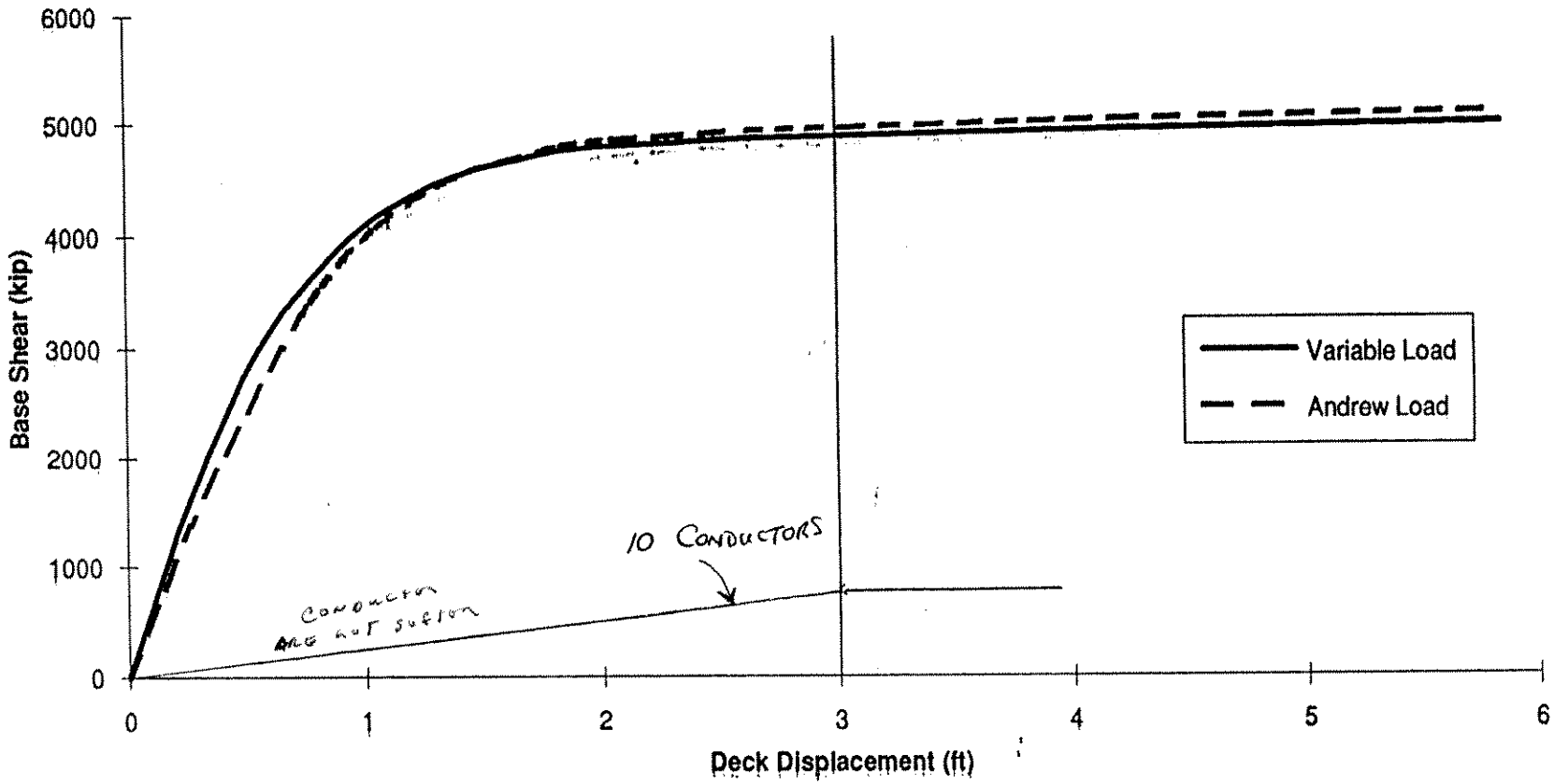
Inelastic Events Legend

———	Elastic	.....	Strut Buckling
- - - - -	Strut Residual	- - - - -	Strut Reloading
.....	Plastic Strut/NLTruss	- - - - -	Beam Clmn Initial Yield
———	Beam Clmn Fully Plastic	.....	Fracture



Uniform Node Displacement

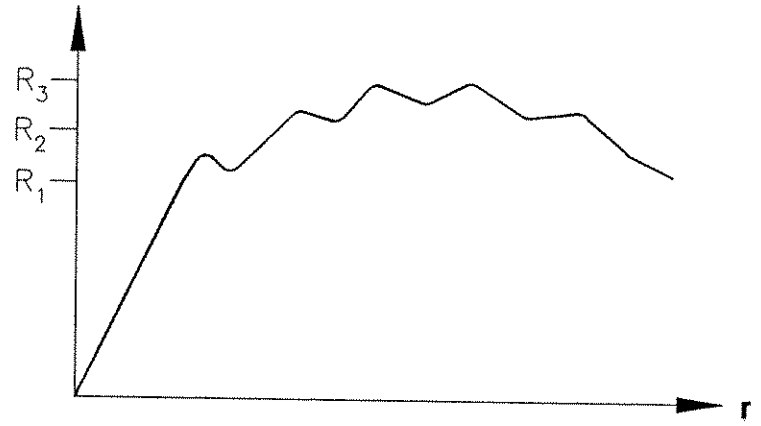
Comparison of Pushover Curves for ST 151K
Variable Load Pattern and Monotonic Load Pattern (Andrew)
Soil Improved 100%

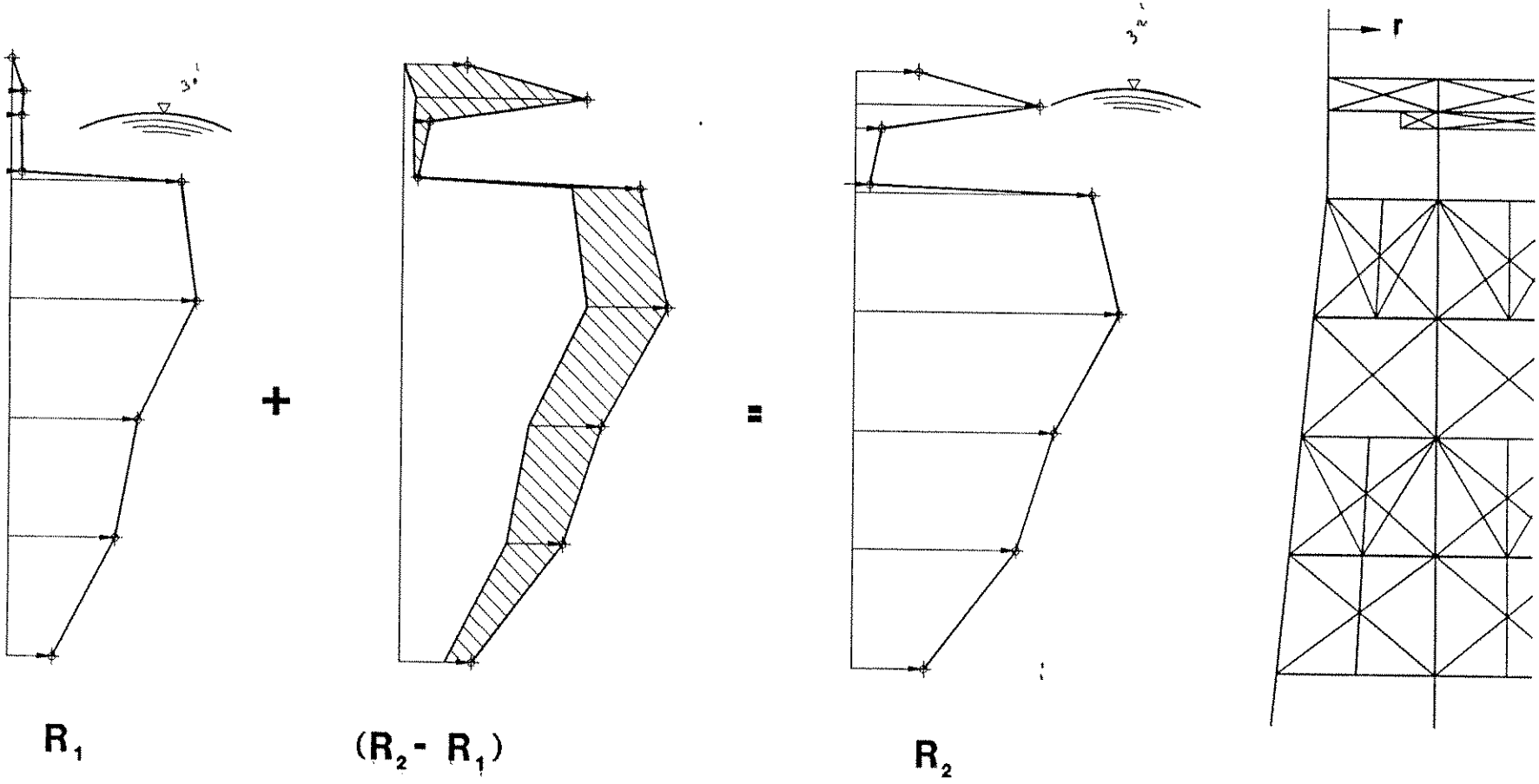


Wave Force Profile

Andrew JIP- Phase II

- **Deck Wave Force**
  - **Phase I Used Section 17 (1.056*H,Cd)**
  - **Phase II Used Revised Section 17 (1.0*H,Cd)**
- **Phase I Used Single Force Profile**
  - **Used Wave Height Close to Ultimate Capacity**
- **Phase II Used Variable Force Profile**
  - **Profile Changed to Reflect 2Ft Increments in Wave**





R_1 + $(R_2 - R_1)$ = R_2

INCREMENTAL WAVE HEIGHT PUSHOVER

X03.DWG AH 11-10-94 PLOT SCALE 1=600 22681-108

ANDREW PHASE II

WAVE FORCE PROFILE

CAP AUTOMATIC APPLICATION FEATURE

STAT

$f^*R_1 \quad 0 < f < 1$

STAT

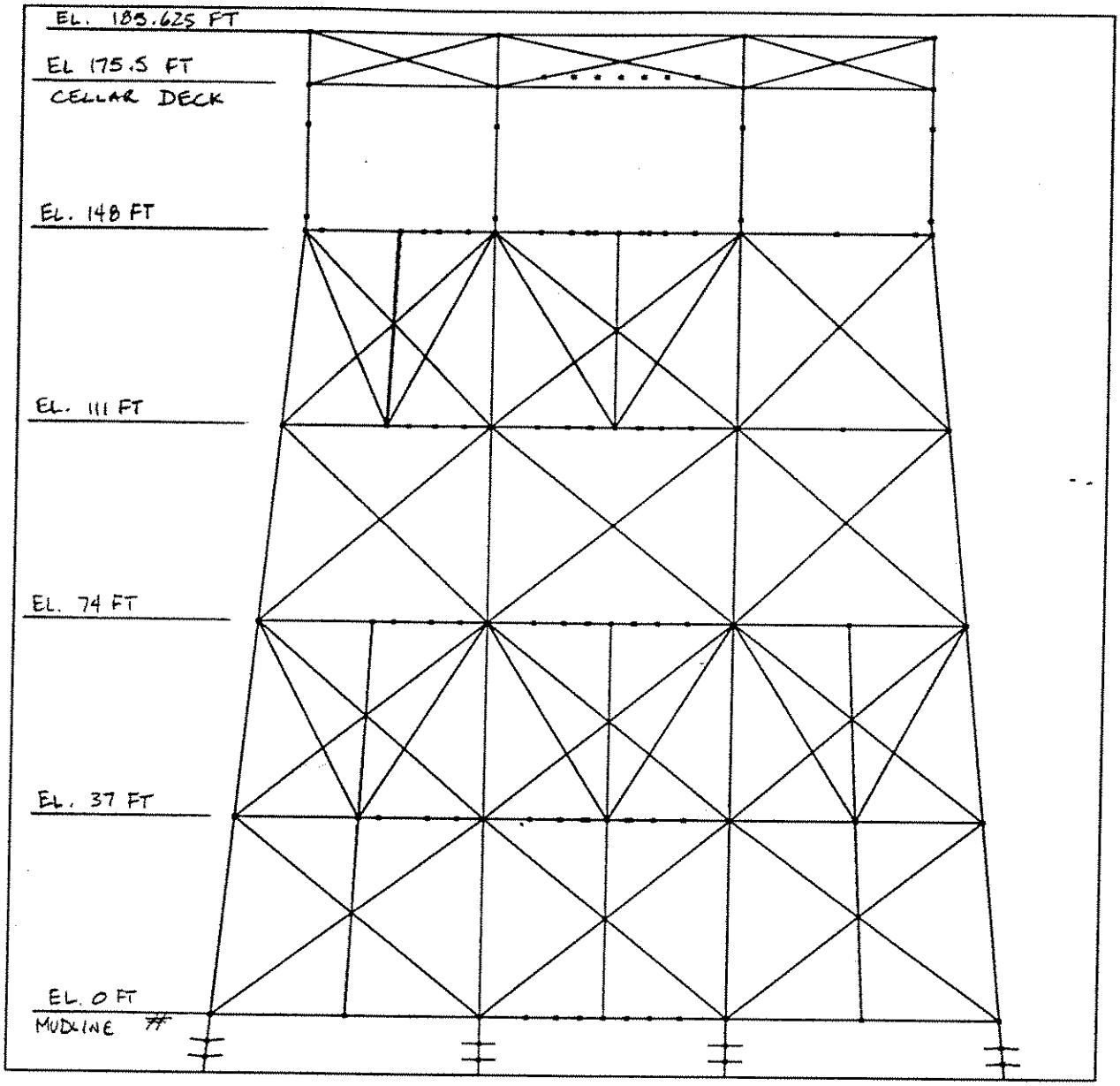
$f^*(R_2-R_1) \quad f < 1$

STAT

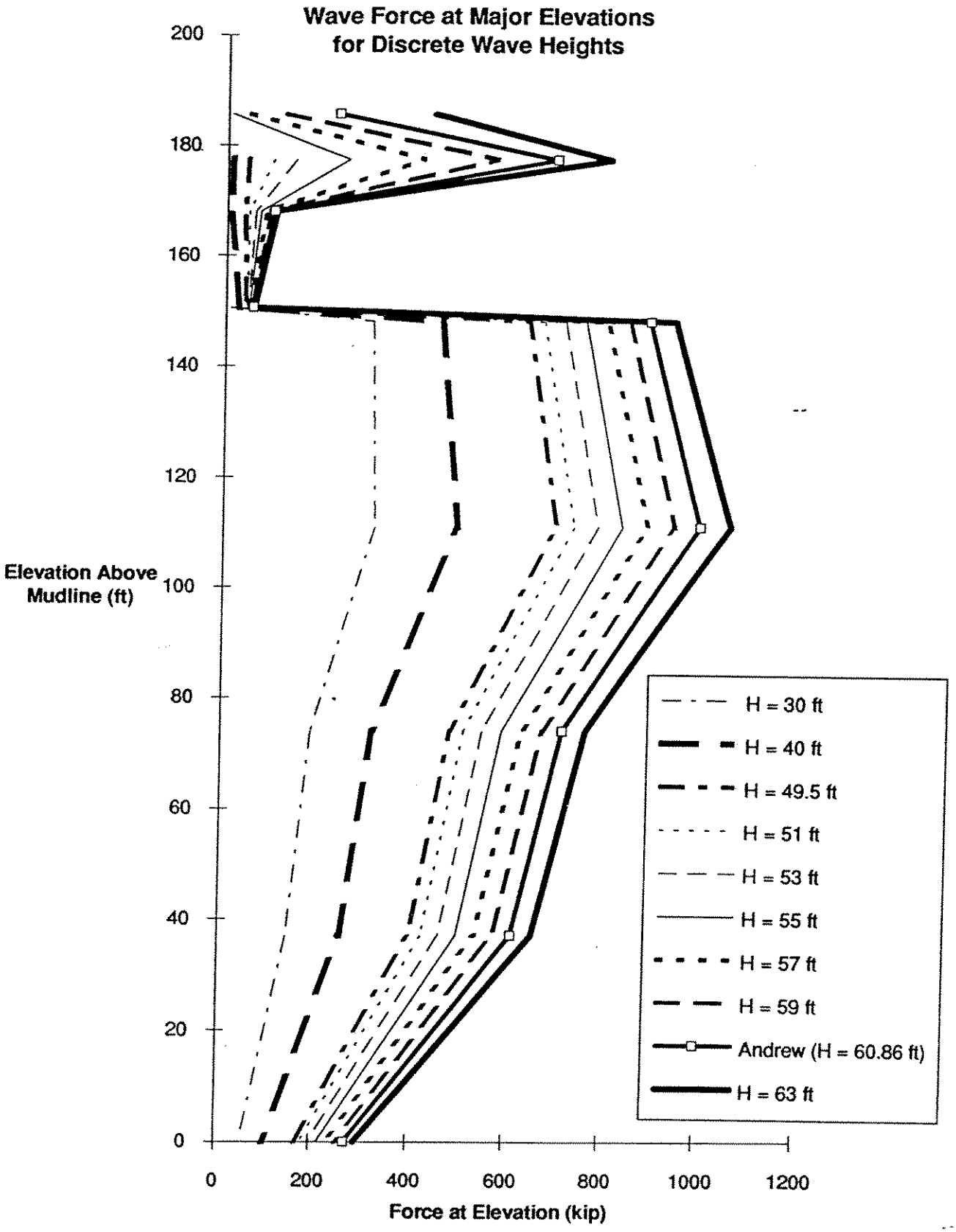
$f^*(R_3-R_2) \quad f < 1$

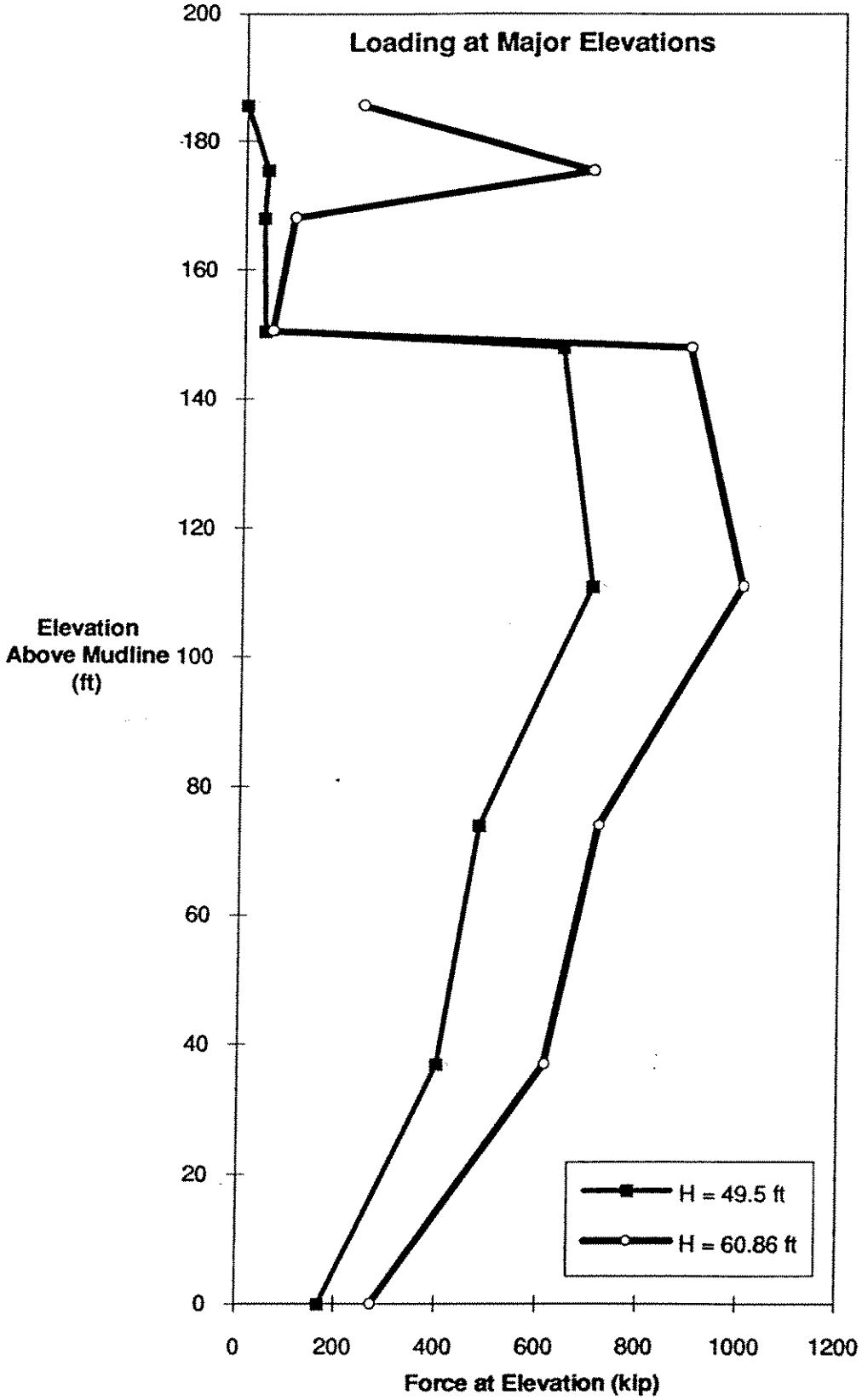
...

Project: ST151K Model: Wave_Loading Version: 1 Tue Nov 8 16:41:07 1994 *

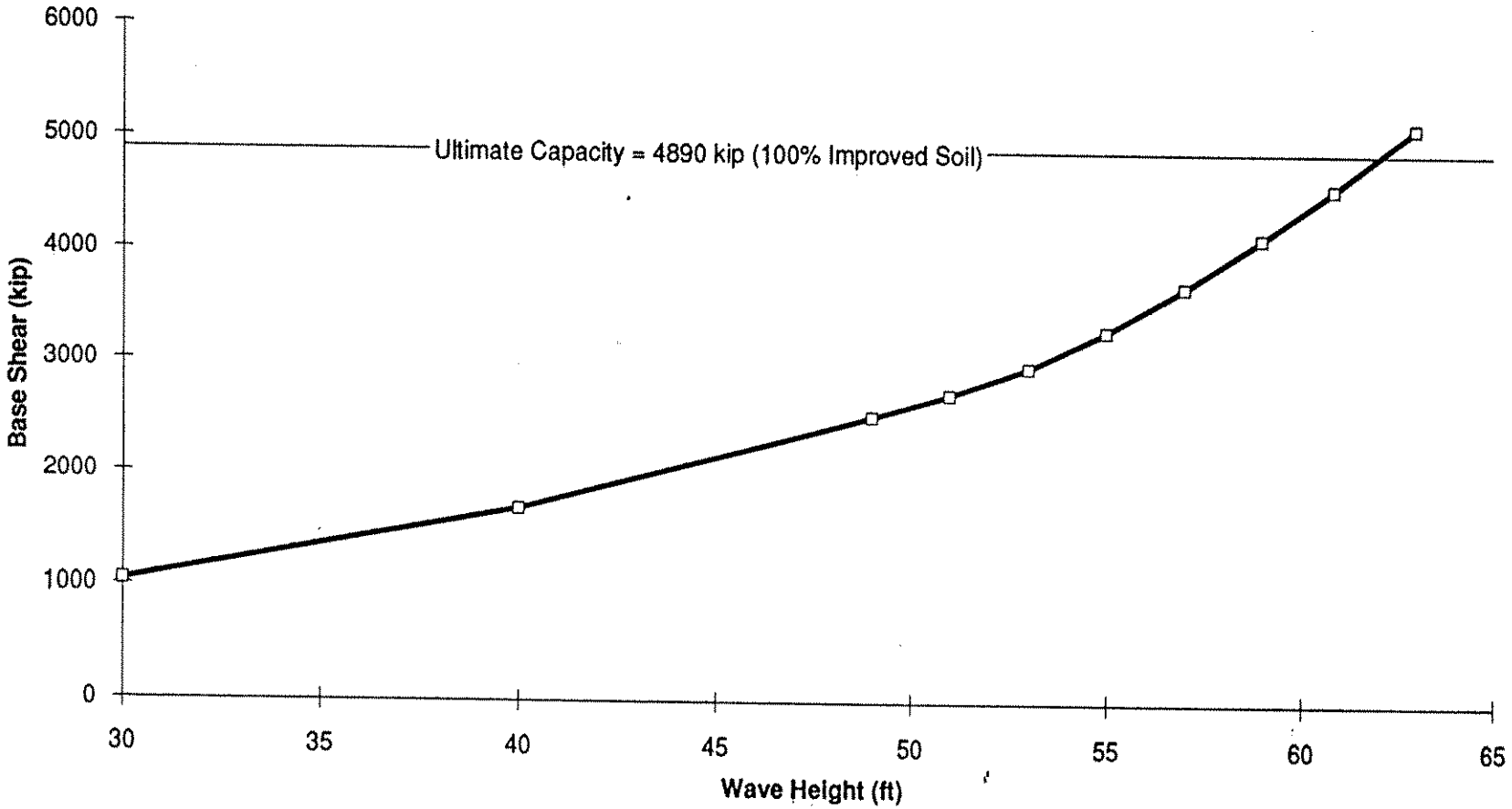


CAP z ↑ →x

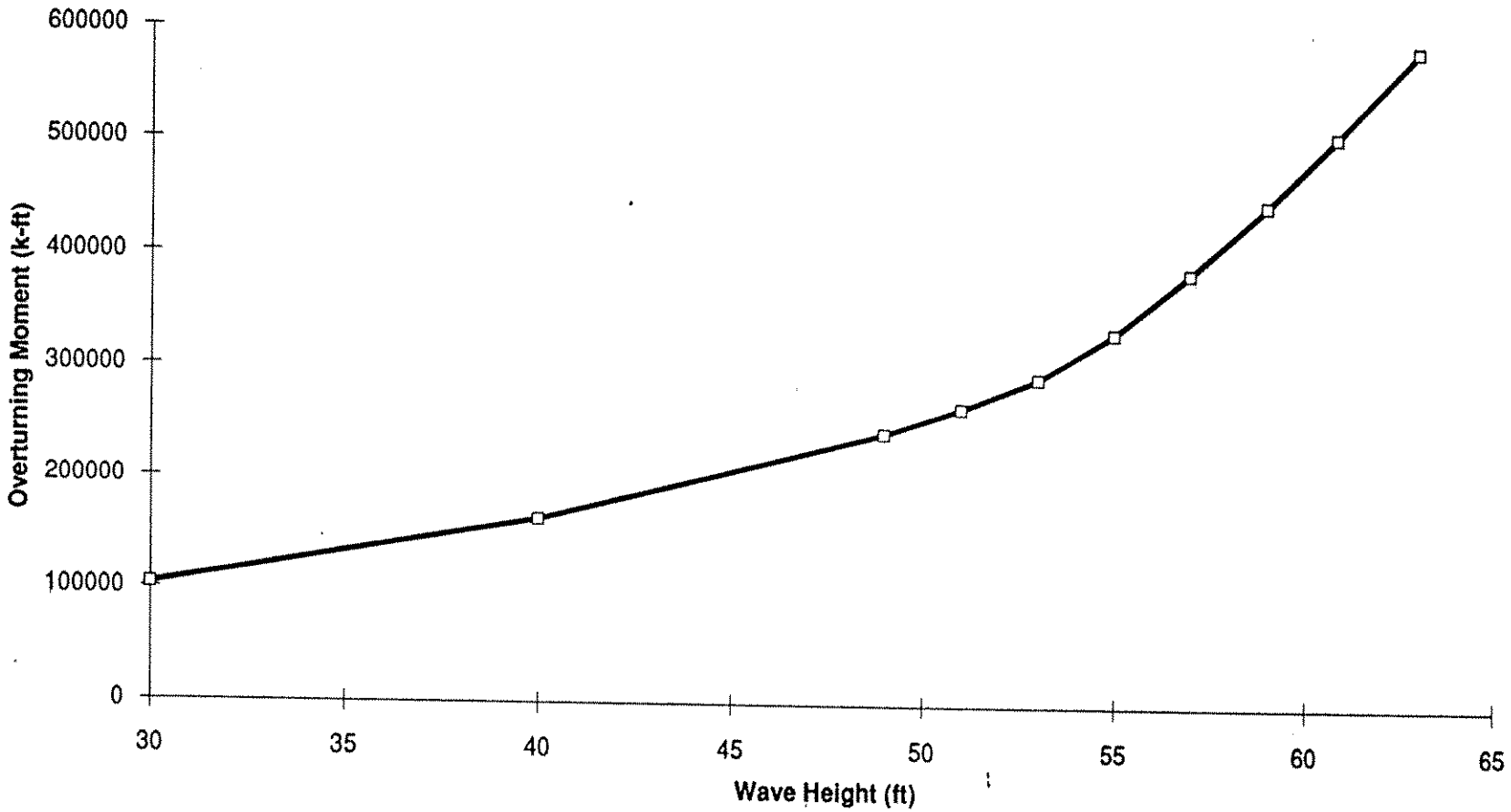

Wave Force at Major Elevations
for Discrete Wave Heights
Elevation Above Mudline (ft)
200
180
160
140
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
Force at Elevation (kip)
H = 30 ft
H = 40 ft
H = 49.5 ft
H = 51 ft
H = 53 ft
H = 55 ft
H = 57 ft
H = 59 ft
Andrew (H = 60.86 ft)
H = 63 ft


Loading at Major Elevations
Elevation Above Mudline (ft)
200
180
160
140
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
Force at Elevation (kip)
H = 49.5 ft
H = 60.86 ft

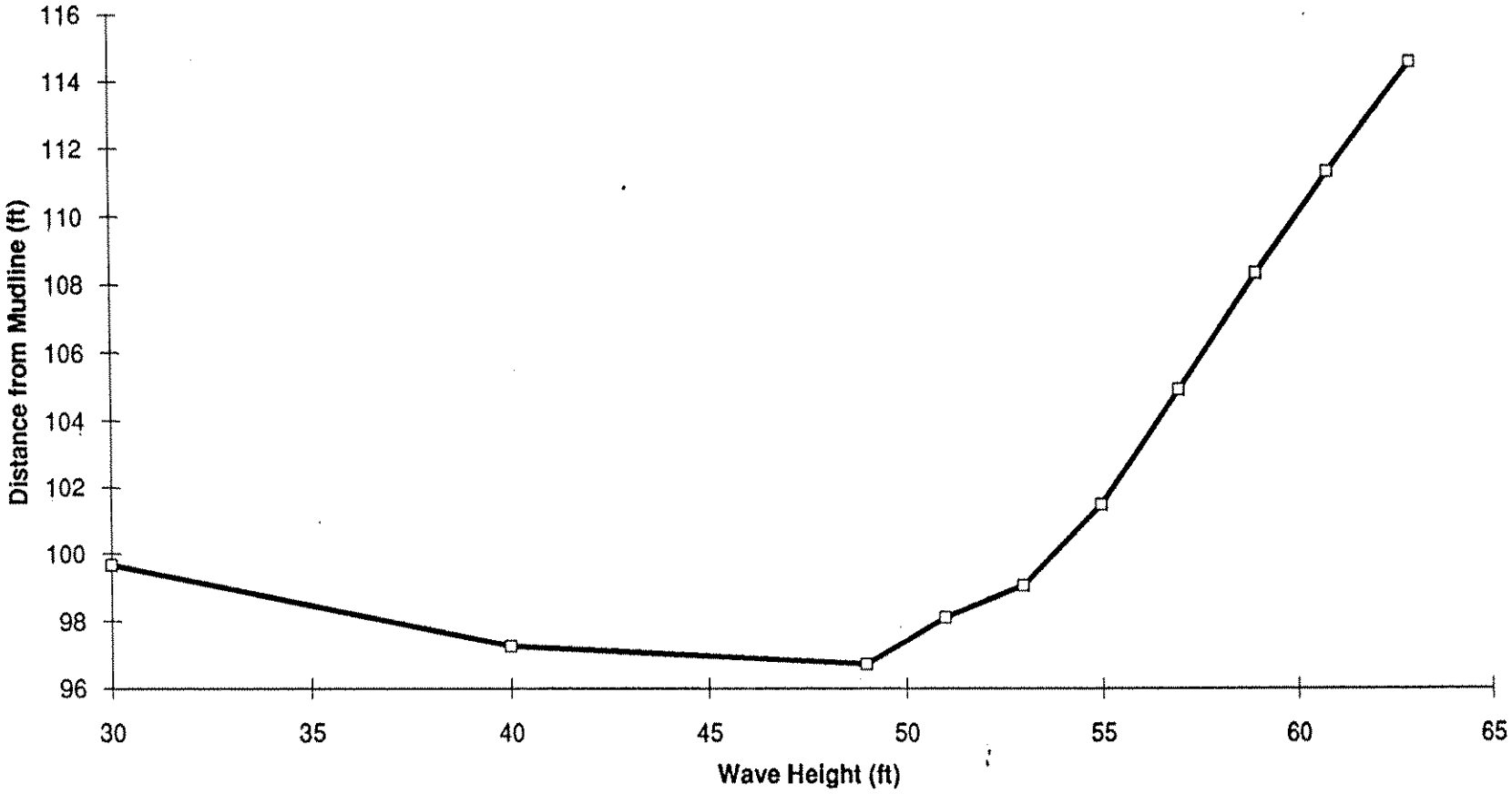
Base Shear vs Wave Height
ST151K



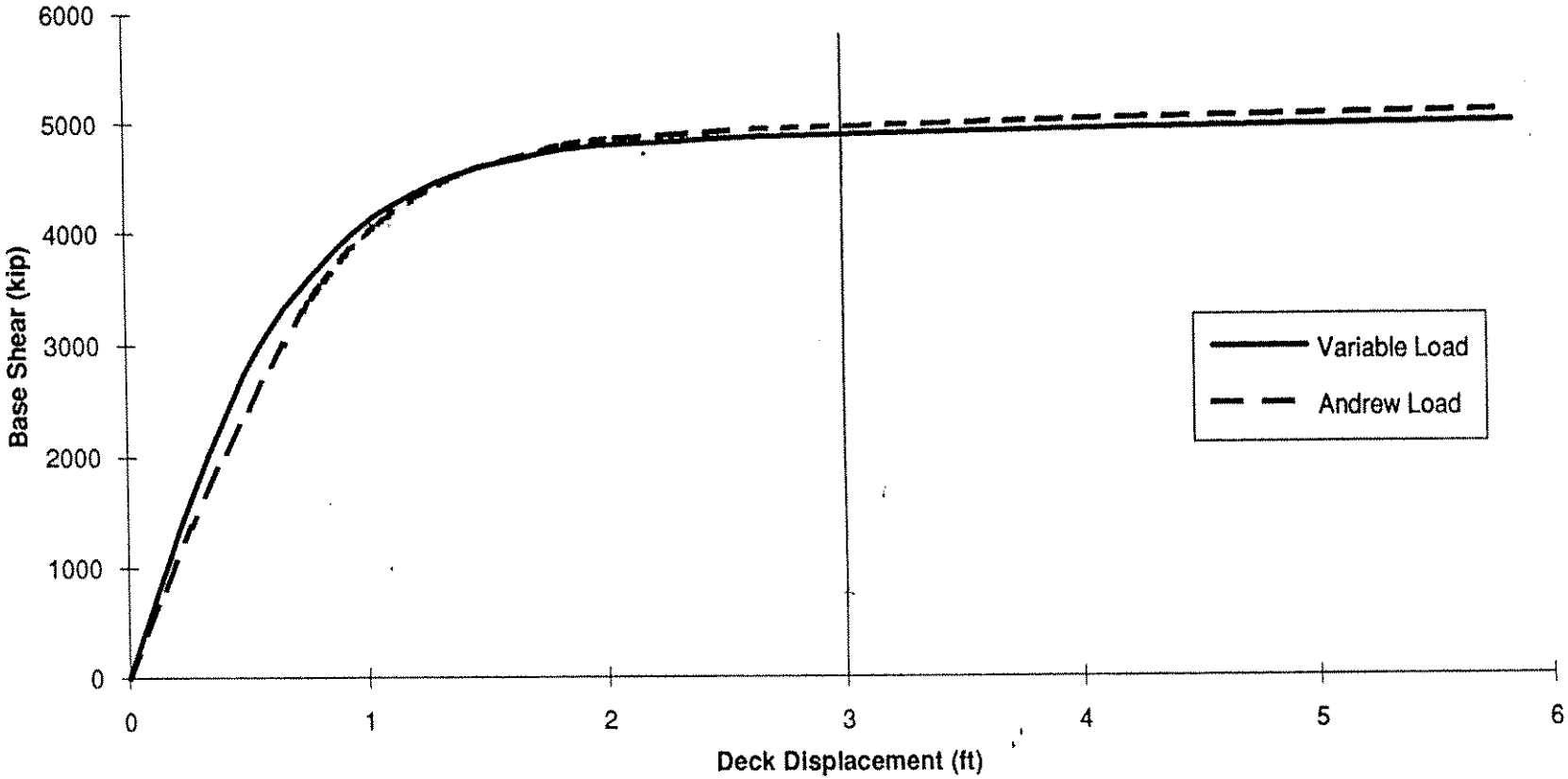
Wave Height vs. Overturning Moment
ST151K



Wave Height vs Center of Action
ST151K



Comparison of Pushover Curves for ST 151K
Variable Load Pattern and Monotonic Load Pattern (Andrew)
Soil Improved 100%



Brace Modeling

Andrew JIP- Phase II

- Phase I Used Struts
- Phase II Study Results
  - Strut Vs Buckling Beam Same Results for Frames Test
- Phase II Used Struts
  - K: 0.55 X, 0.65 K, 0.65 D, LRFD
- Joint Strength Governed Most Braces

NOTE

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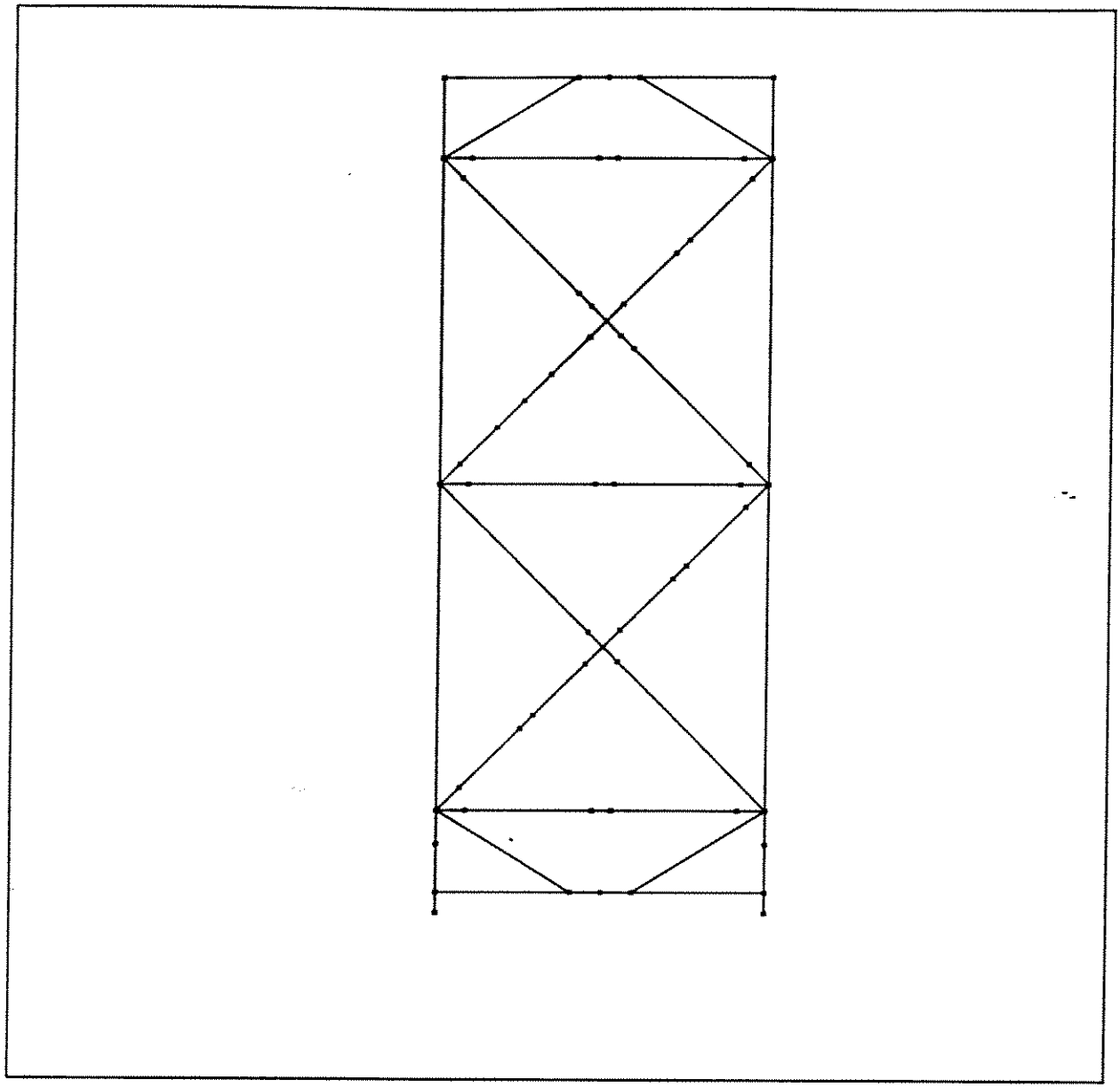
51

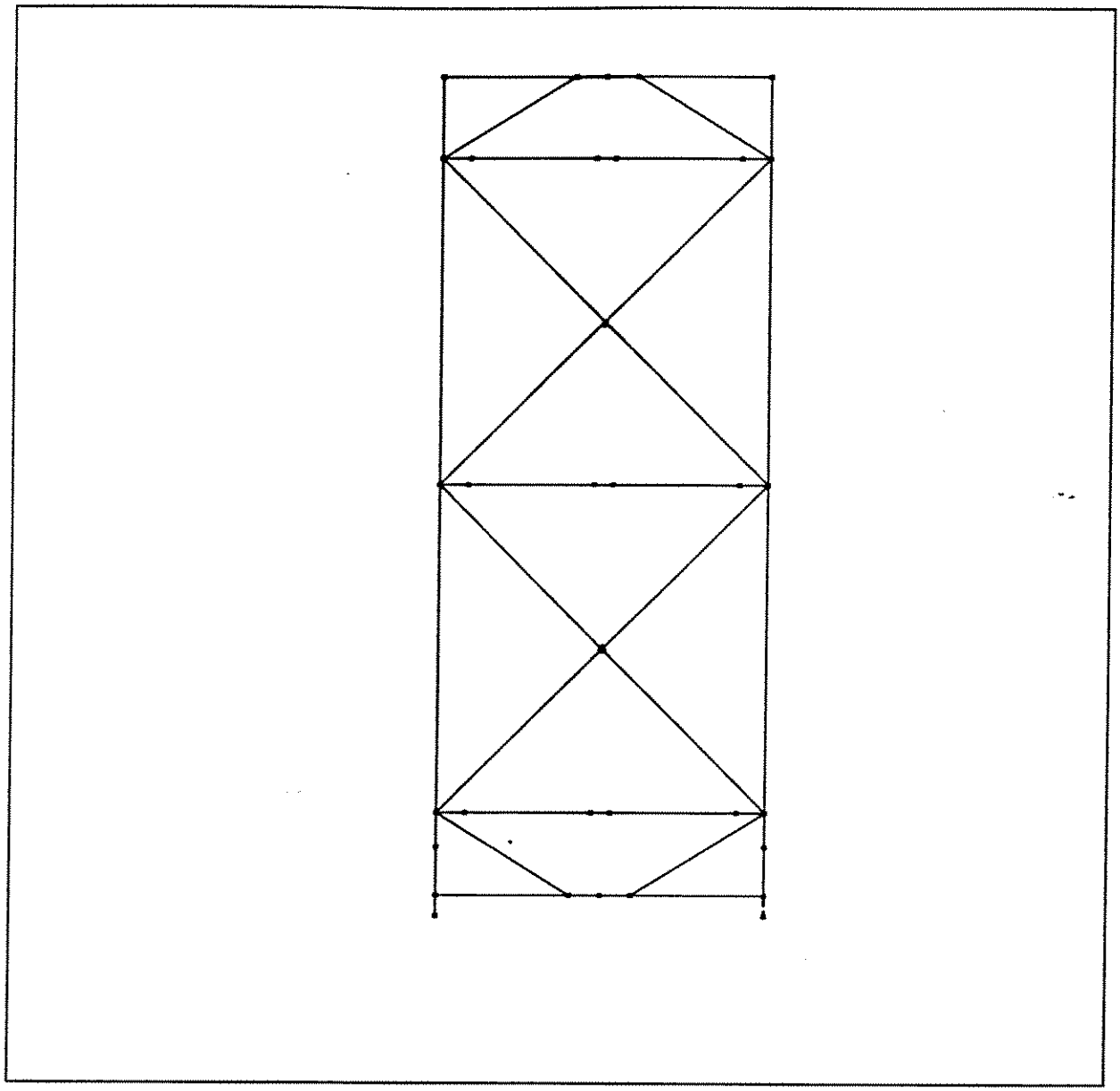
Project: andrew Model: beamframe Version: 1 Mon Nov 14 14:54:47 1994 *



CAP Y

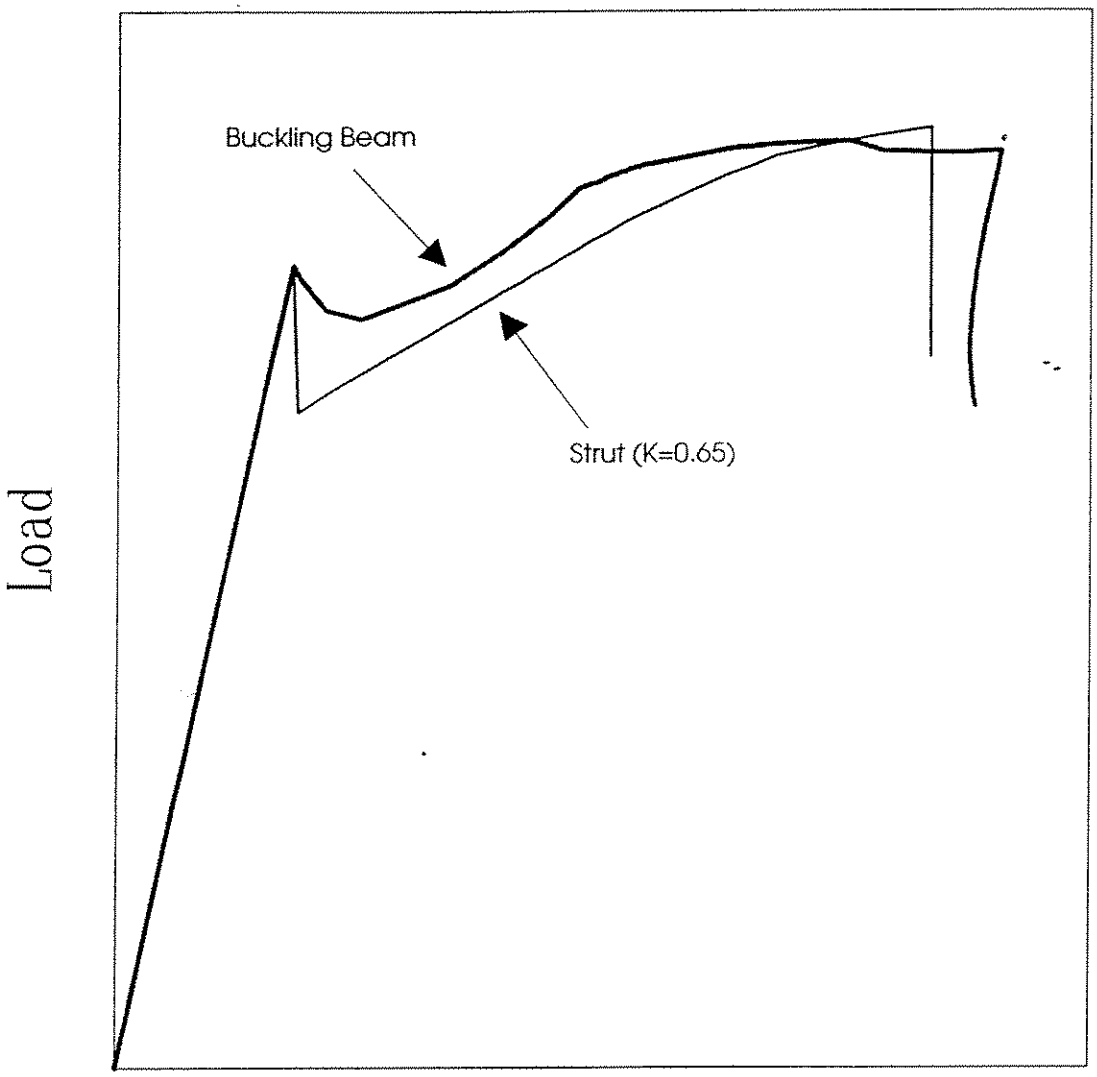
Frame Test: buckling beam-column model

Project: andrew Model: strutframe Version: 1 Mon Nov 14 14:57:54 1994 *



CAP Y

Frame Test: strut model


Buckling Beam
Strut (K=0.65)
Load
Lateral Displacement

Foundations

Andrew JIP- Phase II

- **Phase I: Explicit Nonlinear API**
- **Phase II: Explicit Nonlinear API**
  - **Static P-Y X 1.0**
  - **Static T-Z X 1.0**
- **Shear Strength**
  - **0.23 Ratio of Strength vs. Overburden Pressure**
  - **Mini-Vane on Undisturbed Samples**
  - **Interpreted or Design**
  - **1.2 Increase for Disturbed Driven Samples**

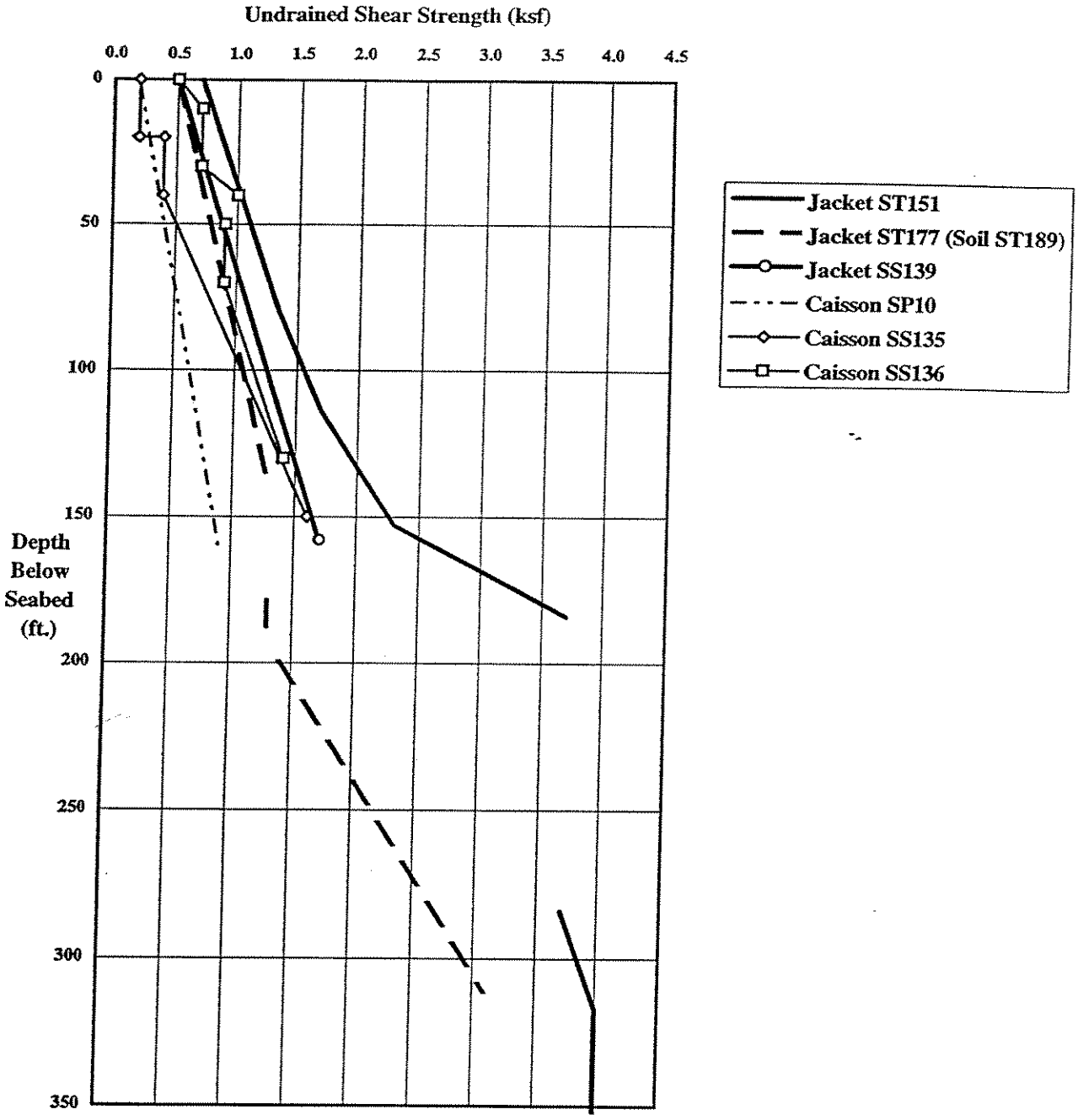


Figure 2-1: Undrained Shear Strength Profiles

Joint Modeling

Andrew JIP- Phase II

- **Phase I**
  - **API Rigid-Plastic Modeling**
  - **Uncoupled Axial & Moment**
- **Phase II**
  - **MSL Supplied Capacity Curves**
  - **Uncoupled Multilinear Modeling**
  - **Coupled Axial & Moment Iterations**

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Joint Modeling: MSL Data

Andrew JIP- Phase II

- **Continuous P-d & M-Ø Curves**
  - **100% K & 100% Y**
  - **Mean Value Not Lower Bound**
  - **Dimensionless P/Pu Vs d/D**
  - **M-Ø Same for K and Y**
- **Required Curve Adjustment**
  - **Brace Load Interaction Effects**
  - **Chord Load Effects**
  - **Joint Classification by Load**

Joint Modeling: MSL Curve Adjustment

Andrew JIP-Phase II

■ Interaction Effects

$$\left|\frac{P}{P_u}\right| + \left(\frac{M_{ipb}}{M_{u,ipb}}\right)^2 + \left|\frac{M_{opb}}{M_{u,opb}}\right| = 1.0$$

$$P_{u,combination} = P_{u(tabulated)} \left[1 - \left(\frac{M_{ipb}}{M_{u,ipb}}\right)^2 - \left|\frac{M_{opb}}{M_{u,opb}}\right|\right]$$

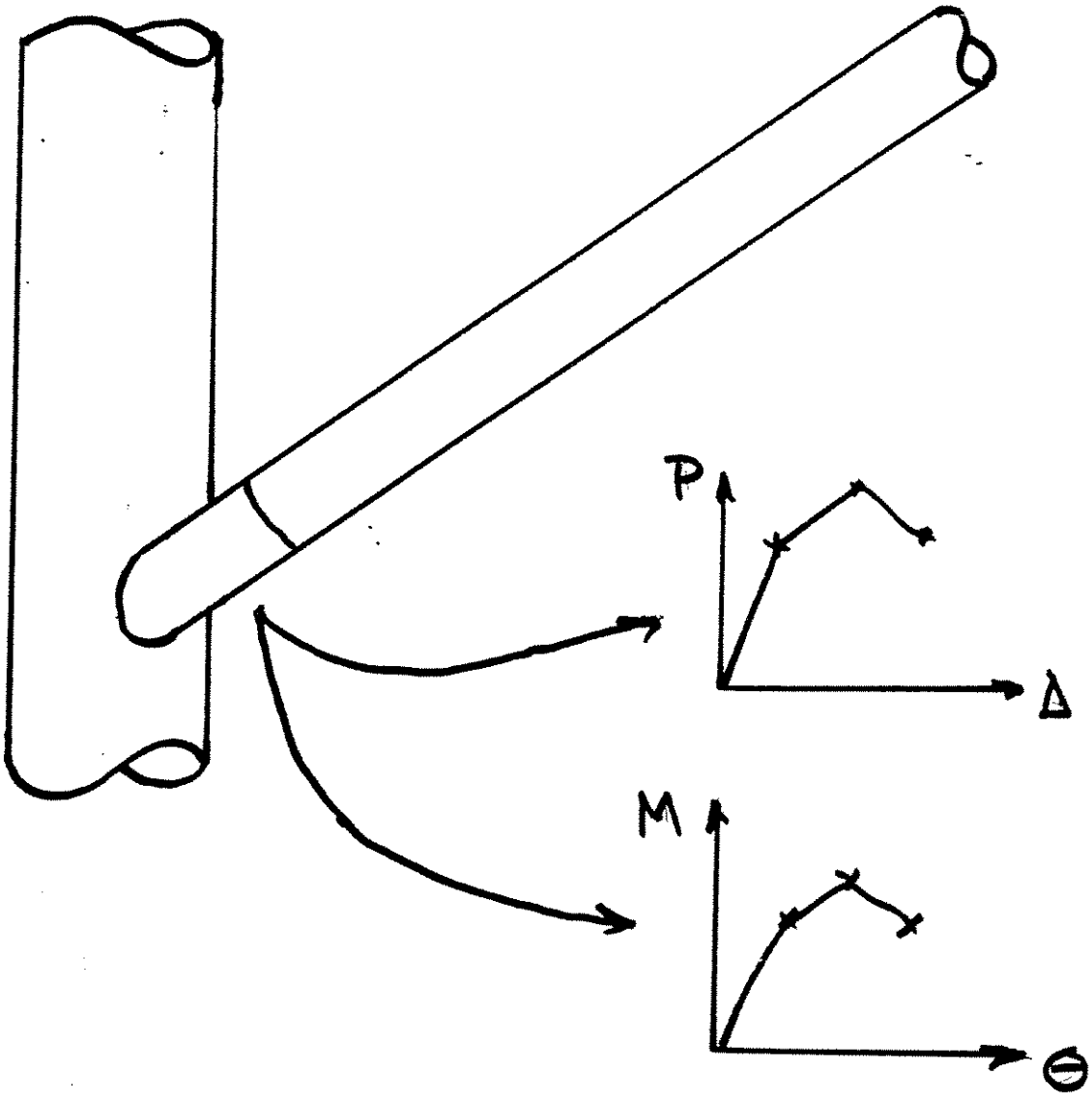
■ Chord Stress Effects

- **Qf = 1.0 when A < 0**
- **Qf = 1.0 - 0.21 when 0 < A < 0.5**
- **Qf = 1.21 - 0.63 when A > 0.5**
- **A =** $\dfrac{f_{ax} + 0.5\left(f_{ipb}^2 + f_{opb}^2\right)^{\frac{1}{2}}}{F_{YC}}$

PMB ENGINEERING

ANDREW PHASE II

JOINT MODELING PHASE II METHOD



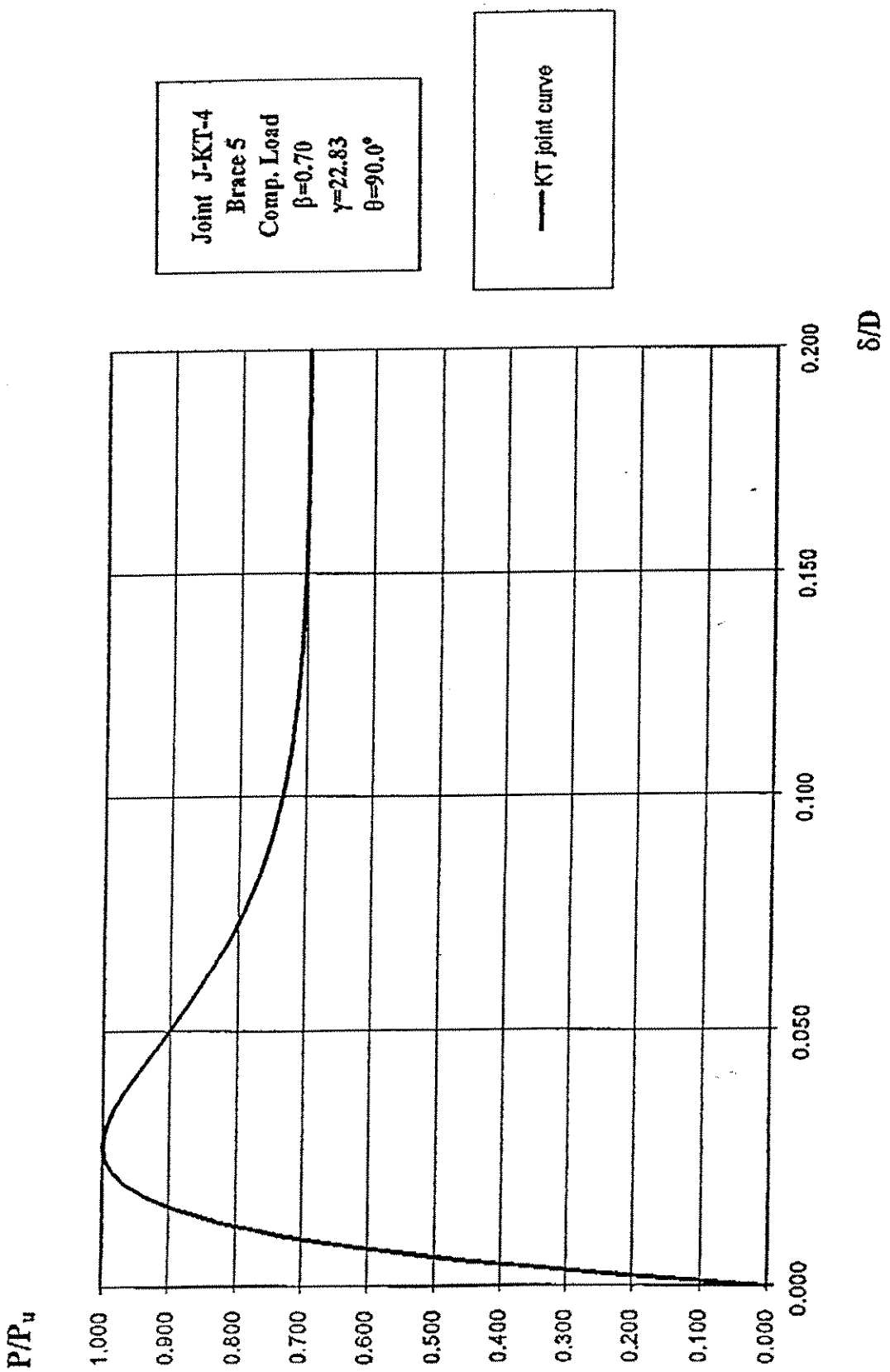
BASIC JOINT STRENGTHS[1]

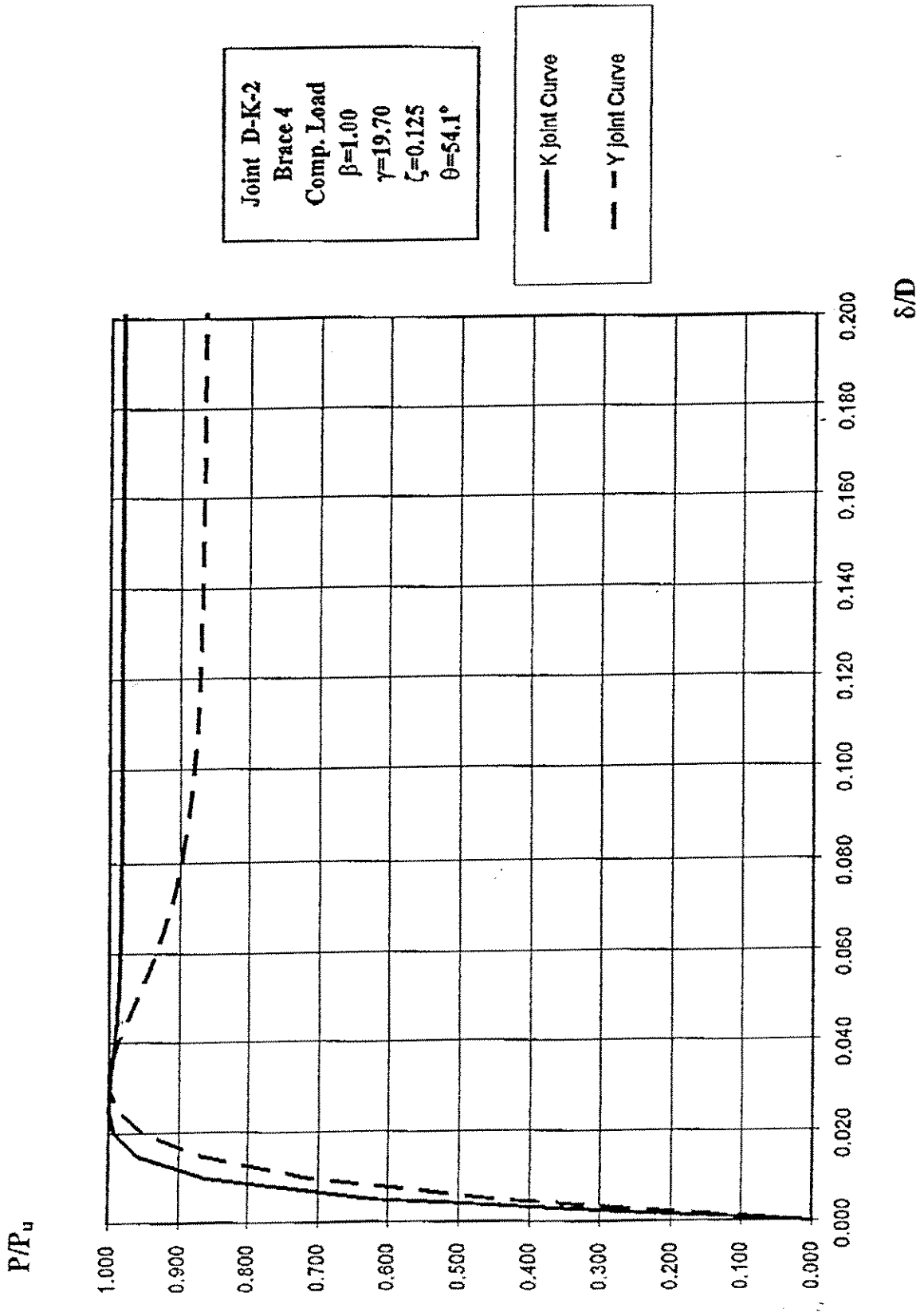
Joint Identification	Brace No	Comp P_u K-joint	Comp P_u Y-joint	Tension P_u K-joint	Tension P_u Y-joint	$M_{u\ IPB}$	$M_{u\ OPB}$
PLATFORM H							
H-K-1	3	14.93	10.34	-	-	10.00	7.69
	4	-	-	16.42	17.64	10.00	7.69
H-K-2	3	16.15	11.01	-	-	10.65	8.19
	4	-	-	17.77	18.78	10.65	8.19
H-KT-3	3	12.35	11.64	-	-	11.25	8.65
	4	-	-	13.59	19.84	11.25	8.65
	5	6.19	4.96	-	-	4.34	2.36
PLATFORM J							
J-X-1[2]	3 & 4	-	7.48	-	-	6.58	5.06
J-K-2	3	-	-	13.71	14.06	6.94	5.34
	4	12.47	8.25	-	-	6.94	5.34
J-K-3	3	-	-	16.15	16.36	9.28	7.13
	4	14.68	9.60	-	-	9.28	7.13
J-KT-4	3	-	-	13.44	15.41	9.09	5.77
	4	12.22	8.34	-	-	9.09	5.77
	5	6.43	4.23	-	-	4.09	2.02

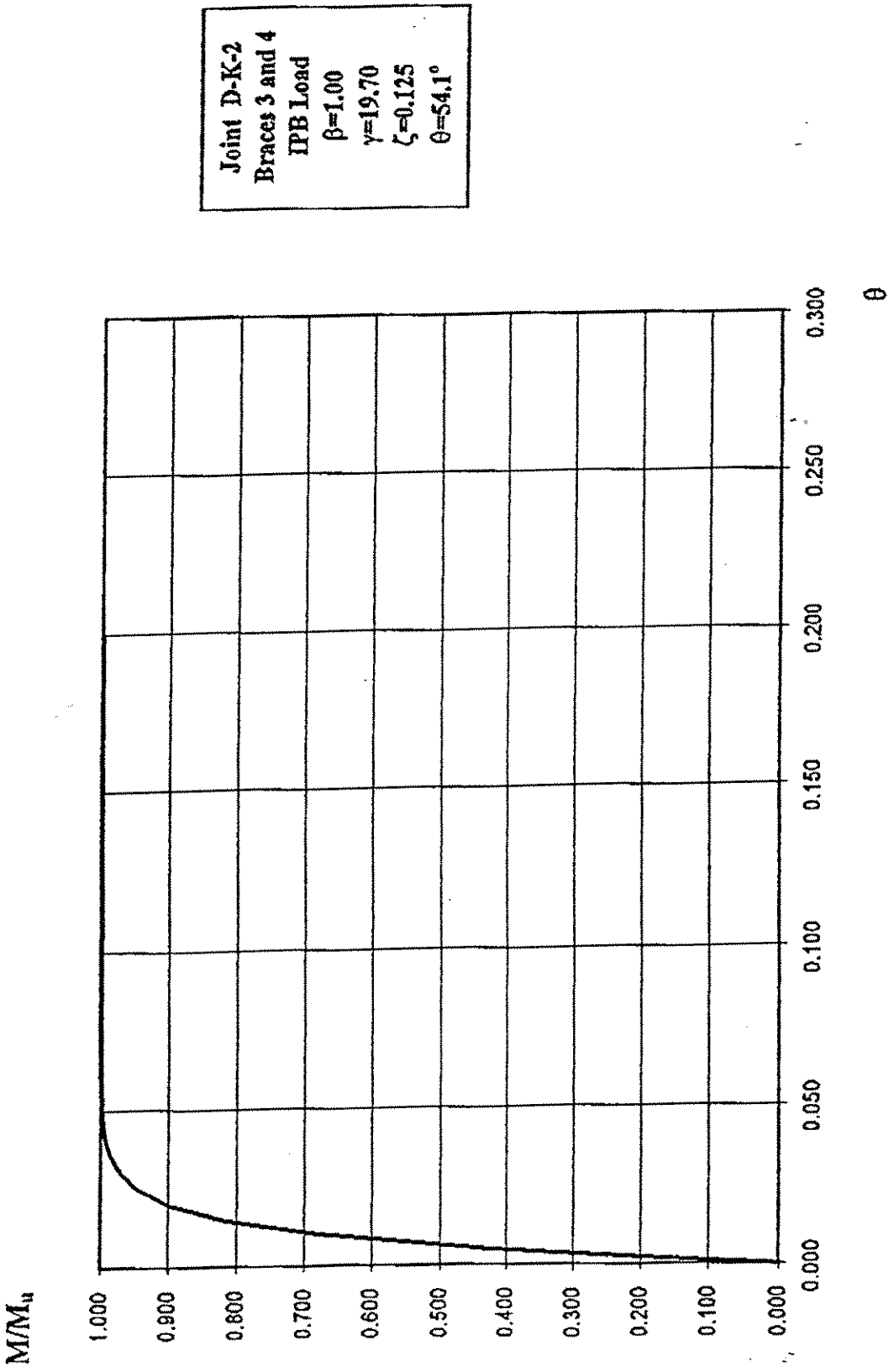
Notes:

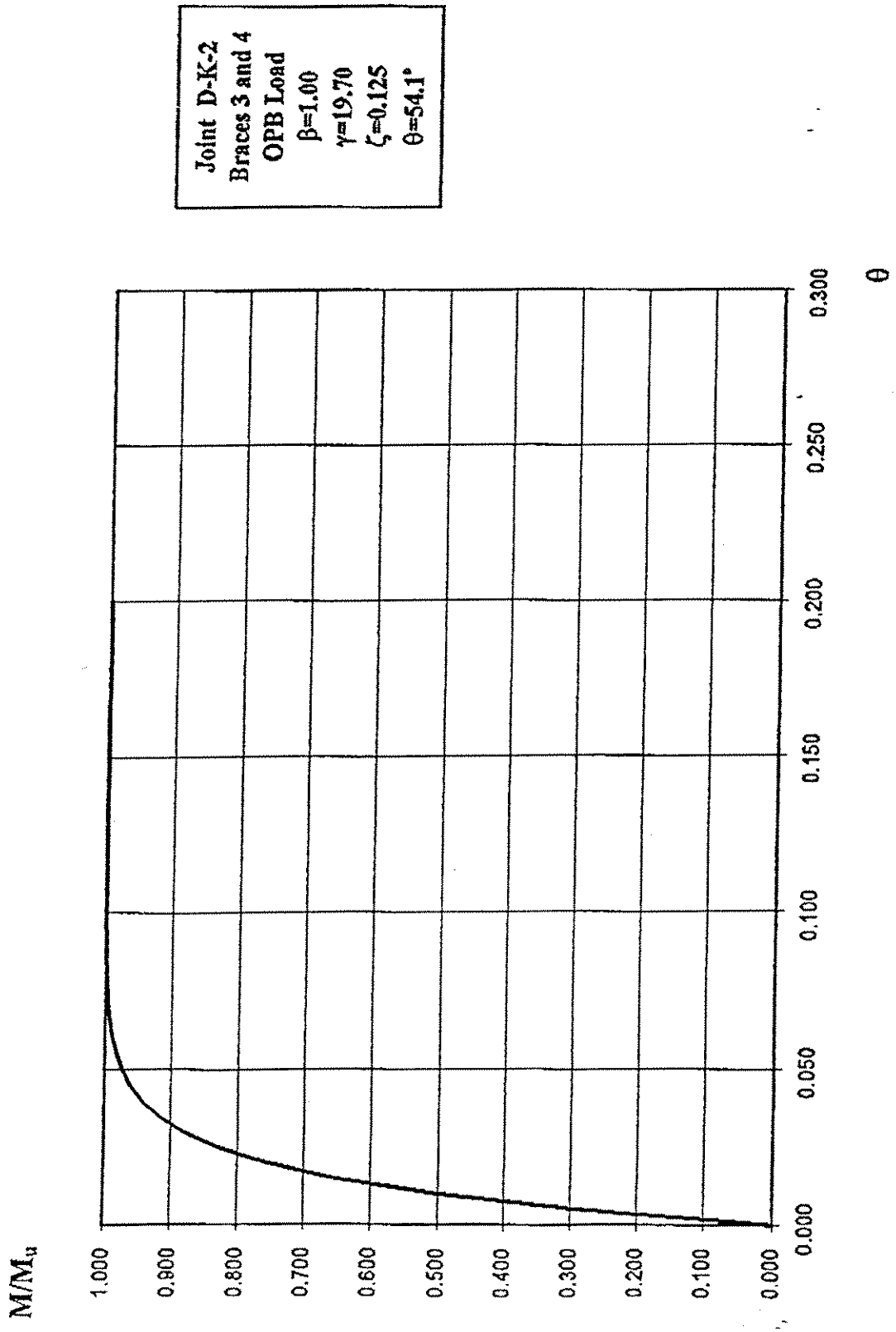
(1) All values to be multiplied by Fy (chord yield in ksi) to give strengths in terms of kips or kips-ft.

(2) Classification of J-X-1 is X joint.


Joint J-KT-4
Brace 5
Comp. Load
β=0.70
γ=22.83
θ=90.0°
KT joint curve
P/Pu
δ/D
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0.000
0.050
0.100
0.150
0.200


Joint D-K-2
Brace 4
Comp. Load
β=1.00
γ=19.70
ζ=0.125
θ=54.1°
K joint Curve
Y joint Curve
P/Pu
δ/D
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0.000
0.020
0.040
0.060
0.080
0.100
0.120
0.140
0.160
0.180
0.200


Joint D-K-2
Braces 3 and 4
IPB Load
β=1.00
γ=19.70
ζ=0.125
θ=54.1°
M/Mu
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0.000
0.050
0.100
0.150
0.200
0.250
0.300
θ


Joint D-K-2
Braces 3 and 4
OPB Load
β=1.00
γ=19.70
ζ=0.125
θ=54.1°
M/Mu
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0.000
0.050
0.100
0.150
0.200
0.250
0.300
θ

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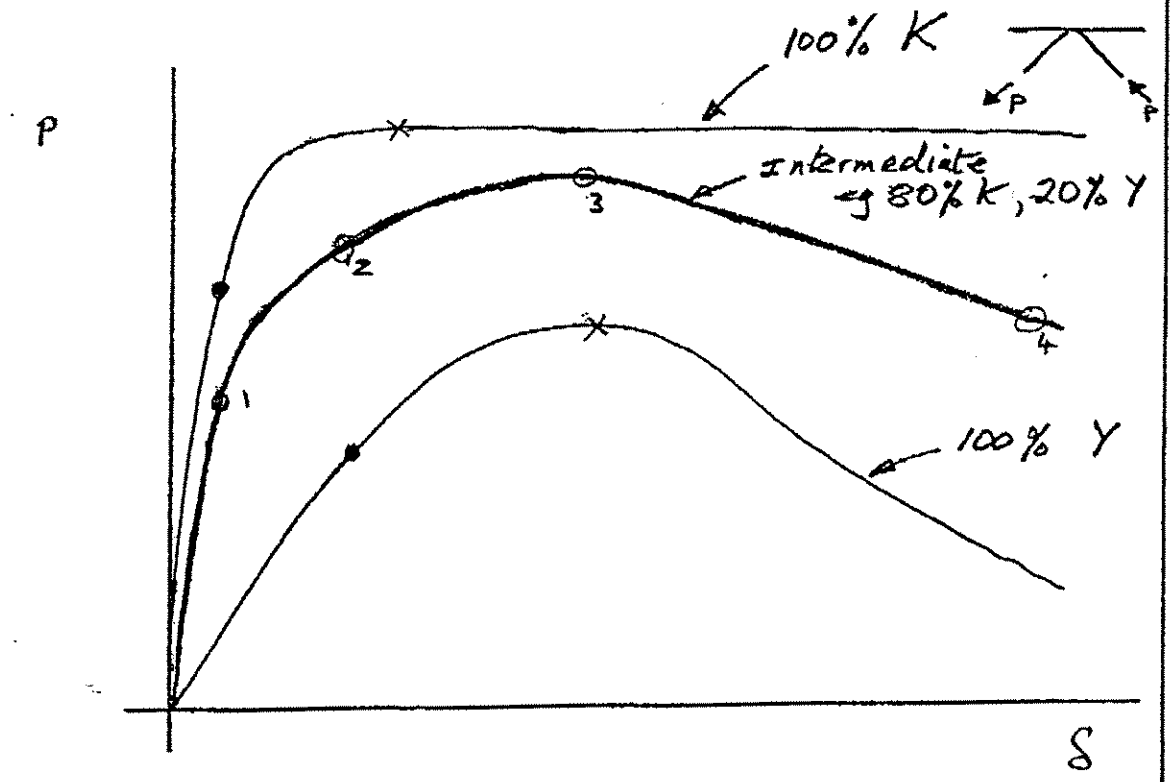
CALCULATION SHEET

MSL Project No. C160		Sheet of	Rev.
Job Title Hurricane Andrew JIP PL 2.			
Client PMB		Report No. F007.	
Made by		Date Jan 95	
Checked by		Date	

REF

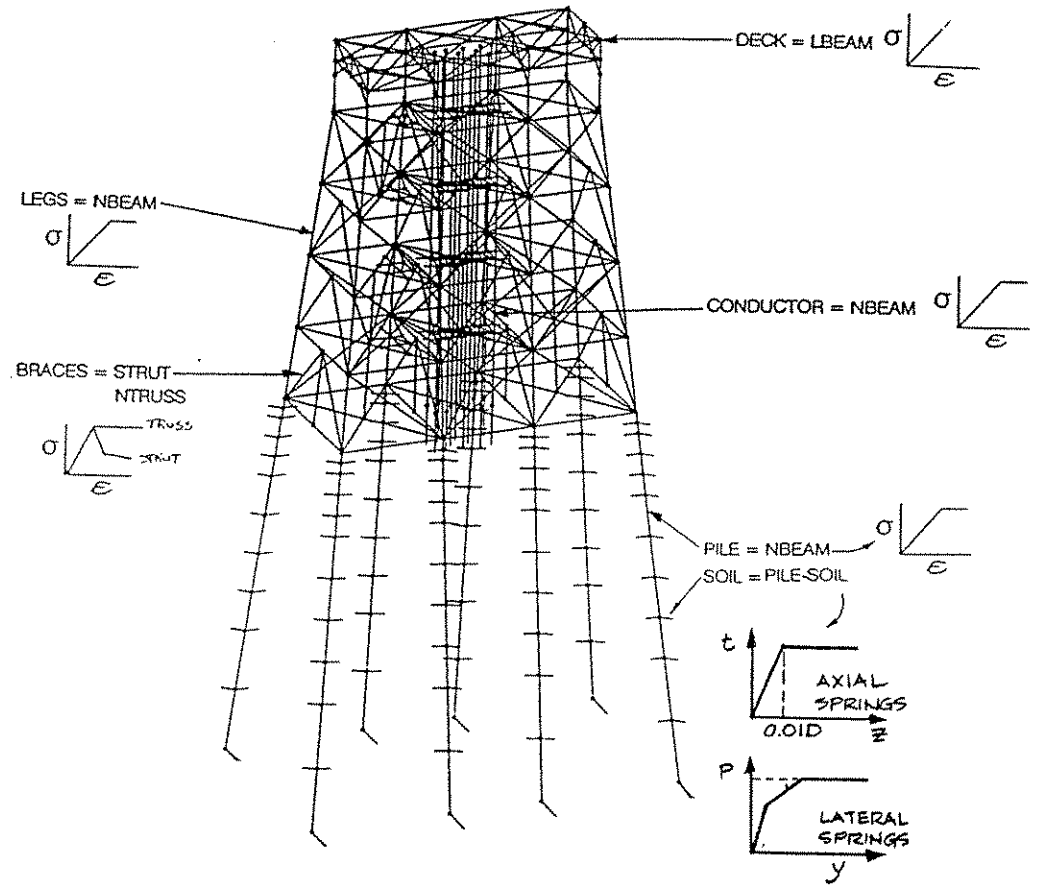


- Initial softening
- × Peak load

$P_{intermediate\ classification} = 0.80 P_{K\ \frac{1}{2}t} + 0.20 P_{Y\ \frac{1}{2}t}$.

Nonlinear Analysis Model

Andrew JIP- Phase II



8-Leg Steel Jacket Platform

rka/June 1995

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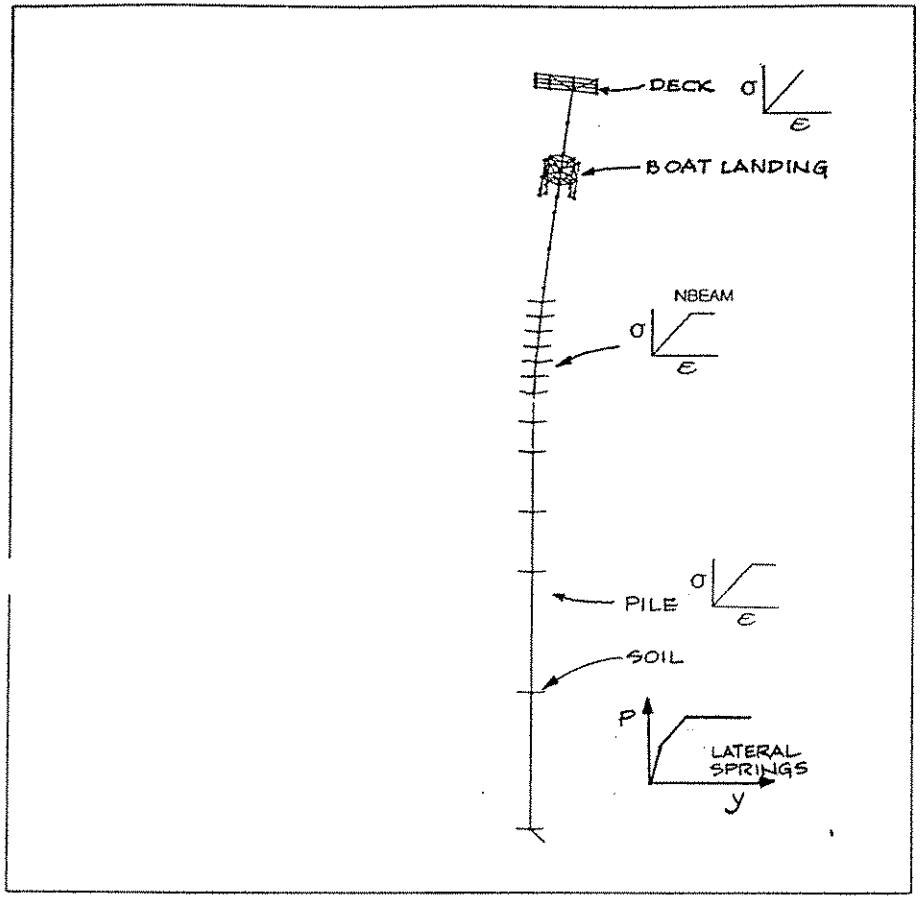
Nonlinear Analysis Model

Andrew JIP- Phase II



Caisson Platform

Hindcast Results

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Andrew Hindcast

- **Phase I vs Phase II**
  - **Phase II Hmax 3-14% lower**
  - **Phase II Base Shear 15-37% lower**
- **Hindcast Interpolation Issues**
  - **Depth vs Spatial**

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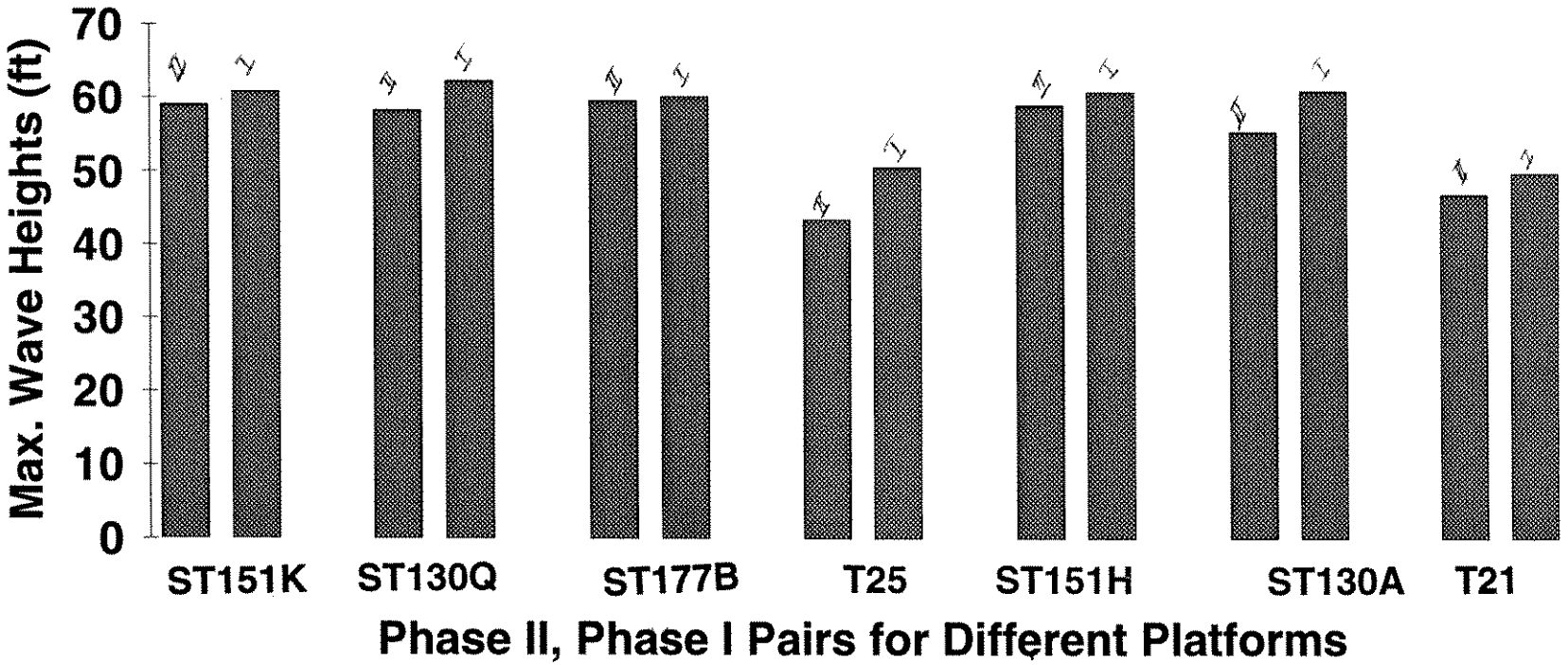
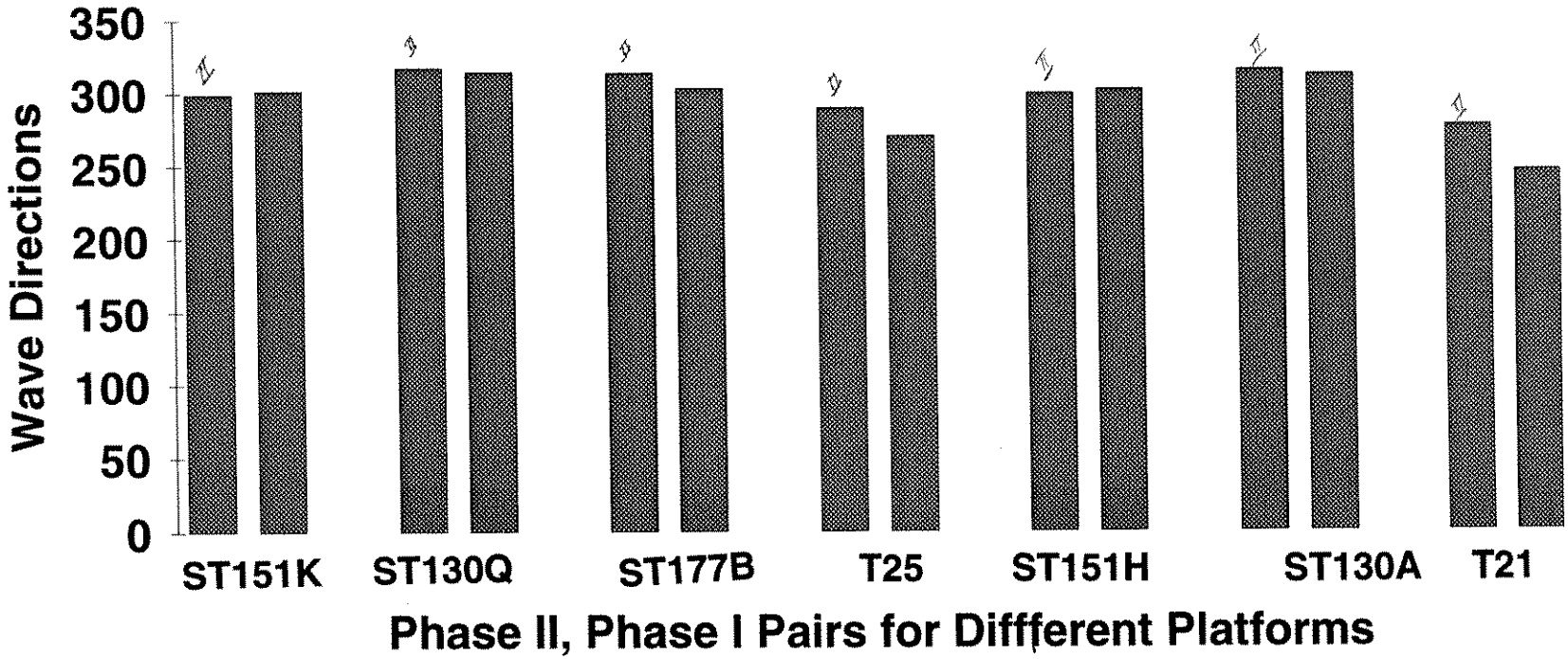
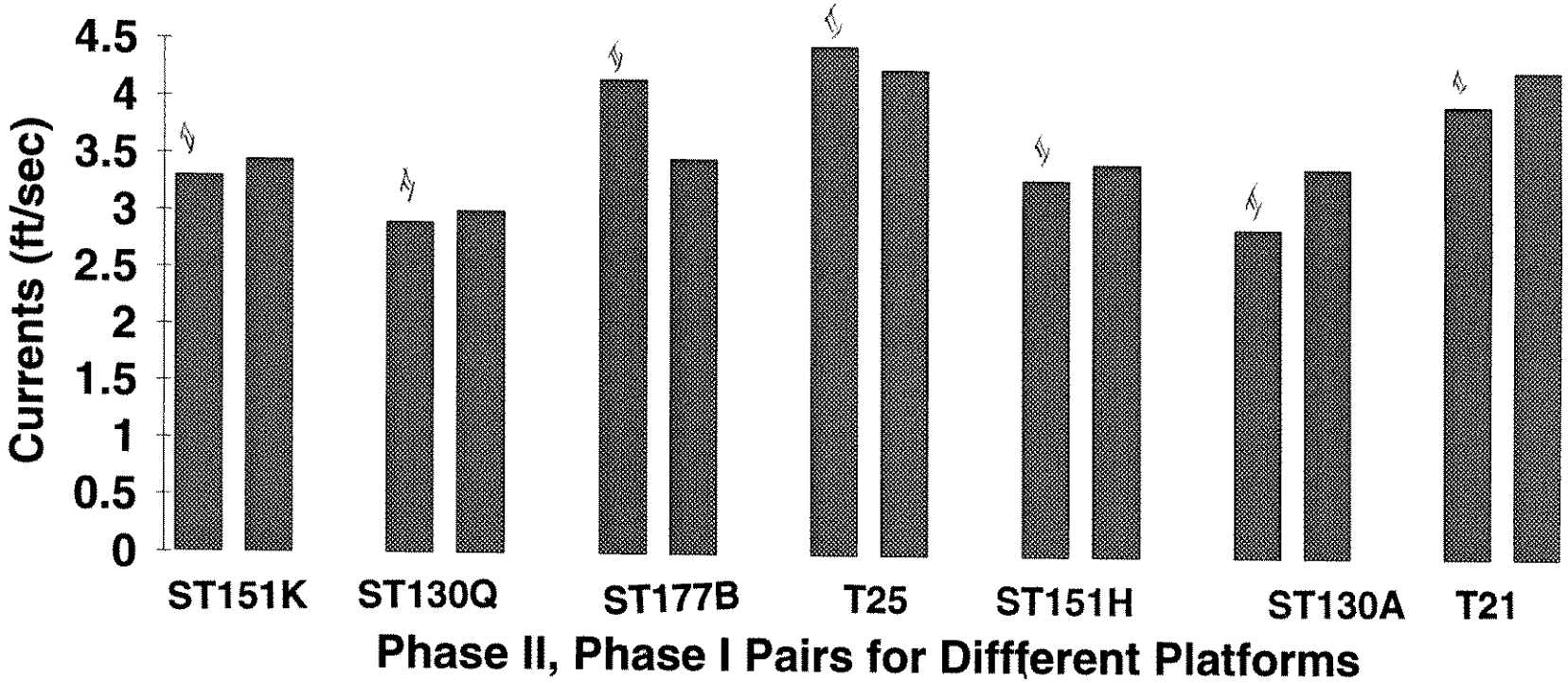
Comparison of Phase II and Phase I Hindcast MaximumWave Heights



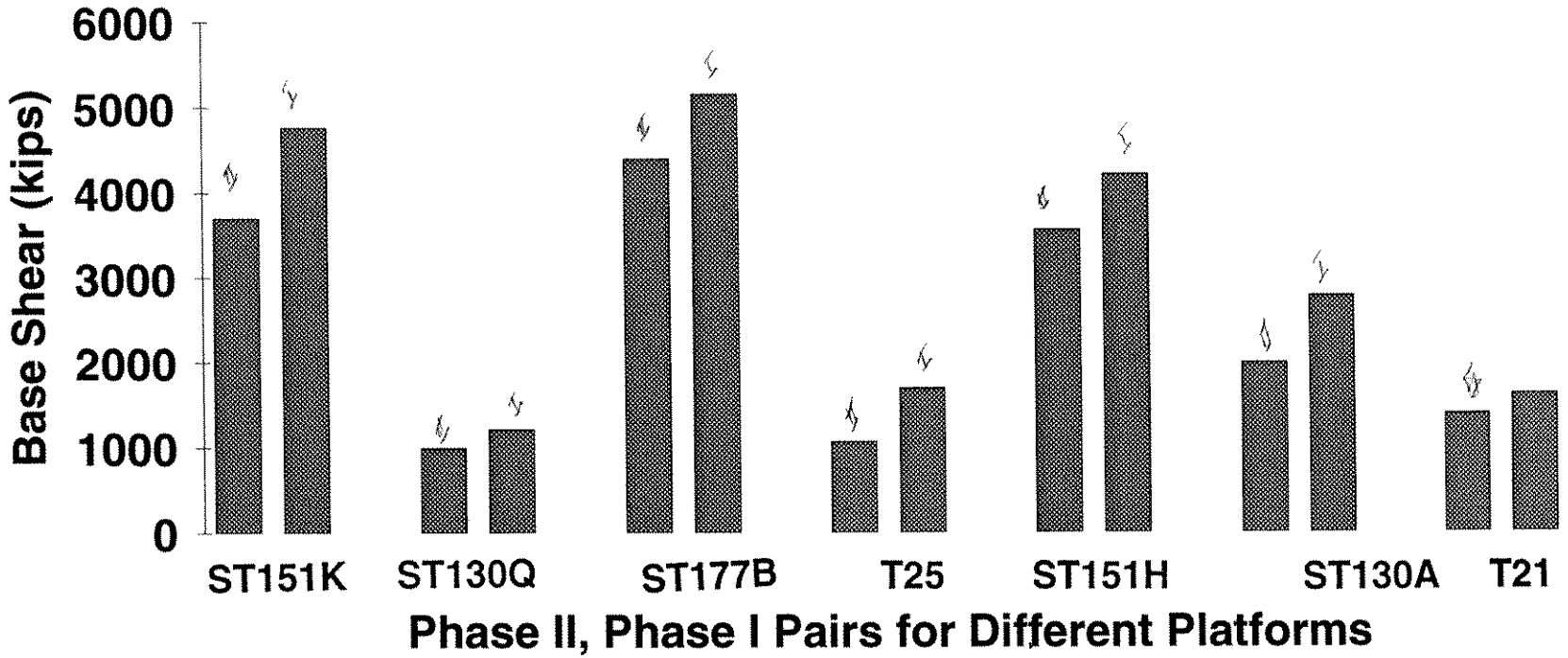
Comparison of Phase II and Phase I Hindcast Wave Directions

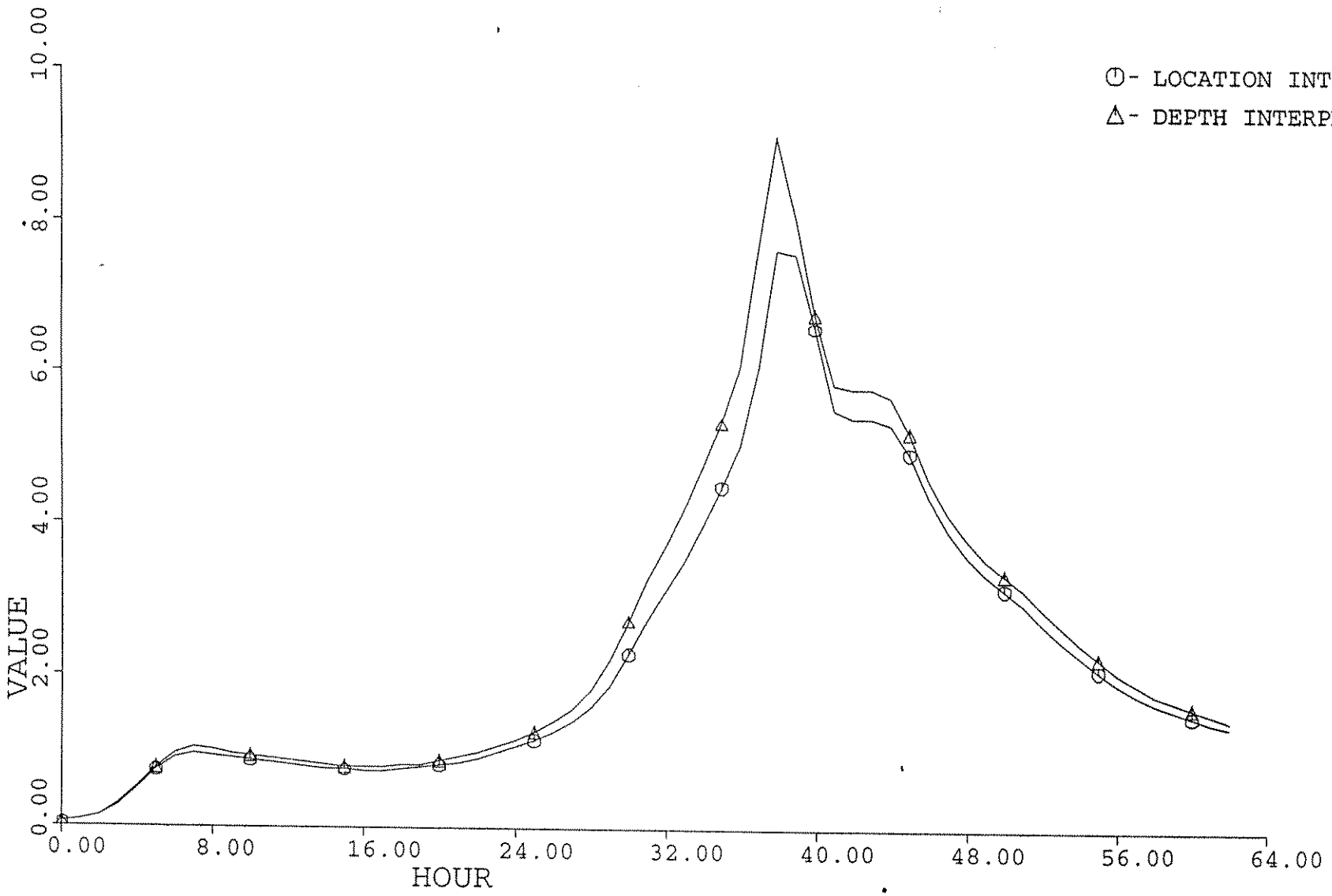


Comparison of Phase II and Phase I Hindcast Currents

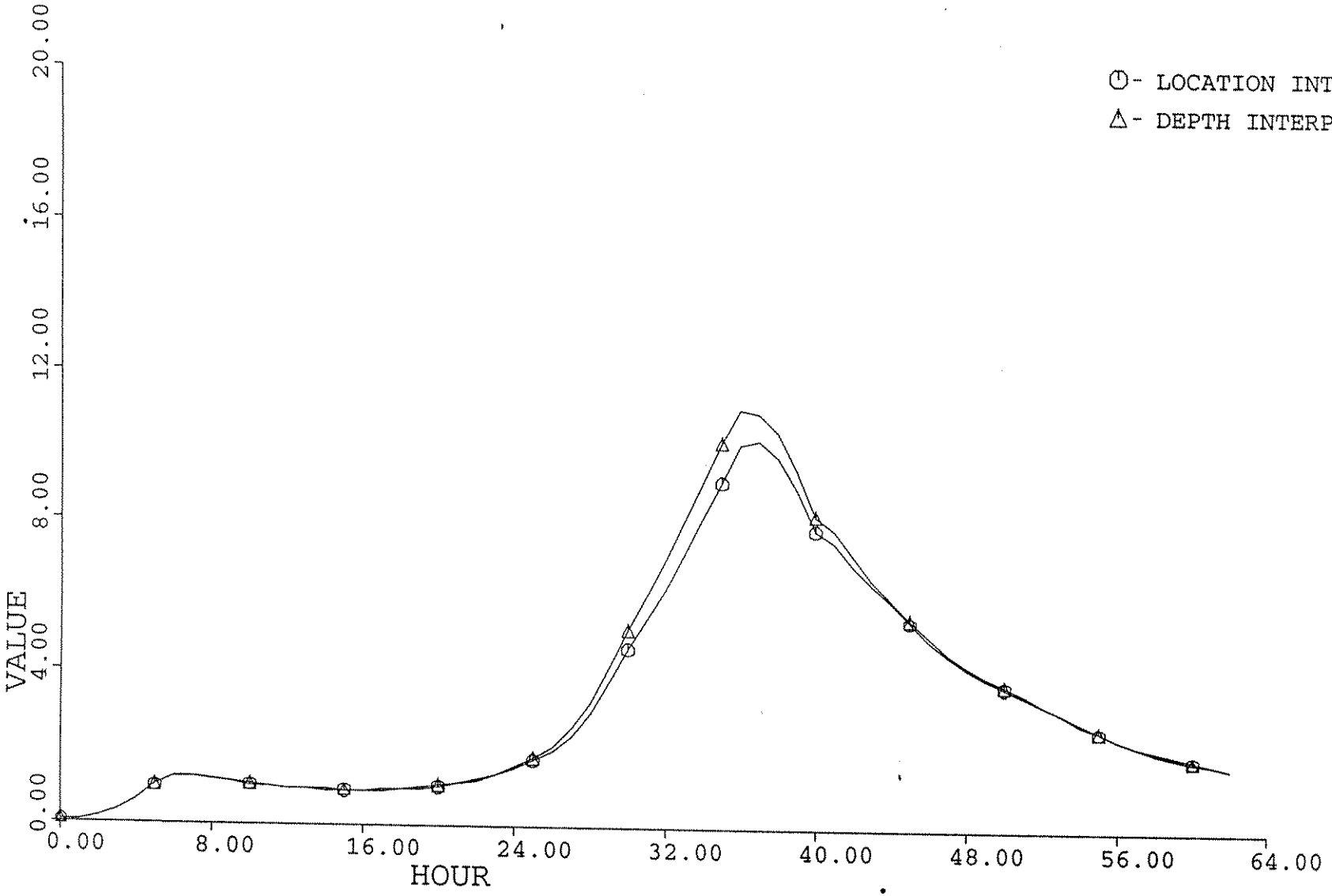


Comparison of Phase II and Phase I Expected Maximum Base Shears

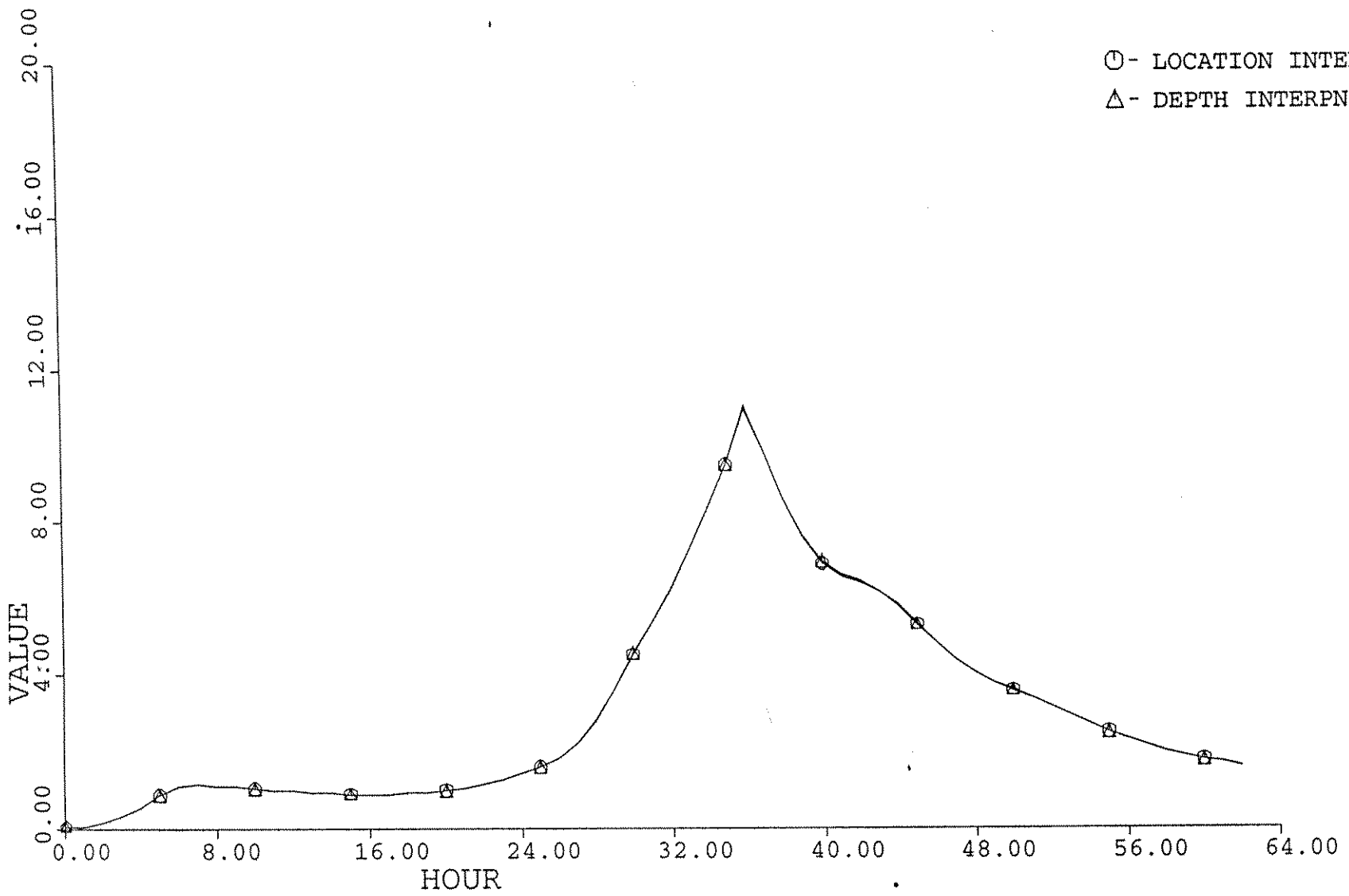



⏲- LOCATION INTERPN.
Δ- DEPTH INTERPN.
VALUE
0.00
2.00
4.00
6.00
8.00
10.00
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
HOUR

T25 Hs


⏀- LOCATION INTERPN.
△- DEPTH INTERPN.
VALUE
0.00
4.00
8.00
12.00
16.00
20.00
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
HOUR

ST130A Hs


⏲- LOCATION INTERPN.
△- DEPTH INTERPN.
VALUE
0.00
4.00
8.00
12.00
16.00
20.00
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
HOUR

ST177B Hs

Capacity Analysis Results

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18a

Capacity Analysis Objectives

Andrew JIP- Phase II

- **Establish Lateral Load Levels Corresponding to:**
  - First and Multiple Failures/Events
  - Uncoupled Estimates of:
    - » Superstructure Capacity
    - » Foundation Lateral Capacity
    - » Foundation Axial Capacity
- **Analysis Types for Steel Jacket Platforms**
  - Base Case : All Failure Modes Modeled
  - Case 1 : Only Jacket Modes Modeled
  - Case 2 : Only Lateral Pile Mode Modeled
  - Case 3 : Only Axial Pile Mode Modeled

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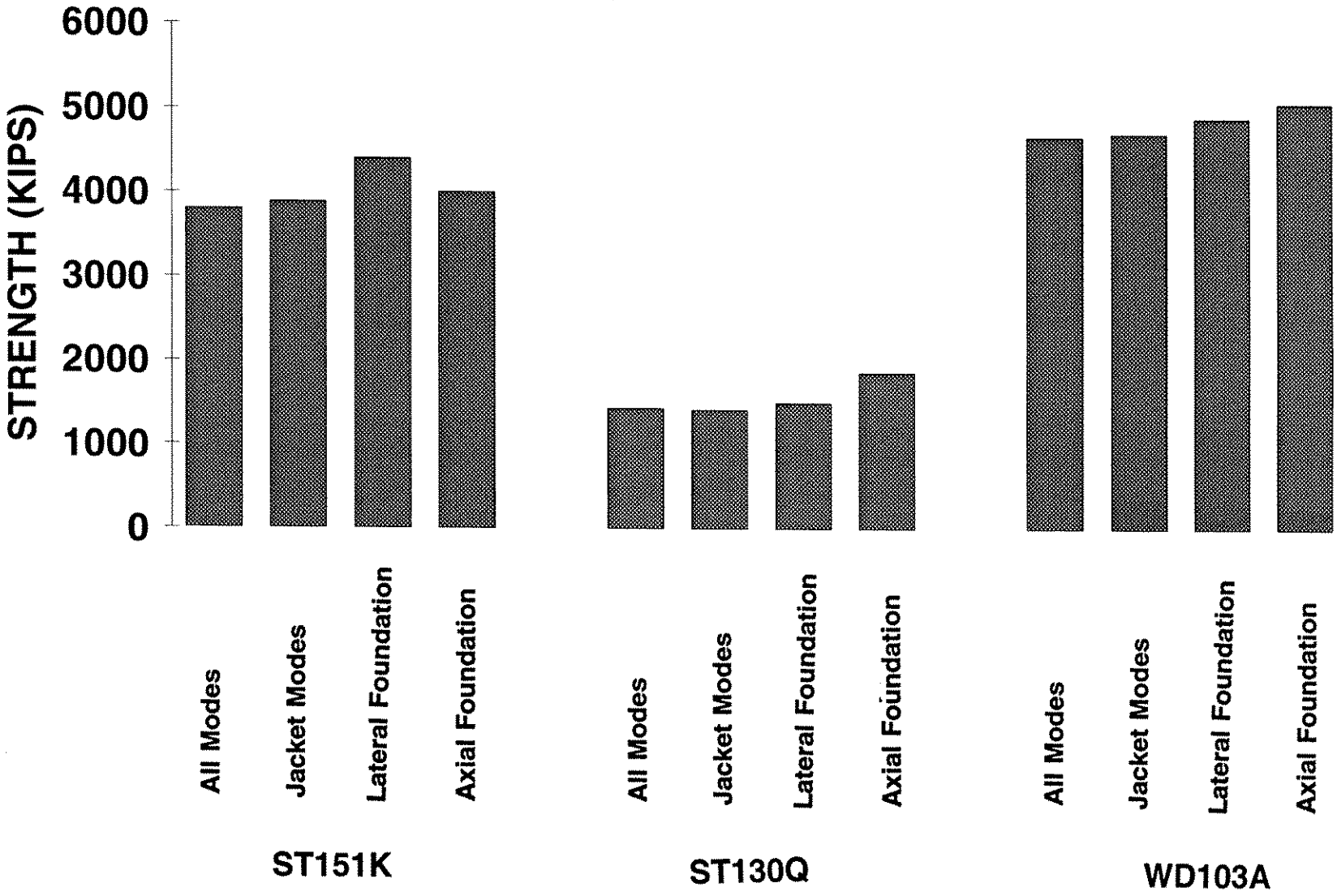
Table 4-6: Comparison of Capacity Analysis Results: Andrew Phase I and II

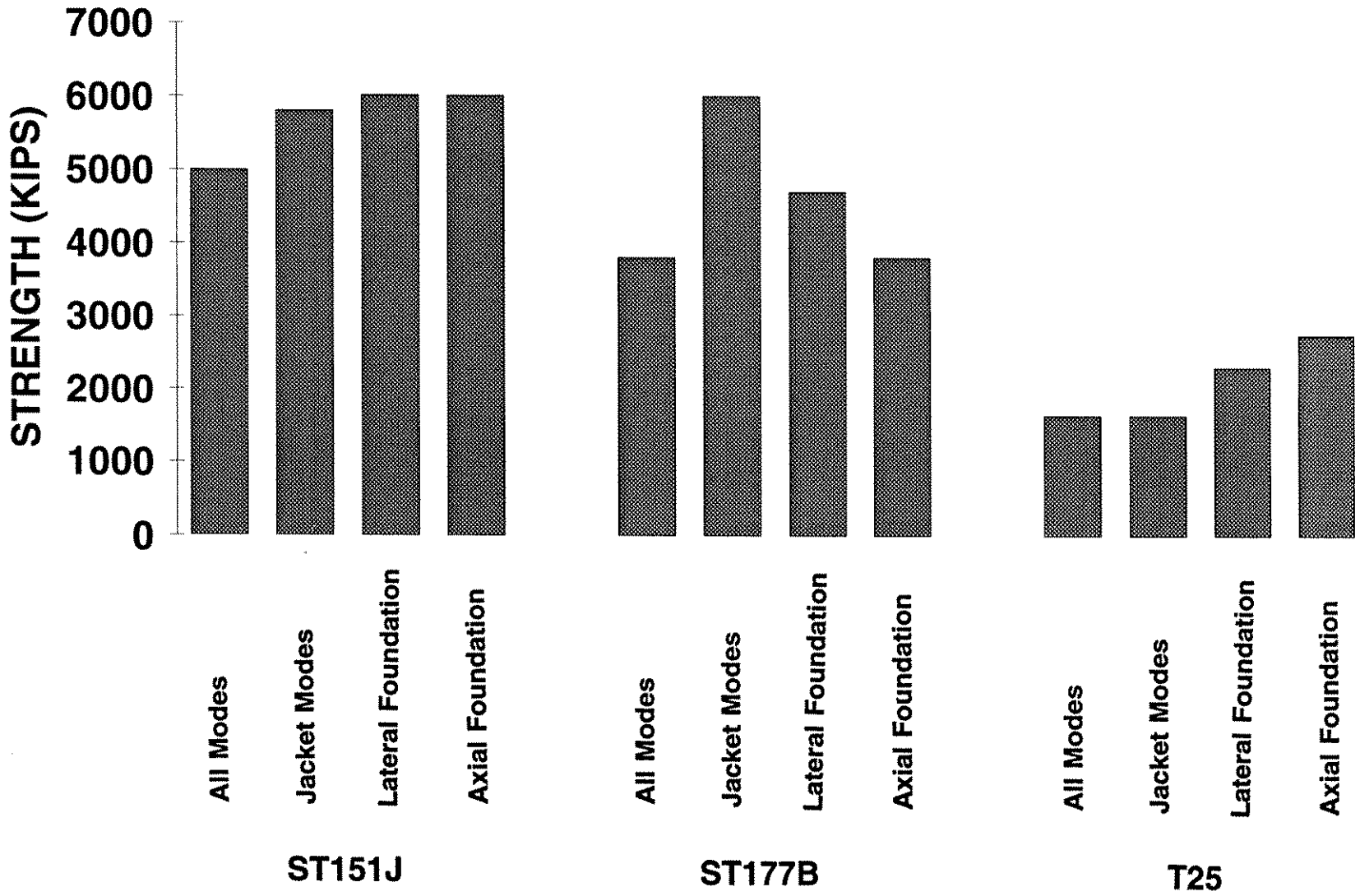
Platform Name	Water Depth (ft.)	Andrew Phase II			Andrew Phase I			Ratios Andrew II/ Andrew I		
		Expected Max. Base Shear (kips)	Ultimate Capacity - Base Case (kips)	Ratio of Ult. Cap./ Base Shear (Ru/ S)	Expected Max. Base Shear (kips)	Ultimate Capacity - Base Case (kips)	Ratio of Ult. Cap/ Base Shear (Ru/ S)	Expected Max. Base Shear (kips)	Ultimate Capacity - Base Case (kips)	Ratio of Ult. Cap./ Base Shear (Ru/ S)
ST151K	137	3,700	3,800	1.03	4,765	3,500	0.73	0.78	1.09	1.40
ST130Q	170	990	1,430	1.44	1,210	1,265	1.05	0.82	1.13	1.38
WD103A	223	2,140	4,660	2.18	-	-	-	-	-	-
ST151J	137	4,450	5,000	1.12	-	-	-	-	-	-
ST177B	142	4,390	3,800	0.87	5,150	4,170	0.81	0.85	0.91	1.07
SS139 (T25)	62	1,060	1,640	1.55	1,690	1,340	0.79	0.63	1.22	1.95
ST151H	137	3,560	3,250	0.91	4,210	4,000	0.95	0.85	0.81	0.96
ST130A	140	1,990	2,500	1.26	2,780	3,000	1.08	0.72	0.83	1.16
ST52 (T21)	61	1,380	-	-	1,615	1,980	1.23	0.85	-	-

Note: The ultimate capacity estimates for the base case shown. The capacity (load) numbers taken differ from these for both Andrew I (single B) and Andrew II (multiple B's) calibration. See Tables in Section-5 for the calibration capacity (load) levels

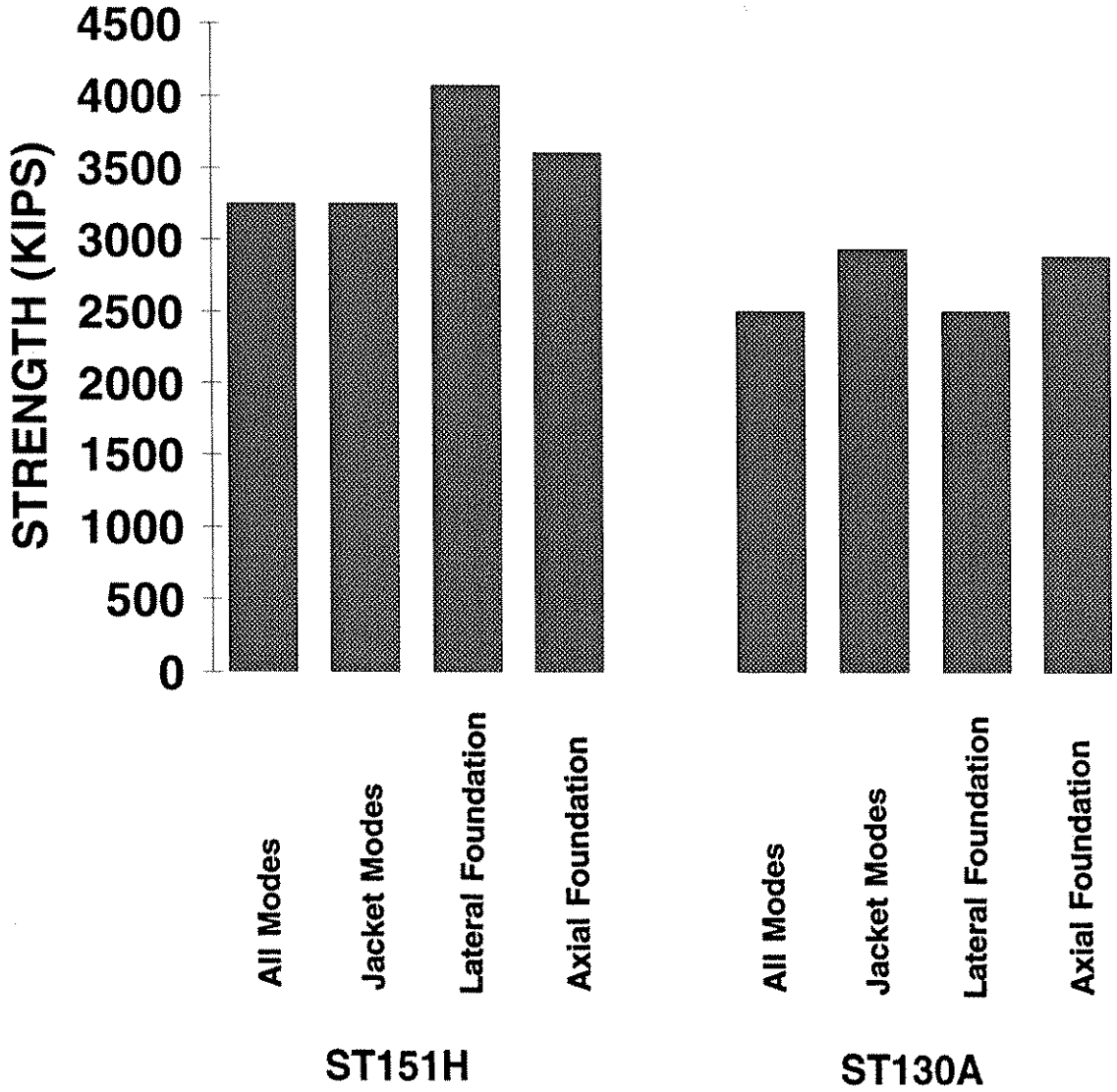
ULTIMATE STRENGTHS FOR DIFFERENT CASES. SURVIVED



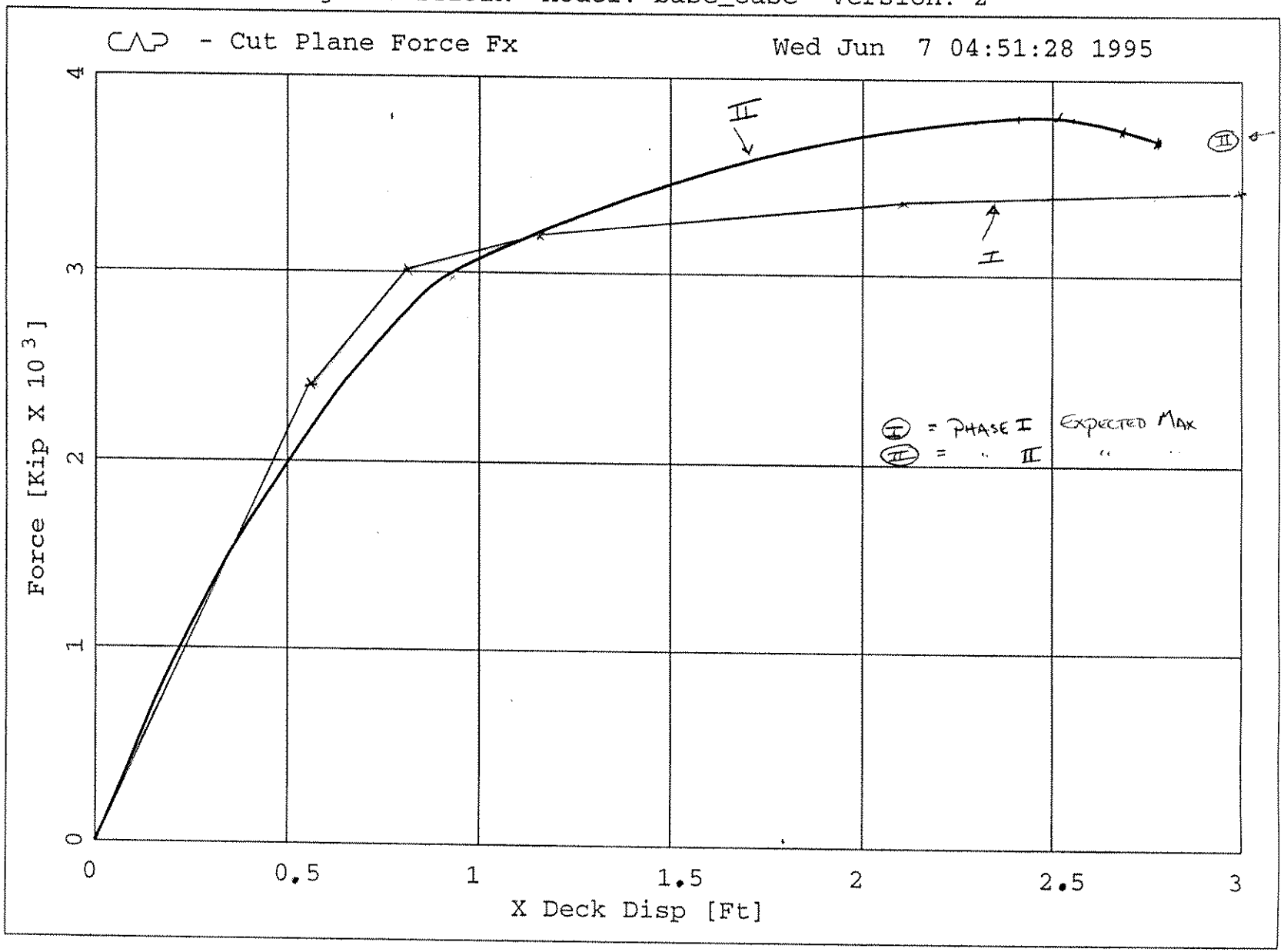
ULTIMATE STRENGTHS FOR DIFFERENT CASES. DAMAGED



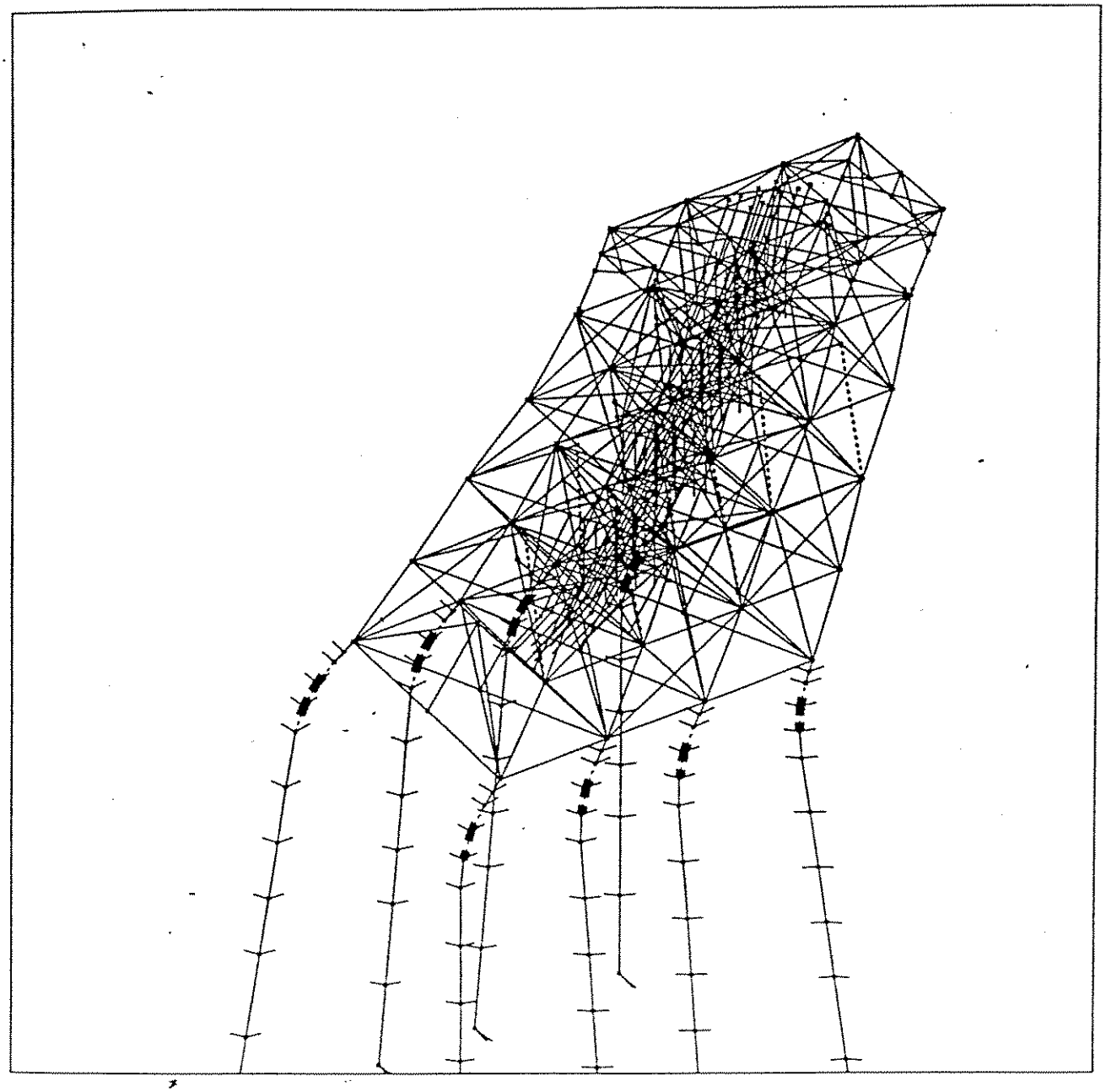
ULTIMATE STRENGTHS FOR DIFFERENT CASES. COLLAPSED



Project: ST151K Model: base_case Version: 2



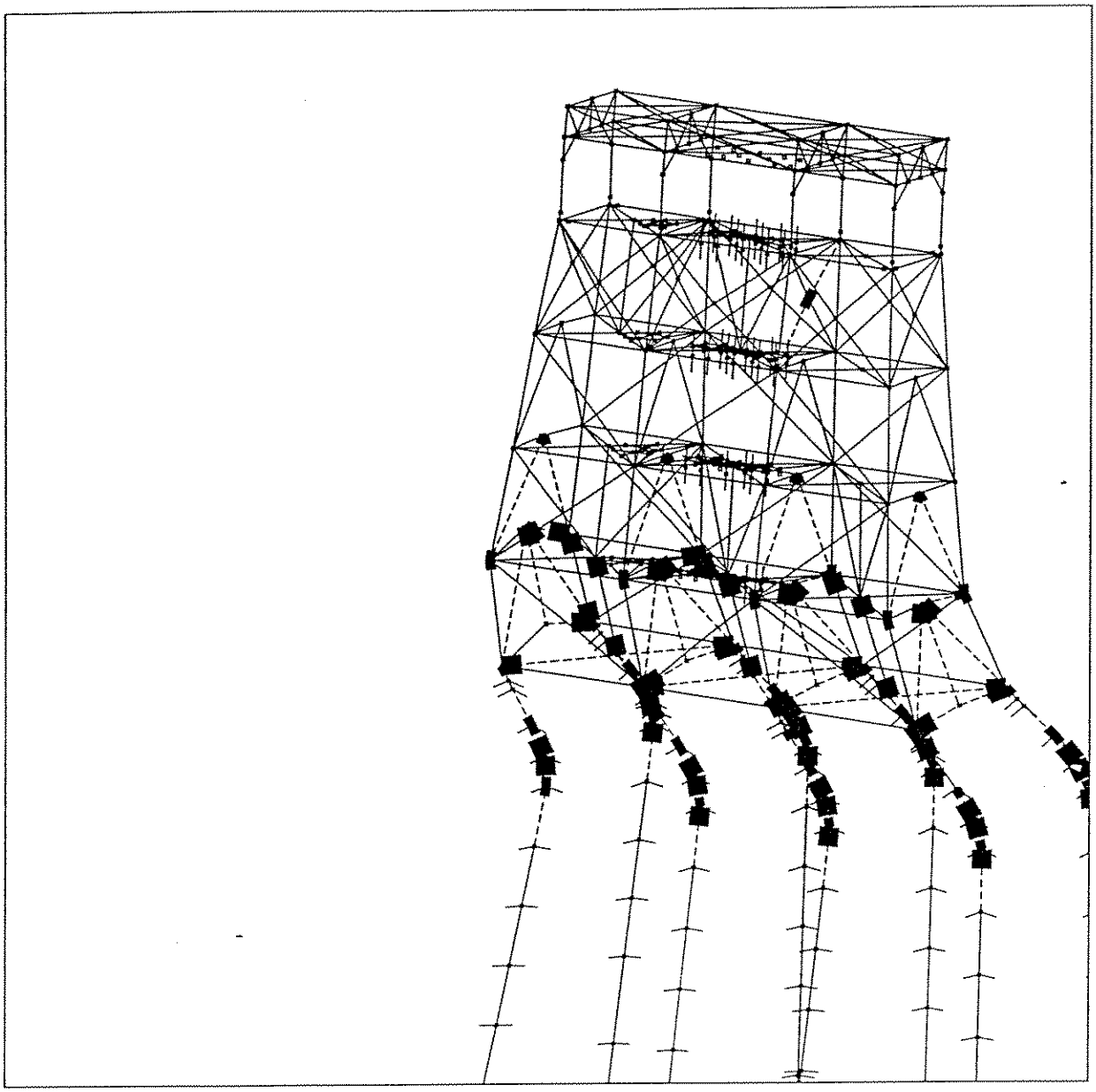
ST151K Base Case analysis



Pushover Analysis Ultimate Collapse Results: Broadside Direction - ST151K

(PHASE I)

Project: ST151K Model: base_case Version: 2

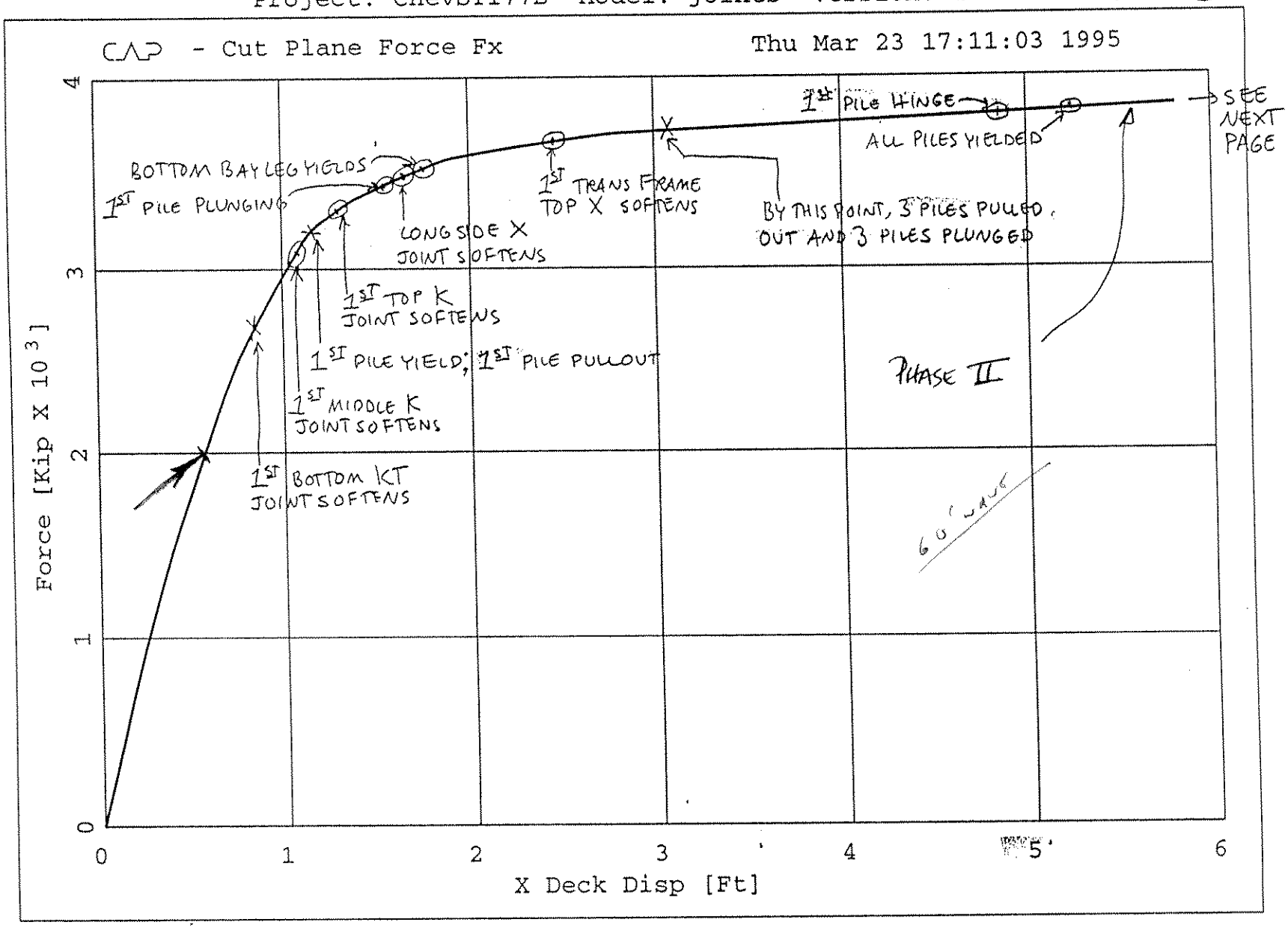


CAP Z X ST151K Base Case LS 110 (PHASE II)

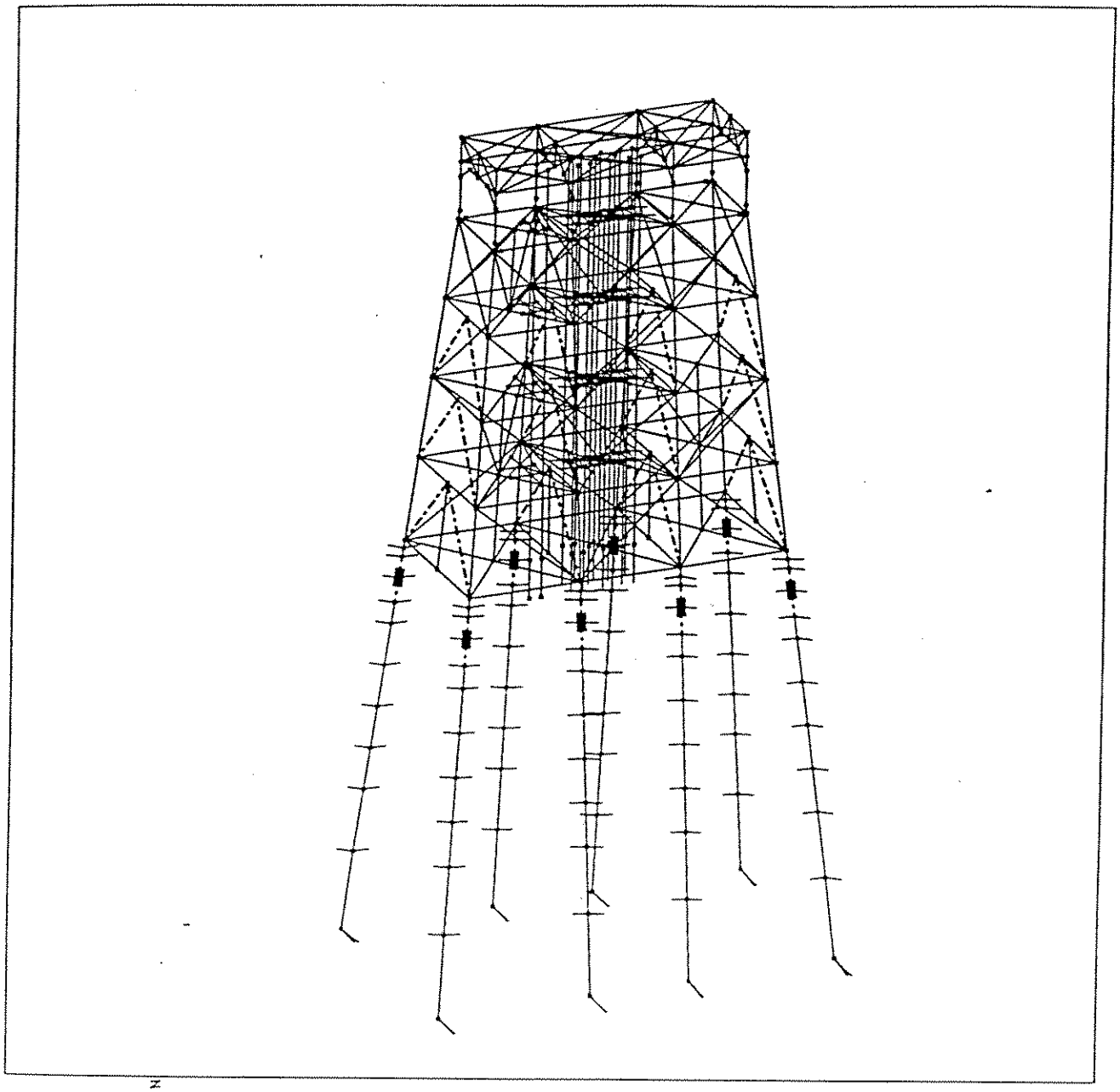
Inelastic Events Legend

Elastic	Strut Buckling
Strut Residual	Strut Reloading
Plastic Strut/NLTruss	Beam Clmn Initial Yield
Beam Clmn Fully Plastic	Fracture

Project: ChevST177B Model: joints Version: 4 4390 II



ST177B(v4): Base Shear



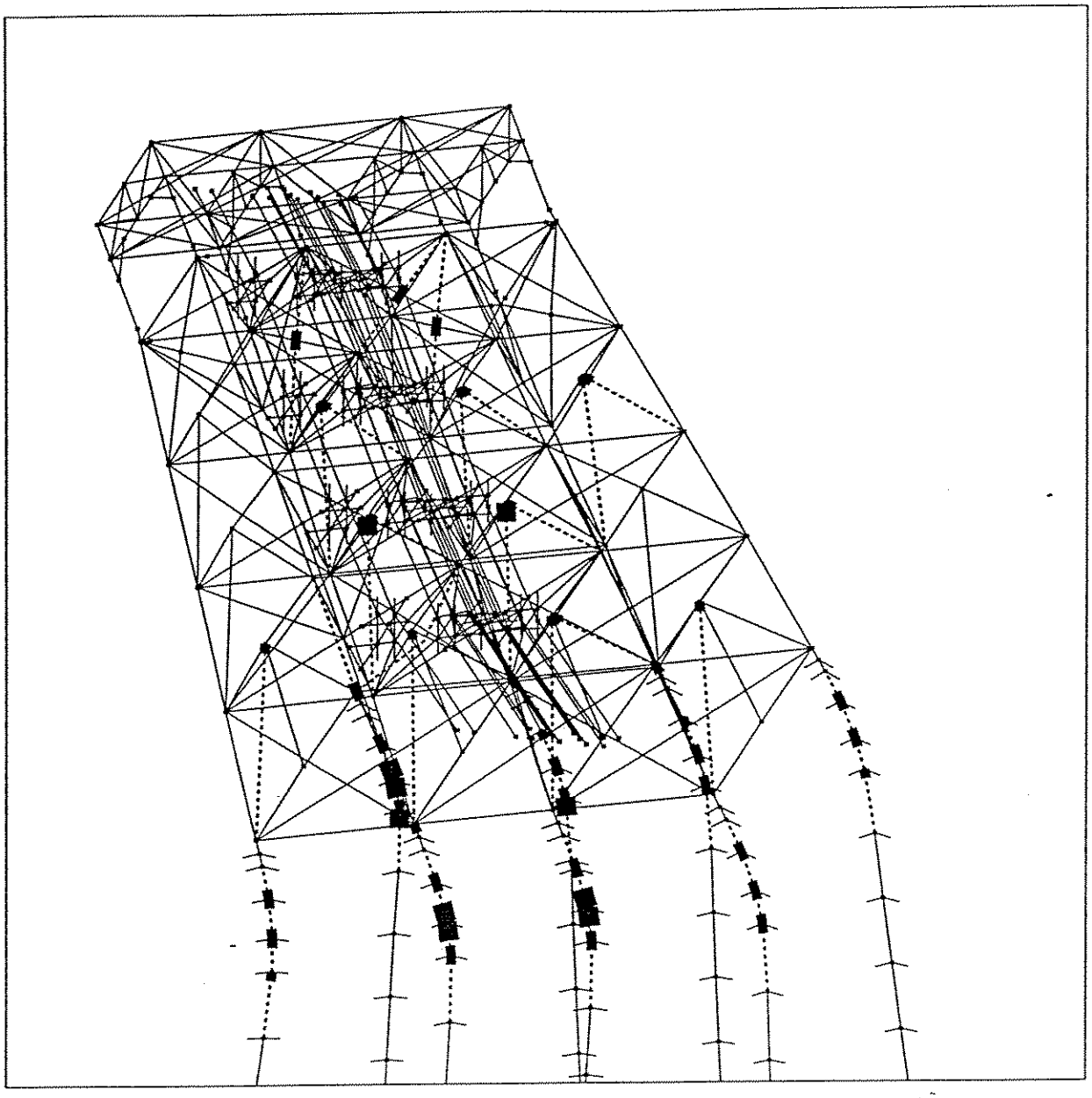
CAP Z X

Chevron ST177B @ 22.5 Deg: Fcap = 4168 Kips

Project: ChevST177B Model: push225 Version: 1

(PHASE I)

Project: ChevST177B Model: joints Version: 4 Fri Mar 24 08:42:26 1995 *

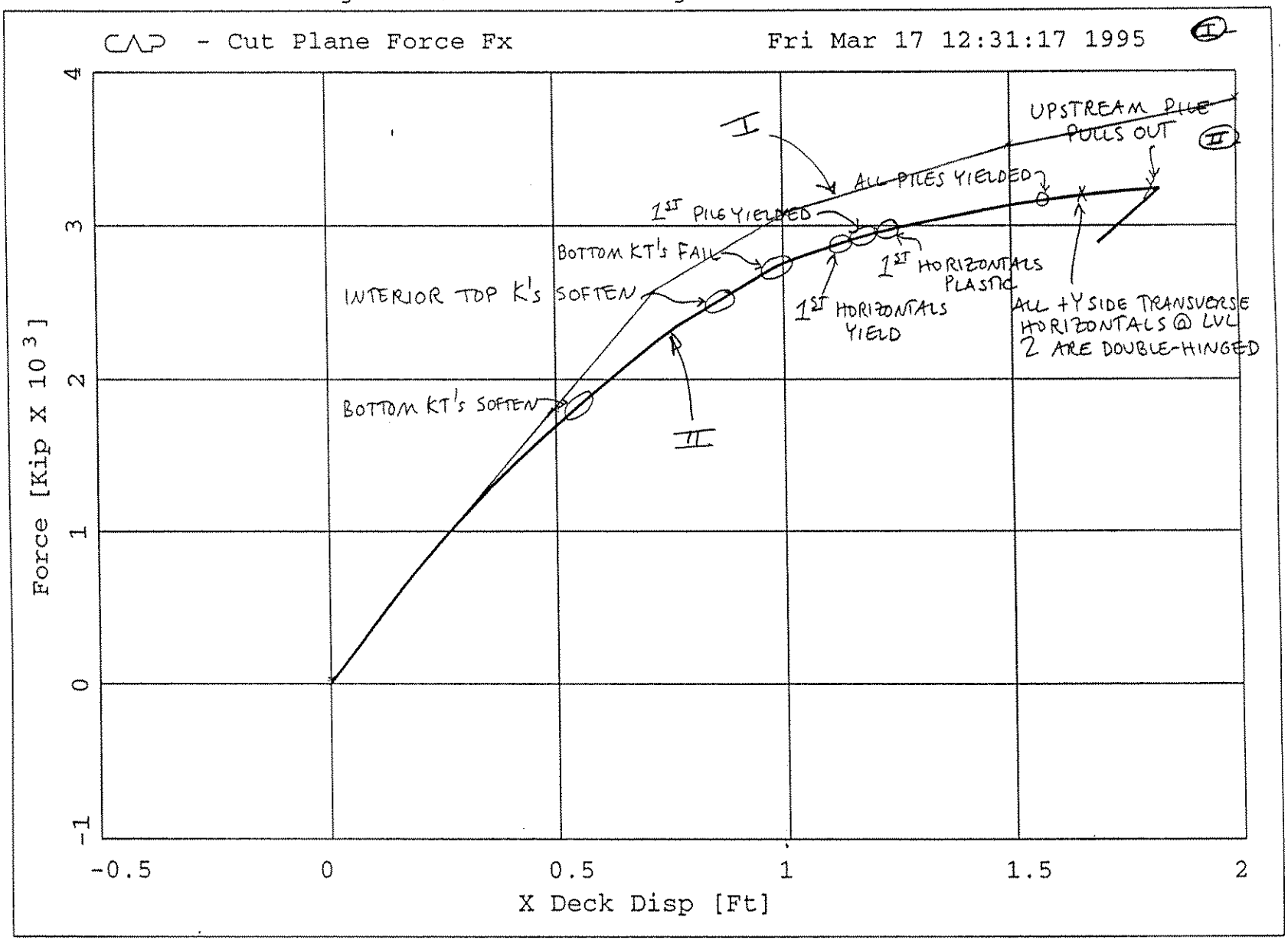


CAP Z 5x ST177B (v4): Step 138, 3970 kips (disp x10) (PHASE II)

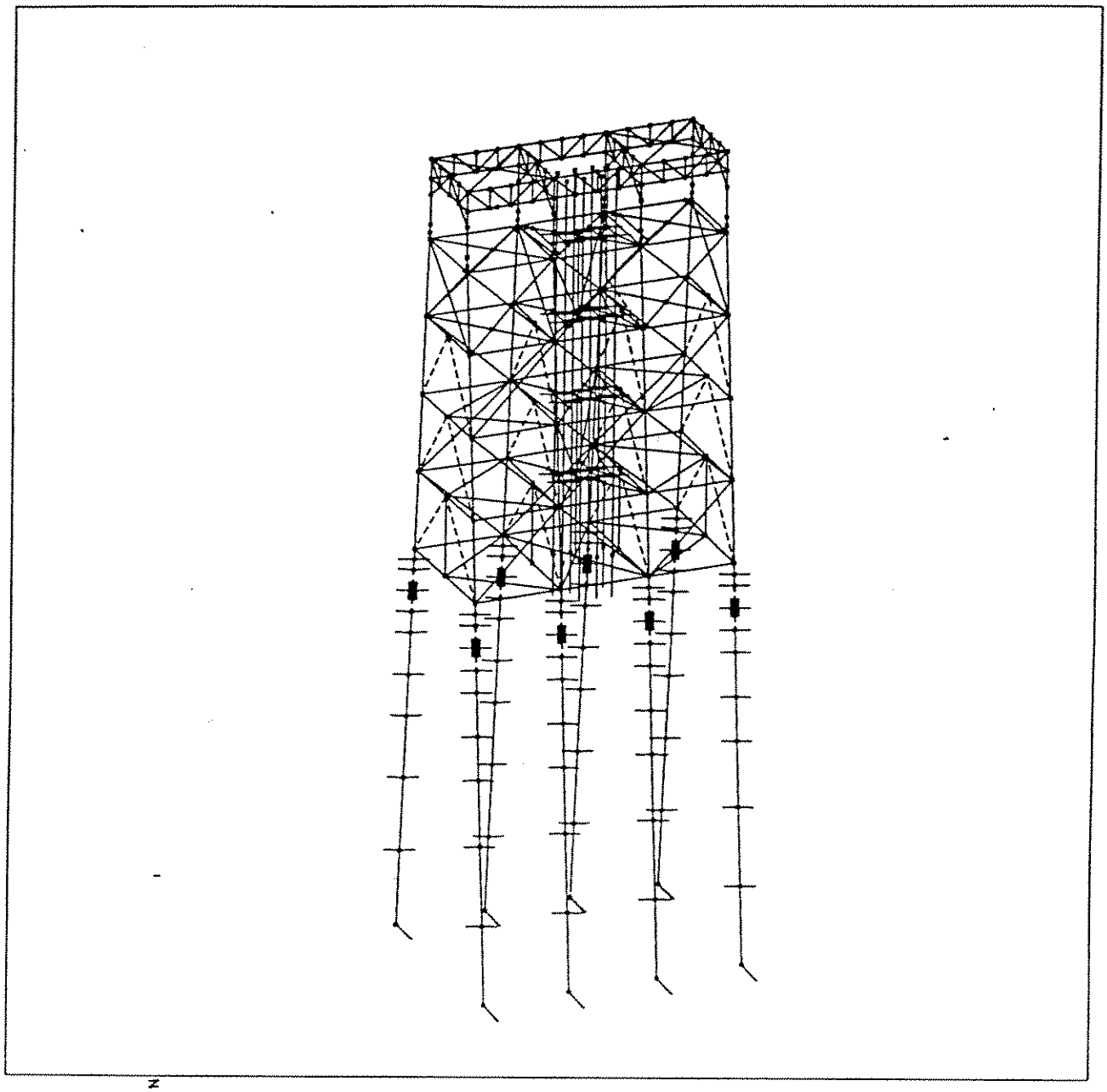
Inelastic Events Legend

_____	Elastic	.....	Strut Buckling
_ _ _ _ _	Strut Residual	_ . _ . _	Strut Reloading
. . . . .	Plastic Strut/NLTruss	. . . . .	Beam Clmn Initial Yield
_____	Beam Clmn Fully Plastic	. . . . .	Fracture

Project: ST151H Model: joints Version: 3



ST151H (run 2)



CAP

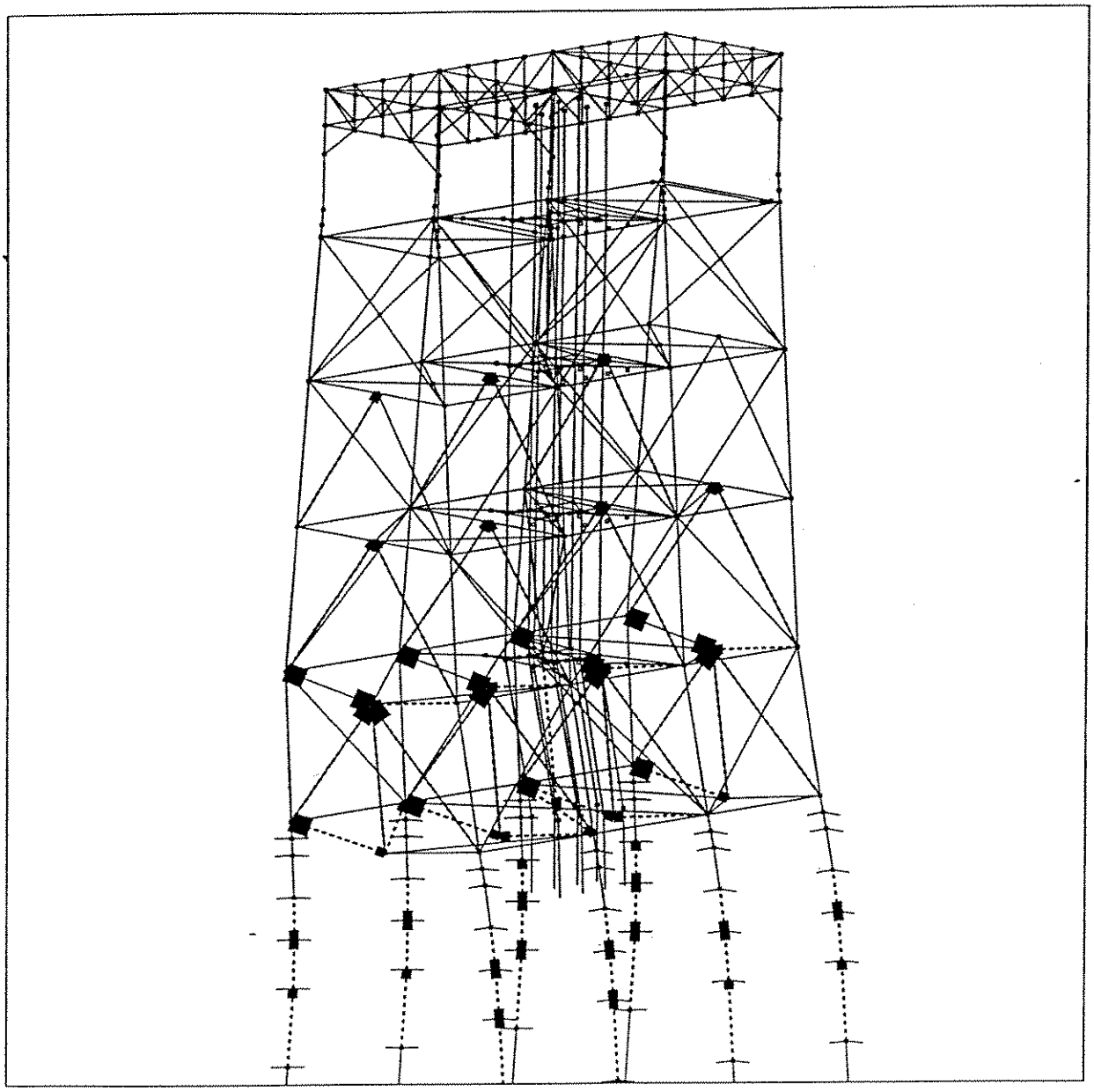
Chevron ST151H @ 22.5 Deg: Fcap = 3999 KIPS

Project: ChevST151H Model: push225 Version: 1

(PHASE I)

OK

Project: ST151H Model: joints Version: 3 Fri Mar 17 13:22:56 1995 *



CAP z ↑ → x ST151H(run2): Step 60, 3240 k (displ x10) (PHASE II)

Inelastic Events Legend

——— Elastic	..... Strut Buckling
- - - - - Strut Residual	_ _ _ _ _ Strut Reloading
..... Plastic Strut/NLTruss	..... Beam Clmn Initial Yield
——— Beam Clmn Fully Plastic	..... Fracture

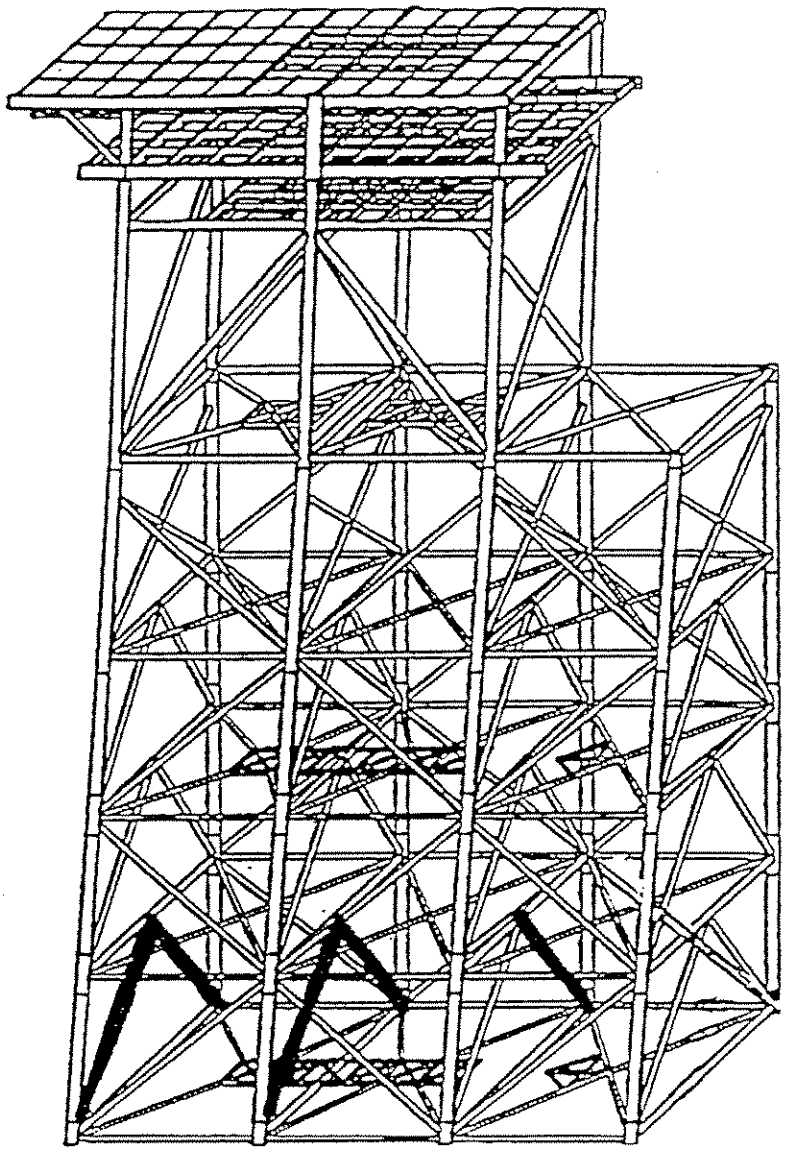
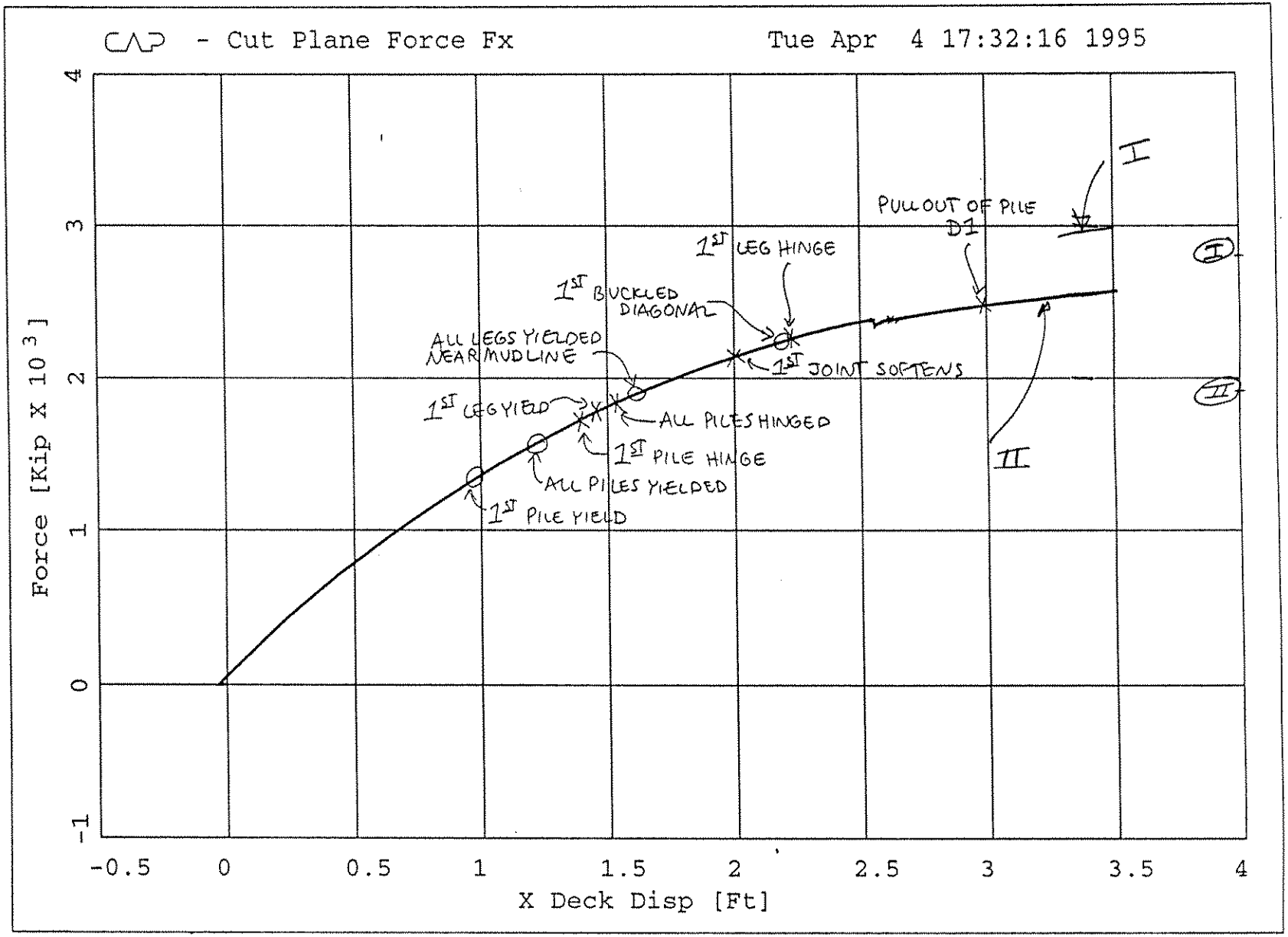


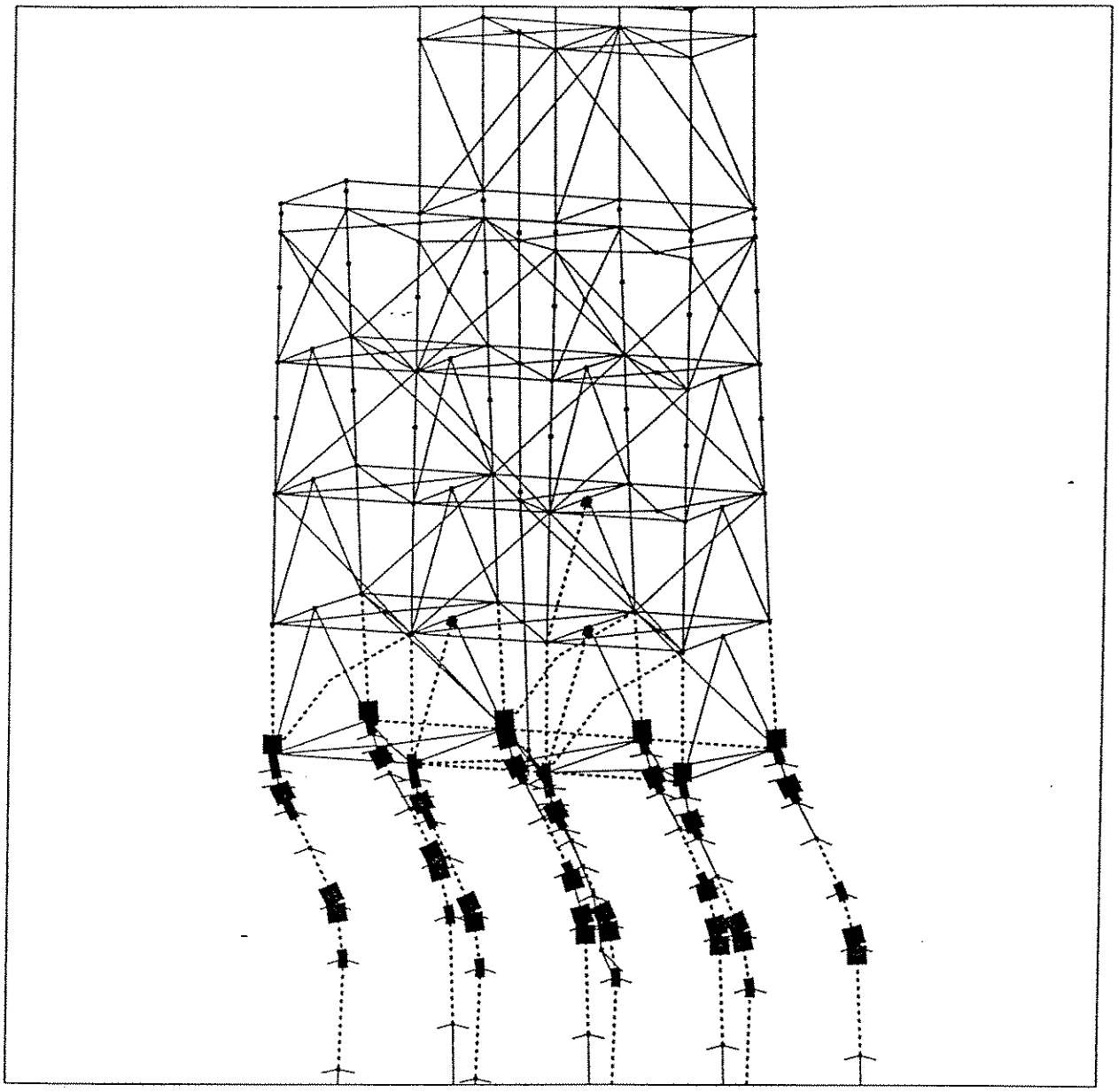
Figure 2-1 Platform ST 130 A - Toppled in Andrew

Project: ST130A Model: joints Version: 4



ST130A 2xCondK

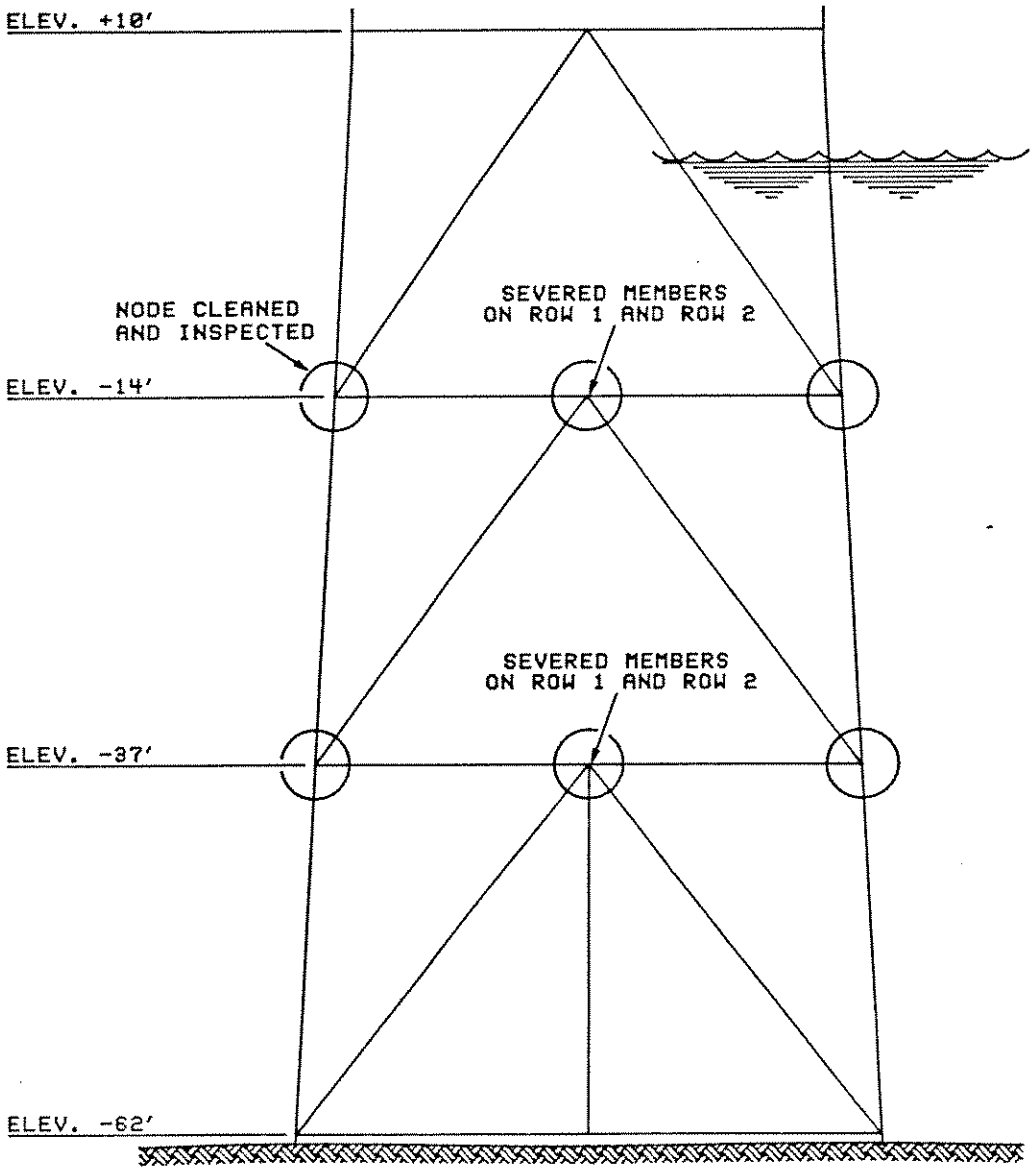
Project: ST130A Model: joints Version: 4 Wed Apr 5 08:59:10 1995 *



CAP ST130A 2xCondK: Step122, 2380 k (displx10) (PHASE II)

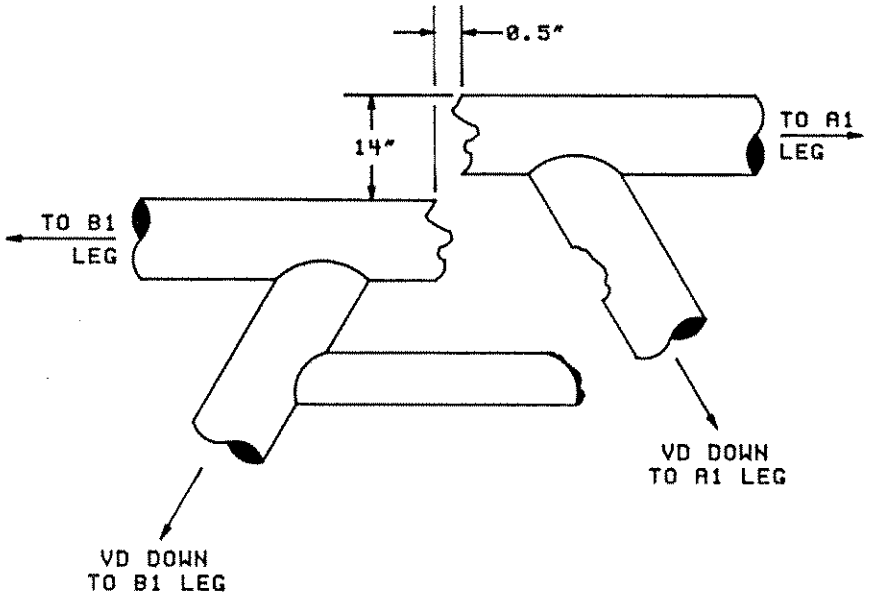
Inelastic Events Legend

———	Elastic	.....	Strut Buckling
- - - - -	Strut Residual	- - - - -	Strut Reloading
.....	Plastic Strut/NLTruss	.....	Beam Clmn Initial Yield
———	Beam Clmn Fully Plastic	.....	Fracture

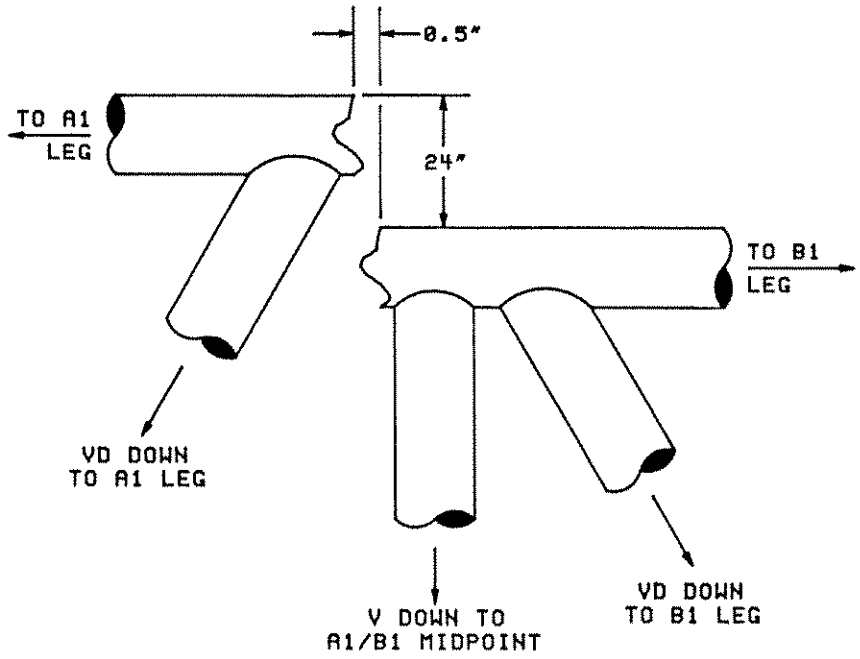


TYPICAL ELEVATION FOR ROWS A, B, 1, AND 2

NOTE: 1. ALL ELEVATIONS ARE MEASURED WITH A PNEUMOFATHOMETER.
2. NODE AREAS CLEANED AND INSPECTED ARE SHOWN IN RED ON THIS DRAWING.



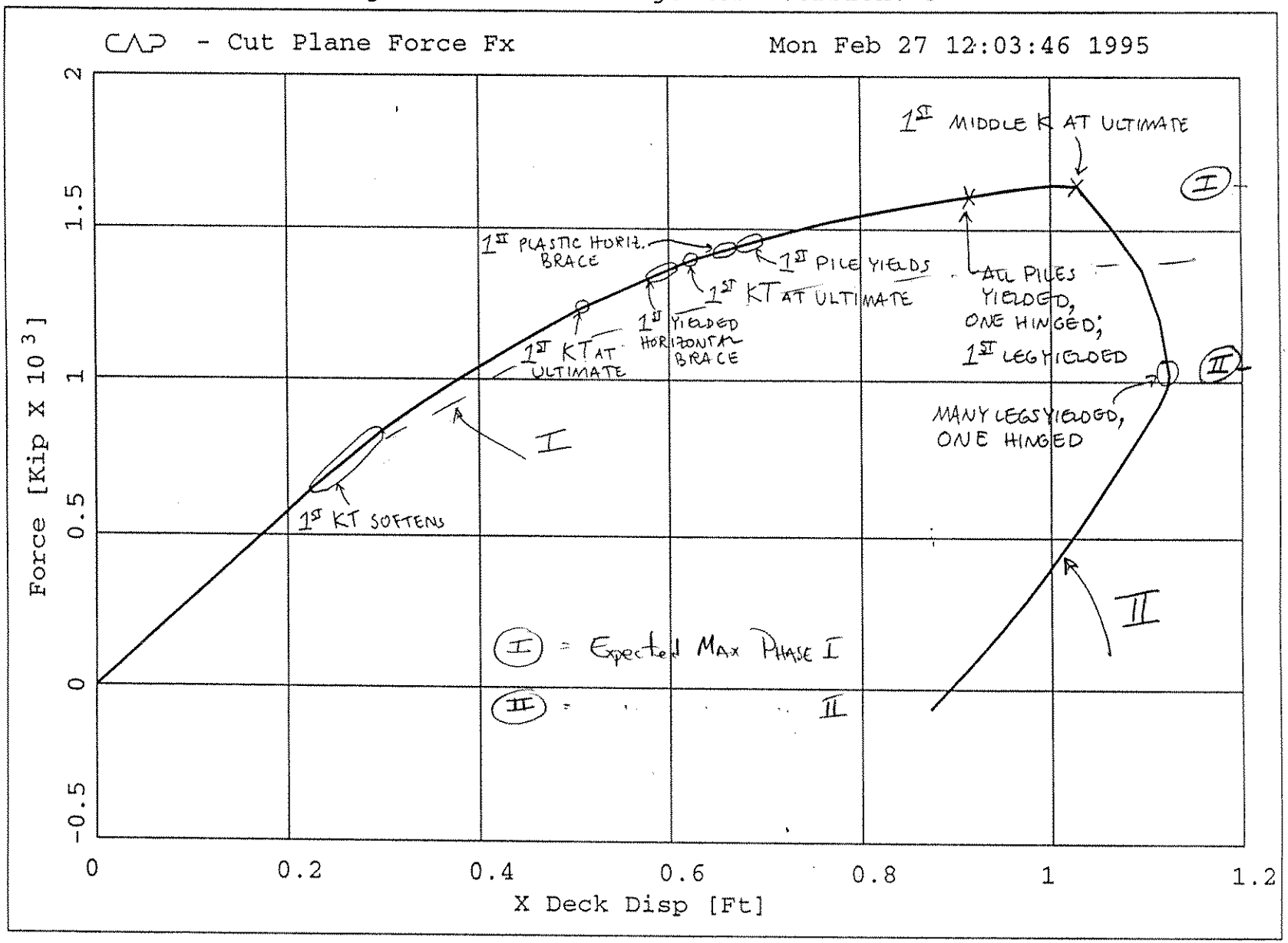
-14' A1/B1 HORIZONTAL (BREAK)



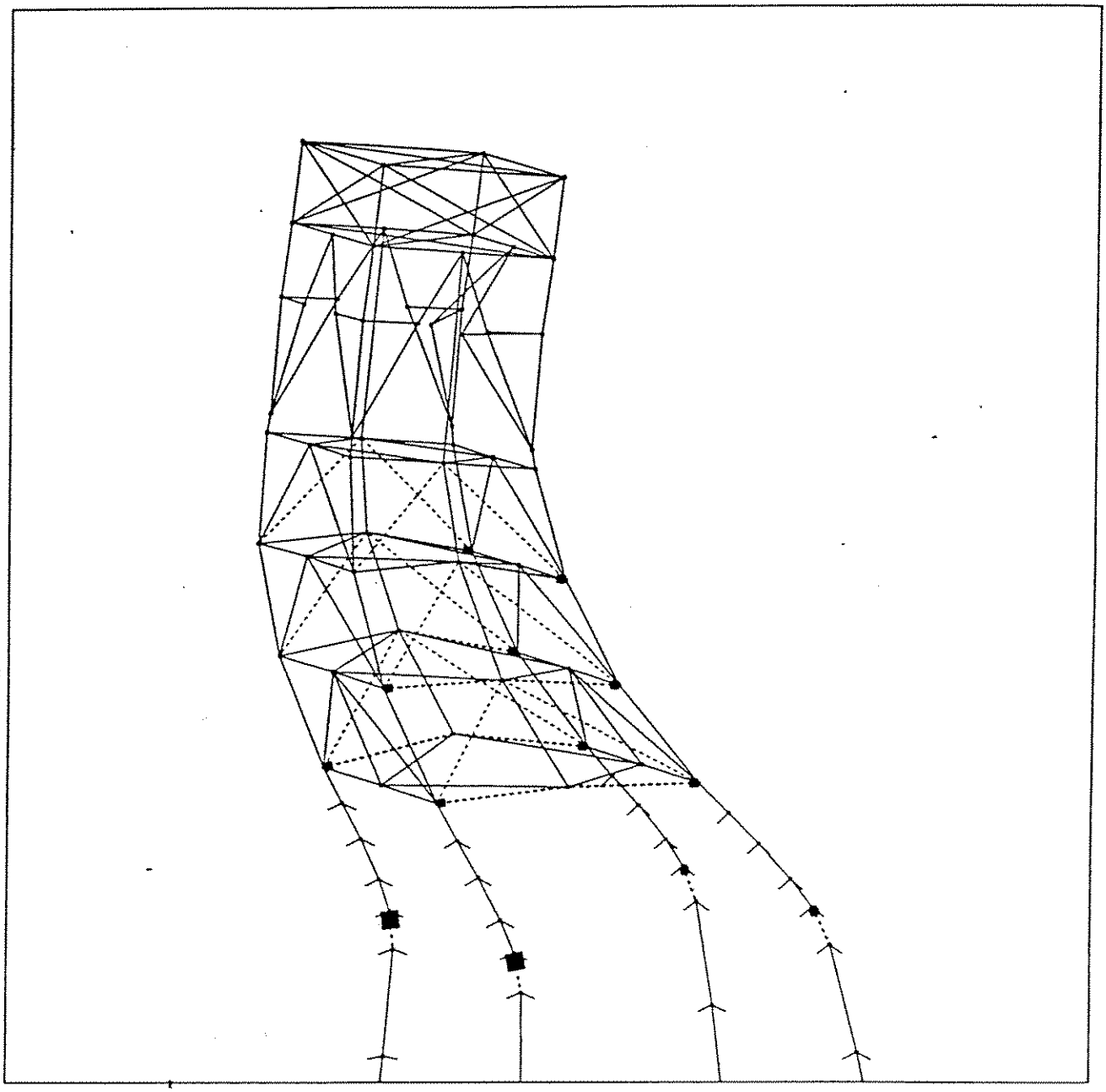
-37' A1/B1 HORIZONTAL (BREAK)

NOTE: 1. THIS DRAWING IS NOT DRAWN TO ANY SCALE.

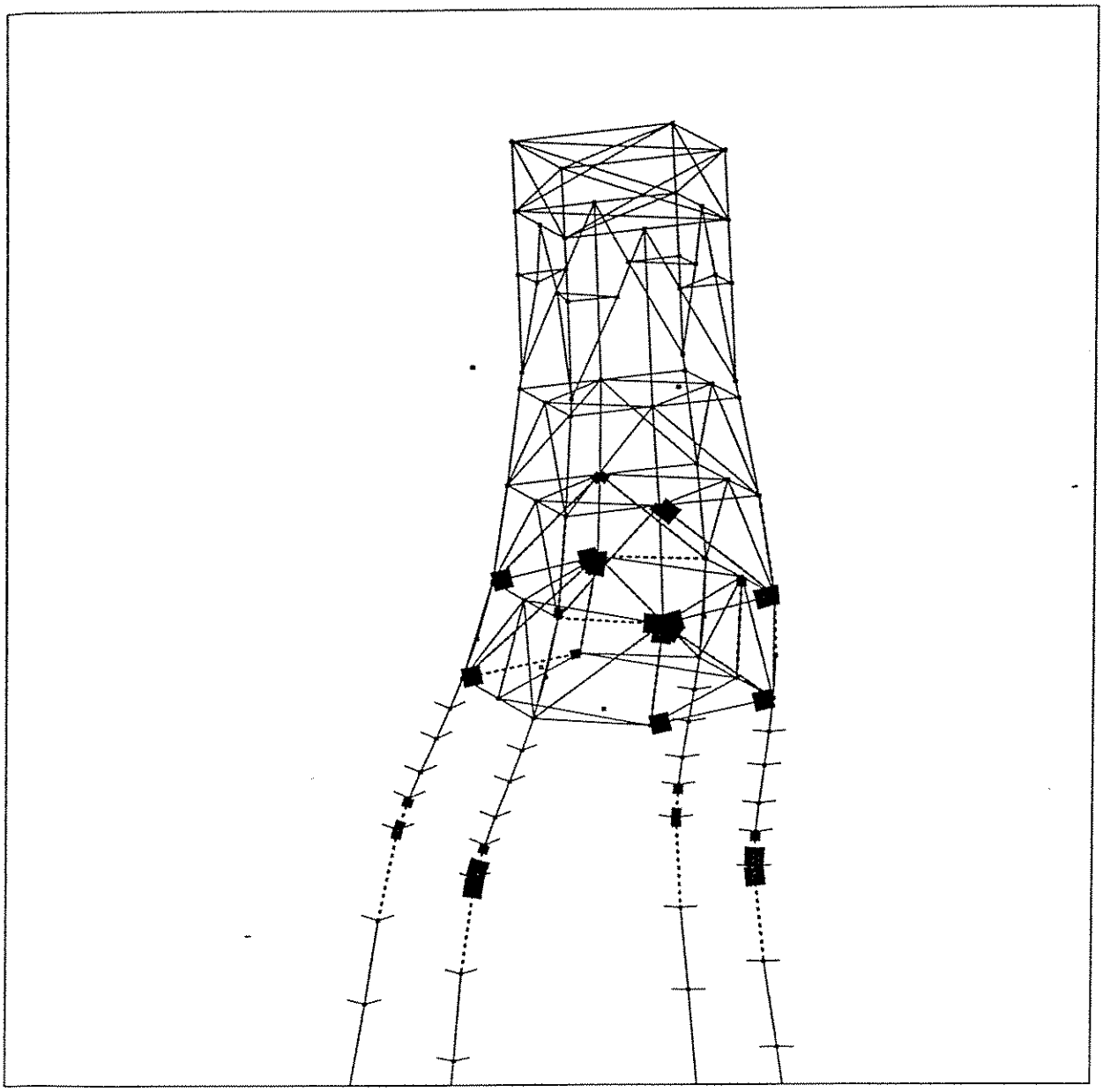
Project: T25 Model: joints Version: 5



T25 Final


CAP
T25 Yplus
LS24
Project: T25 Model: Y-plus Version: 2
(Phase I)

Project: T25 Model: joints Version: 5 Mon Feb 27 13:30:15 1995 *

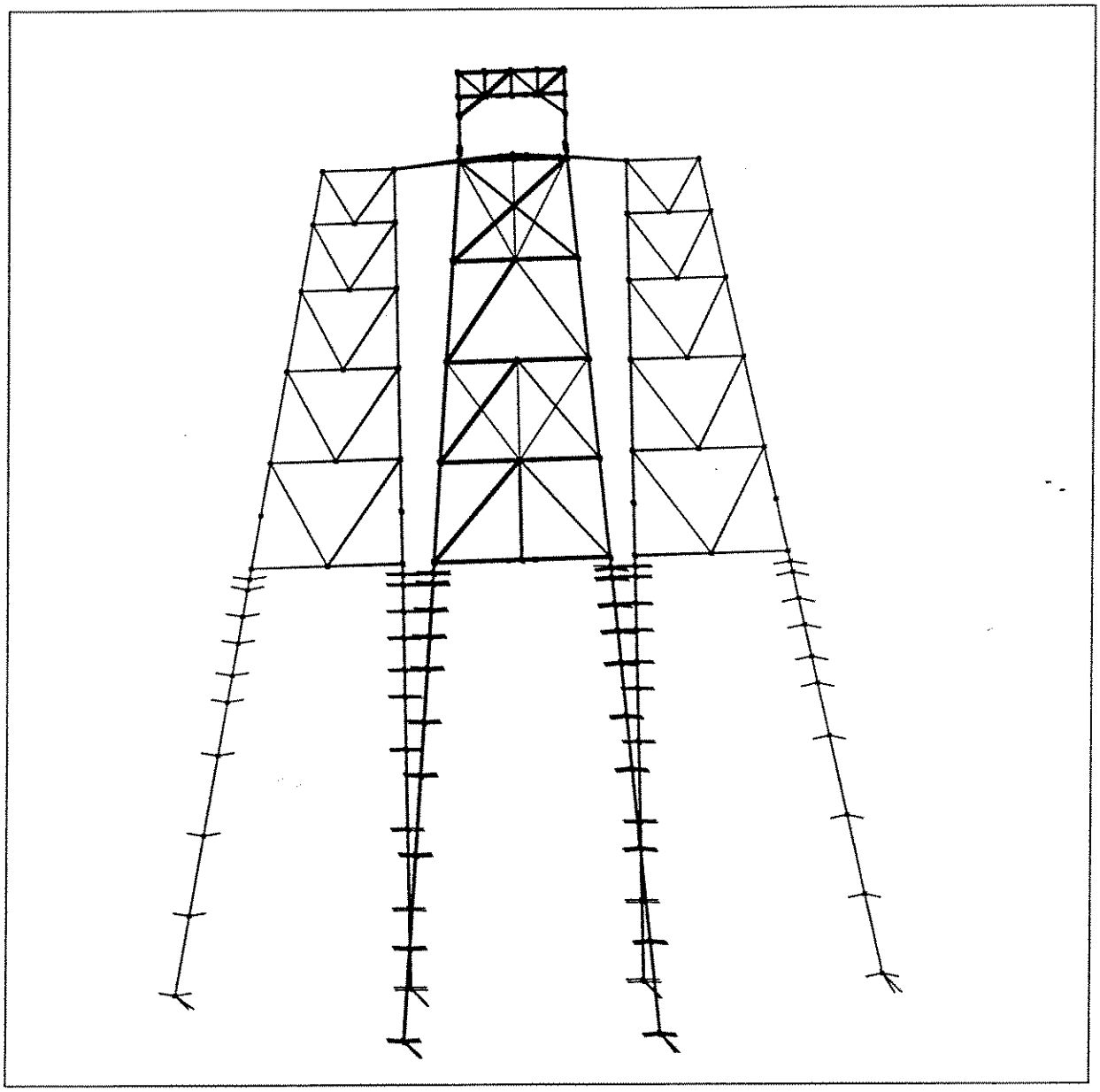


CAP T25: Step 57, 1640 kips; max load (x10) (Phase II)

Inelastic Events Legend

Elastic	Strut Buckling
Strut Residual	Strut Reloading
Plastic Strut/NLTruss	Beam Clmn Initial Yield
Beam Clmn Fully Plastic	Fracture

Project: ST151J Model: case1 Version: 1 Wed Jun 7 17:20:35 1995 *



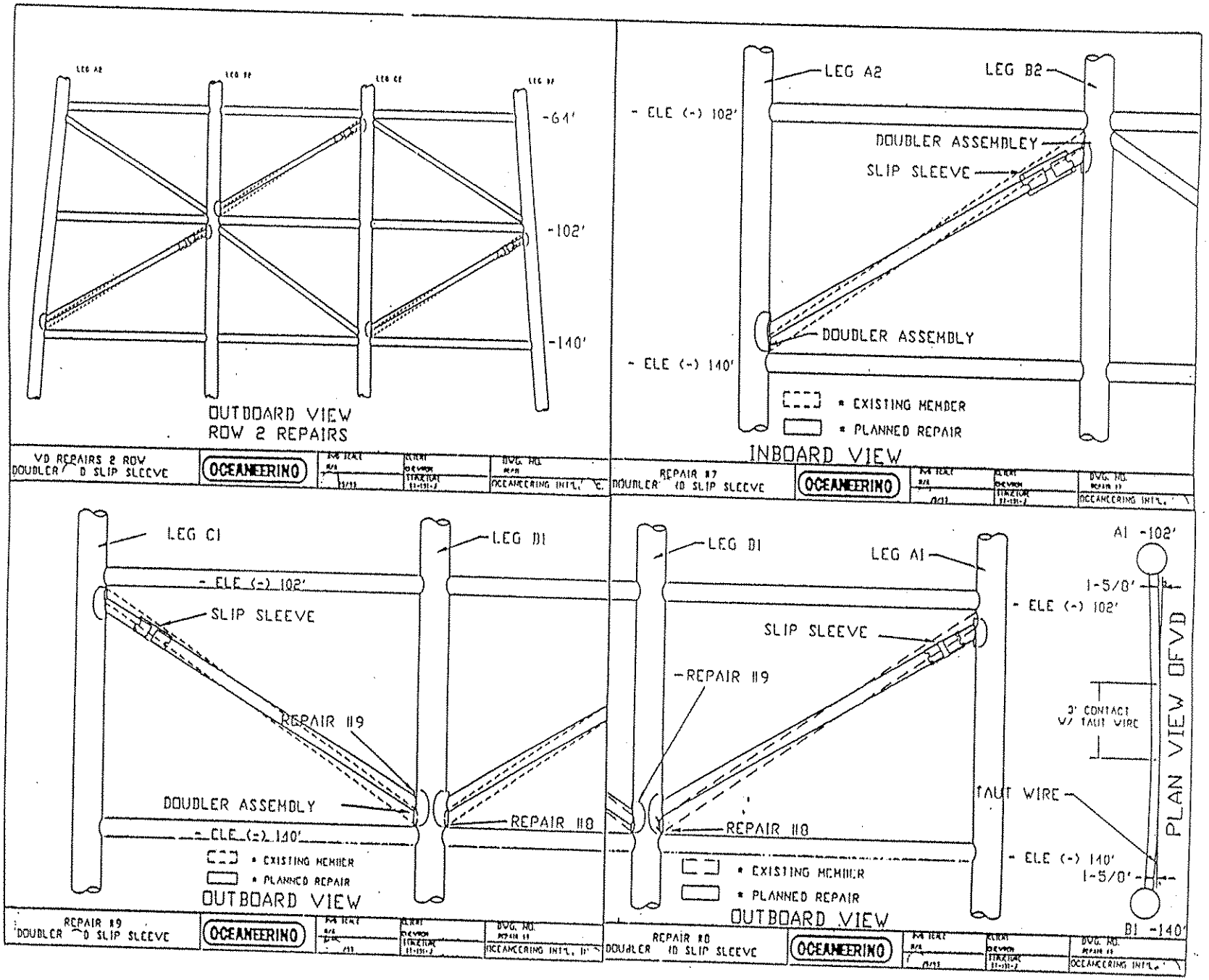
CAP

ST151J Platform with Tripods

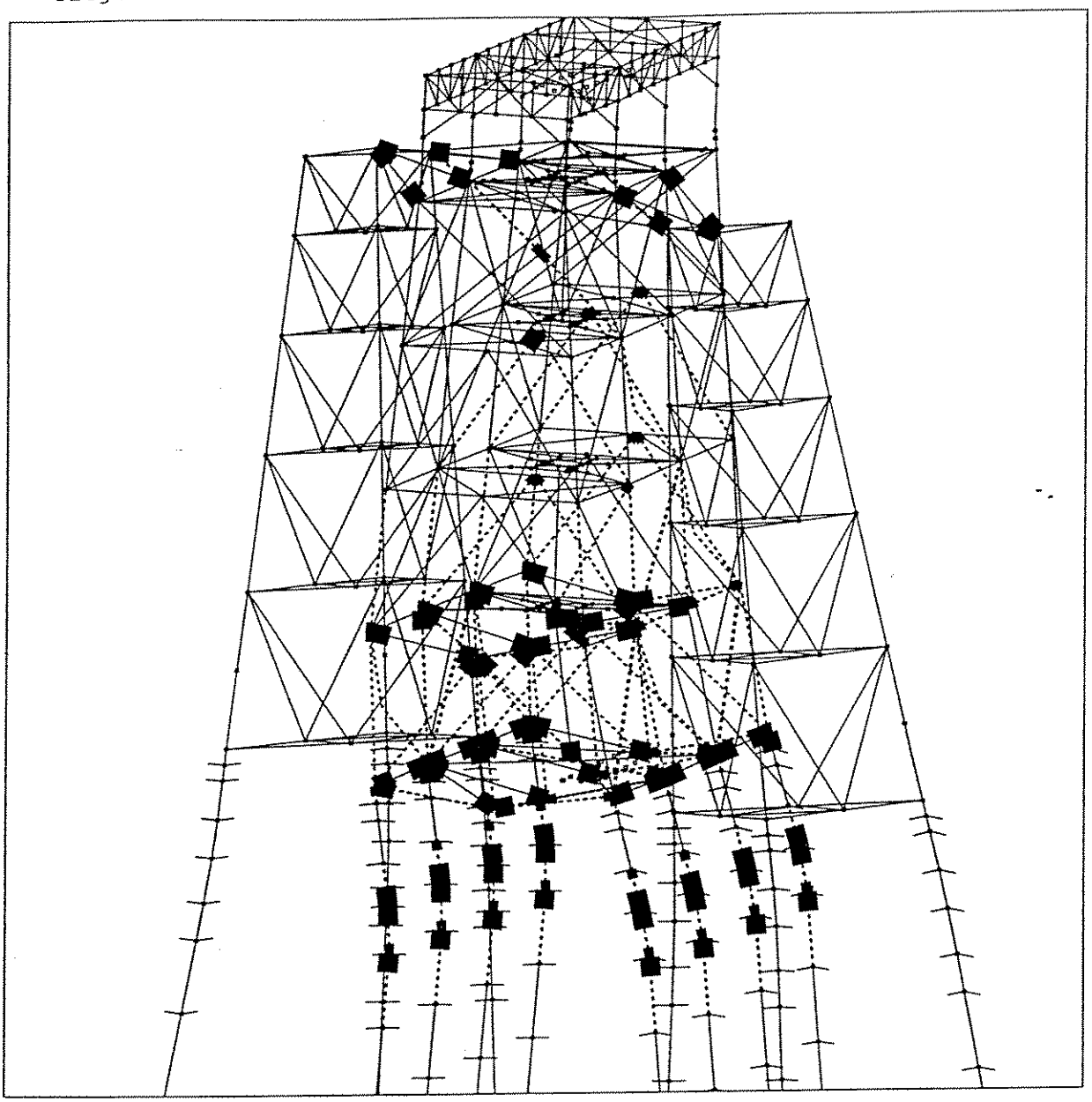
Inelastic Events Legend

_____	Elastic	----------	Strut Buckling
_ _ _ _ _	Strut Residual	_ _ _ _ _	Strut Reloading
.....	Plastic Strut/NLTruss	_ _ _ _ _	Beam Clmn Initial Yield
_____	Beam Clmn Fully Plastic	----------	Fracture

South Timbalier 151 J Platform Repairs



Project: ST151J Model: basic Version: 2 Wed Mar 22 12:06:12 1995 *

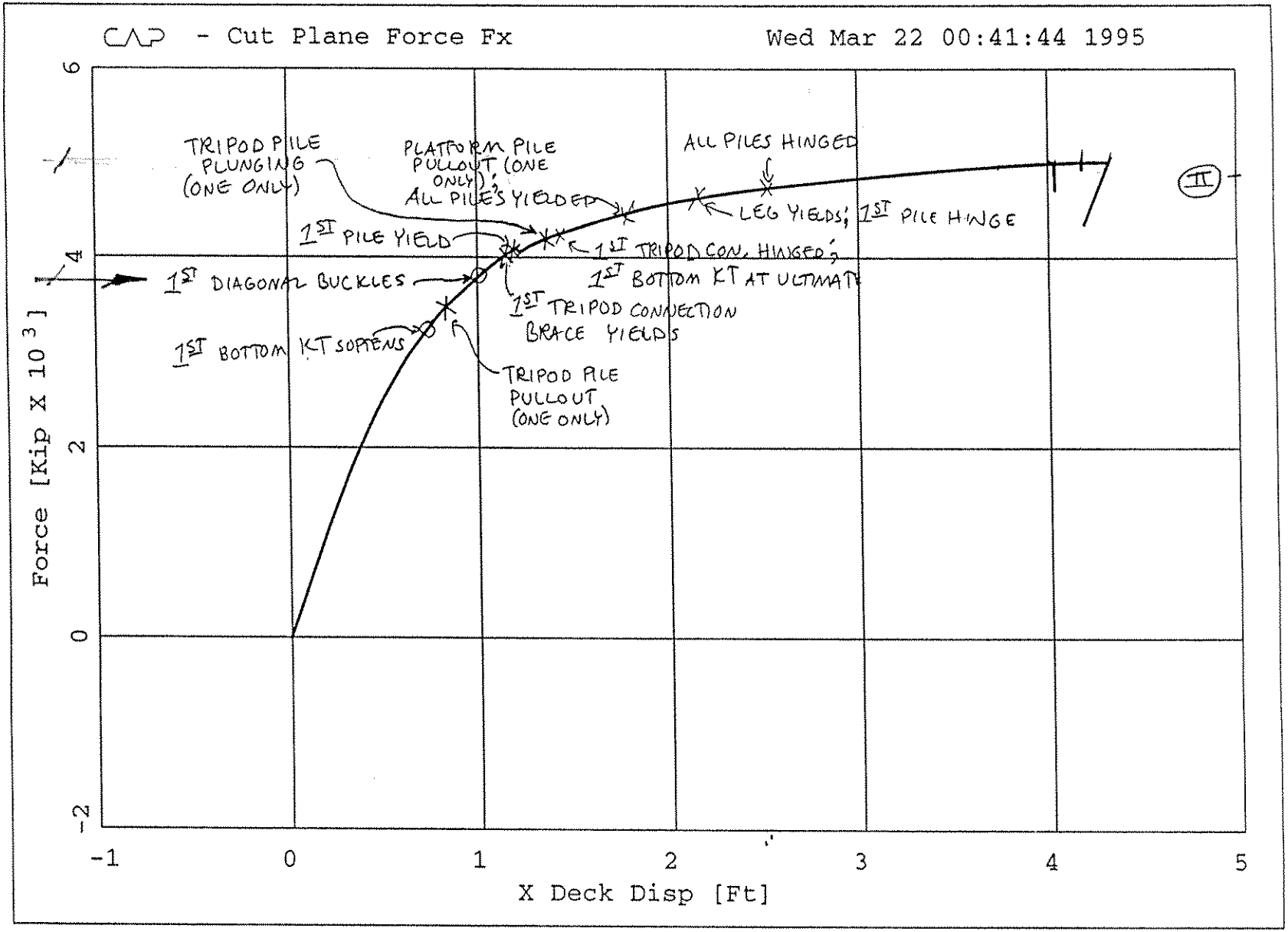


CAP ST151J run 1: Step 267, 5020 kips

Inelastic Events Legend

_____	Elastic	.....	Strut Buckling
- - - - -	Strut Residual	- - - - -	Strut Reloading
.....	Plastic Strut/NLTruss	.....	Beam Clmn Initial Yield
_____	Beam Clmn Fully Plastic	.....	Fracture

Project: ST151J Model: basic Version: 2



ST151J (run 1): Total Base Shear

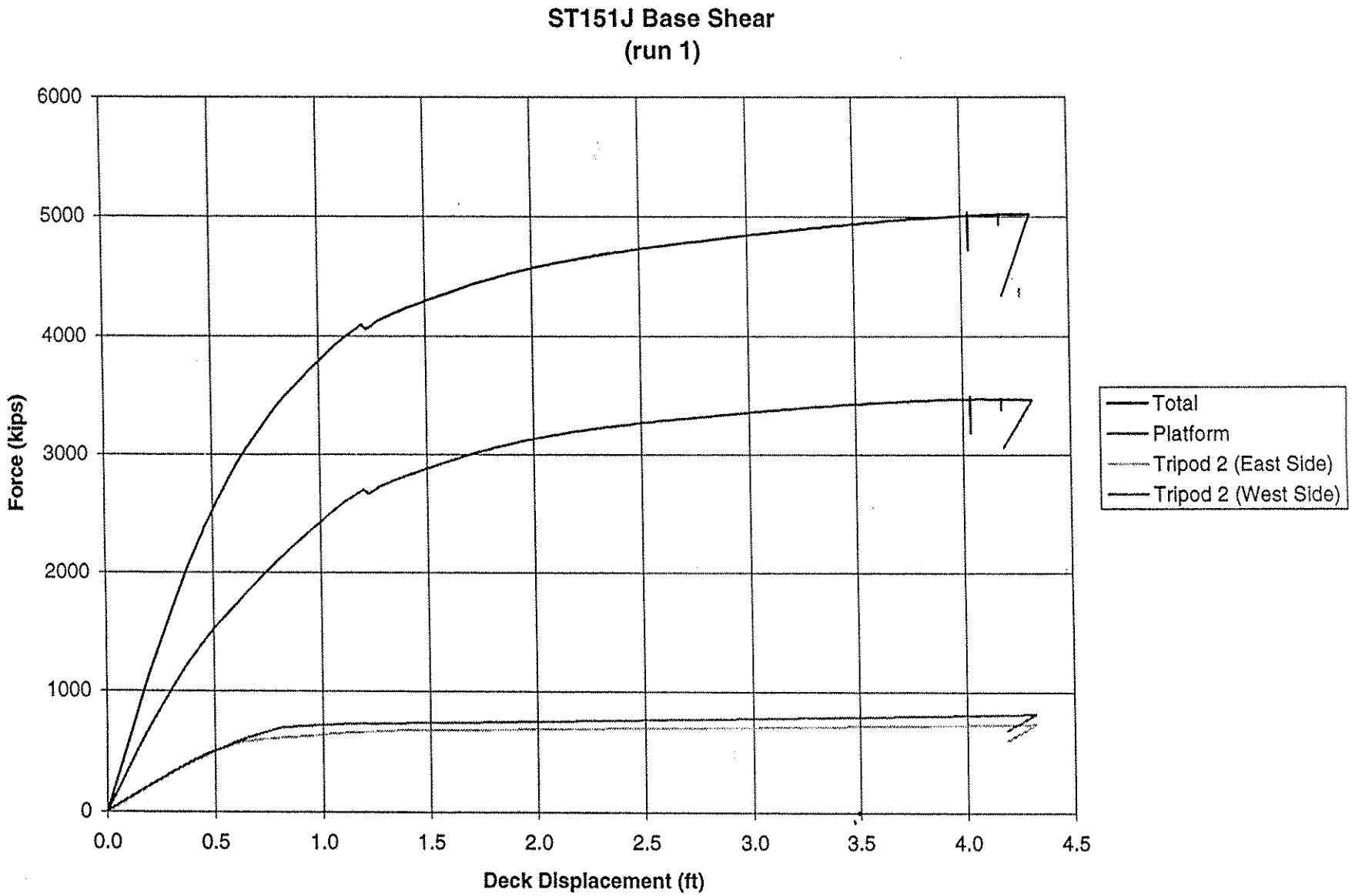

ST151J Base Shear
(run 1)
Force (kips)
6000
5000
4000
3000
2000
1000
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Deck Displacement (ft)
Total
Platform
Tripod 2 (East Side)
Tripod 2 (West Side)

Table 4-2: Capacity Analysis Results - Steel Jacket Platforms - Survival Cases

Platform/	Platform Characteristics: Configuration	Platform Characteristics: Water Depth/ Year Installed (ft.)	Analysis Case (Failure Modes)	Expected Maximum Hindcast Max. Base Shear (Sa)	Base Shear (at First Failures) from Static Pushover Analysis: Brace/ Joint Event (RI1) (kips)	Base Shear (at First Failures) from Static Pushover Analysis: Pile or leg First Yield Event (RI2) (kips)	Base Shear (at First Failures) from Static Pushover Analysis: Pile or leg Plasticity Event (RI3) (kips)	Base Shear (at First Failures) from Static Pushover Analysis: Pile pullout/ Plunging (RI4) (kips)	Base Shear (at multiple failures) from Static Pushover Analysis: Brace/ Joint Events (Ra) (kips)	Base Shear (at multiple failures) from Static Pushover Analysis: Pile or leg Plasticity Events (Rfl) (kips)	Base Shear (at multiple failures) from Static Pushover Analysis: Pile pullout/ Plunging (Rfa) (kips)	Pushover Analysis Ultimate Capacity (Rus, Rufa, or Rufl) (kips)	Platform Collapse Mode	Ratio of Ult. Cap./ Andrew Base Shear = (Ru/Sa)	System Factor = (Ru/RI) (#1)	System Factor (Pile-Lateral Capacity) = (Rfl/RI3)	System Factor (Pile-Axial Capacity) = (Rfa/RI4)
ST 151 K	8 Leg - Grouted Double Battered K Braced 30" dia. piles 175' penetration	137 ft. 1963	**Base Case (All Failure Modes)**	3,700	2,900	3,100	3,570	3,450	3,000	3,700	-	3,800	Bottom bay KT-joints, horiz. fully plastic; all piles fully plastic at depth below mudline; 1 pile pullout	1.03	1.10	-	-
			Case-1 (Only Jacket - Super Structure Failure Modes)	3,700	2,900	-	-	-	3,000	-	-	3,880	Bottom bay KT joints and inner verticals, and bottom horizontals fully plastic	1.05	1.03	-	-
			Case-2 (Only Pile Foundation Yield/Hinge failure Modes)	3,700	-	3,280	3,850	-	-	4,230	-	4,400	All 8-piles with fully plastic sections at two levels (just below and at depth below mudline)	1.19	-	1.10	-
			Case-3 (Only Pile Foundation Pullout/Plunging Failure Modes)	3,700	-	-	-	3,430	-	-	4,000	4,000	3 piles pullout and 3 plunge	1.08	-	-	1.17
ST130Q	4 Leg - Grouted Double Battered K Braced 30" dia. piles 240' penetration Wave height = 58.3' Dir.- 291.6 from TN Current - 2.91 ft/sec	170 ft. 1964	**Base Case (All Failure Modes)**	990	-	800	1,010	-	-	1,380	-	1,430	Fully plastic pile sections	1.44	1.79	1.37	-
			Case-1 (Only Jacket - Super Structure Failure Modes)	990	1,380	955	1,100	-	1,410		-	1,410	Bottom bay leg sections and bottom horiz.. braces with fully plastic sections: 2-KT joints fail	1.42	1.02	-	-
			Case-2 (Only Pile Foundation Yield/Hinge failure Modes)	990	-	800	1,080	-	-	1,470	-	1,500	All four piles with fully plastic sections at two levels (just below and at depth below mudline)	1.52	-	1.36	-
			Case-3 (Only Pile Foundation Pullout/Plunging Failure Modes)	990	-	-	-	1,820	-	-	1,860	1,860	1 pile pullout and 1 pile plunge	1.88	-	-	1.02
WD103	8 Leg - Ungrouted Double Battered K Braced/Diagonals 42" dia. piles 270' penetration	223 ft.	**Base Case (All Failure Modes)**	2,140	4,250	3,880	4,530	4,150	4,520	4,660	4,460	4,660	All legs and piles yield near the mudline	2.18	1.20	-	-
			Case-1 (Only Jacket - Super Structure Failure Modes)	2,140	4,380	-	-	-	4,425	-	-	4,700 (+)	Three diagonals buckled and leg sections with first yield	2.20	1.07	-	-
			Case-2 (Only Pile Foundation Yield/Hinge failure Modes)	2,140	-	4,120	4,480	-	-	4,880	-	4,880	All 8 piles with fully plastic sections below mudline	2.28	-	1.09	-
			Case-3 (Only Pile Foundation Pullout/Plunging Failure Modes)	2,140	-	-	-	4,100	-	-	5,040	5,060	3 Piles pullout and 3 piles plunge	2.36	-	-	1.23

Notes: (#1): RI the lesser of RI1, RI2, and RI3.

Table 4-3: Capacity Analysis Results - Steel Jacket Platforms - Damage Cases

Platform/	Platform Characteristics		Analysis Case	Expected Maximum Hindcast Max. Base Shear (Sa)	Base Shear (at First Failures) from Static Pushover Analysis				Base Shear (at multiple failures) from Static Pushover Analysis			Pushover Analysis Ultimate Capacity (Rus, Rufa, or Ruft) (kips)	Platform Collapse Mode	Ratio of Ult. Cap./ Andrew Base Shear = (Ru/Sa)	System Factor = (Rw/R1) (#1)	System Factor (Pile-Lateral Capacity) = (Rf1/R13)	System Factor (Pile-Axial Capacity) = (Rfa/R14)
	Configuration	Water Depth/ Year Installed (ft.)			Brace/ Joint Event (R11) (kips)	Pile First Yield Event (R12) (kips)	Pile Plasticity Event (R13) (kips)	Pile pullout/ Plunging (R14) (kips)	Brace/ Joint Events (Rs) (kips)	Pile Plasticity Events (Rf) (kips)	Pile pullout/ Plunging (Rfa) (kips)						
ST 151 J	8 Leg - Grouted Single Battered K Braced 30" dia. piles 175' penetration Strengthened by Tripods	137 ft. 1962	Base Case (All Failure Modes)	4,450	3,750	4,040	4,630	3,460	4,520	4,730	4,935	5,000	Pullout and plunging of piles; Failure of KT joints; Fully plastic section in the jacket piles & at jacket-tripod connections	1.12	1.45	-	-
			Case-1 (Only Jacket - Super Structure Failure Modes)	4,450	4,640	-	-	-	5,105	-	-	5,800 (+)	3-braces buckle and 1 yields and 1-KT joint fails in the bottom bay	1.30	1.25	-	-
			Case-2 (Only Pile Foundation Yield/Hinge failure Modes)	4,450	-	4,870	5,710	-	-	6,000	-	6,020	Fully plastic section at two levels in all 8 piles of jacket; No event predicted in tripod piles	1.35	-	1.05	-
			Case-3 (Only Pile Foundation Pullout/Plunging Failure Modes)	4,450	-	-	-	3,550	-	-	5,785	6,010	Three piles pullout and three piles plunge	1.35	-	-	1.63
ST 177B	8 Leg - Grouted Double Battered K Braced 30" dia. piles 187' penetration	142 ft. 1965	Base Case (All Failure Modes)	4,390	3,850	3,200	3,800	3,200	-	3,900	3,720	3,800	Three piles pullout and 3 piles plunge; First yield in K and X joints; Fully plastic section in a pile	0.87	1.19	1.03	1.16
			Case-1 (Only Jacket - Super Structure Failure Modes)	4,390	3,900	-	-	-	5,210	-	-	6,000	All bottom bay KT-joints fail and horioz. braces with plastic sections and 3 diag. buckle; 3 K-joints in 2 bays above fail	1.37	1.54	-	-
			Case-2 (Only Pile Foundation Yield/Hinge failure Modes)	4,390	-	3,180	4,200	-	-	4,700	-	4,700	Fully plastic section at two levels in all 8 piles	1.07	-	1.12	-
			Case-3 (Only Pile Foundation Pullout/Plunging Failure Modes)	4,390	-	-	-	3,200	-	-	3,700	3,800	Three piles pullout and three piles plunge	0.87	-	-	1.16
SS139 (T25)	4 Leg - Grouted Double Battered K Braced 36" dia. piles 165' penetration	62 ft. 1969	Base Case (All Failure Modes)	1,060	1,230	1,440	1,625	-			-	1,640	First yield in all 4 piles, joint failures, yielding of jacket legs, and hinge in a pile	1.55	1.33	-	-
			Case-1 (Only Jacket - Super Structure Failure Modes)	1,060	1,250	-	-	-	1,640	-	-	1,640	KT joints in bottom bay and K joints in 2nd bay fail; horiz. at bottom 2 levels fully plastic	1.55	1.31	-	-
			Case-2 (Only Pile Foundation Yield/Hinge failure Modes)	1,060	-	1,860	2,070	-	-	2,240	-	2,300	Fully plastic section at two levels in all 4 piles	2.17	-	1.08	-
			Case-3 (Only Pile Foundation Pullout/Plunging Failure Modes)	1,060	-	-	-	2,190	-	-	2,665	2,740	One pile pullout and one pile plunge	2.58	-	-	1.22

Notes: (#1): Rl the lesser of Rl1, Rl2, and Rl3.

Table 4-4: Capacity Analysis Results - Steel Jacket Platforms - Collapse Cases

Platform/	Platform Characteristics: Configuration	Platform Characteristics: Water Depth/ Year Installed (ft.)	Analysis Case	Expected Maximum Hindcast Max. Base Shear (Sa)	Base Shear (at First Failures) from Static Pushover Analysis: Brace/ Joint Event (RI1) (kips)	Base Shear (at First Failures) from Static Pushover Analysis: Pile First Yield Event (RI2) (kips)	Base Shear (at First Failures) from Static Pushover Analysis: Pile Plasticity Event (RI3) (kips)	Base Shear (at First Failures) from Static Pushover Analysis: Pile pullout/ Plunging (RI4) (kips)	Base Shear (at multiple failures) from Static Pushover Analysis: Brace/ Joint Events (Rs) (kips)	Base Shear (at multiple failures) from Static Pushover Analysis: Pile Plasticity Events (Rf) (kips)	Base Shear (at multiple failures) from Static Pushover Analysis: Pile pullout/ Plunging (Rfa) (kips)	Pushover Analysis Ultimate Capacity (Rus, Rufa, or Ruf) (kips)	Platform Collapse Mode	Ratio of Ult. Cap./ Andrew Base Shear = (Ru/Sa)	System Factor = (Ru/RI) (#1)	System Factor (Pile-Lateral Capacity) = (Rf/RI3)	System Factor (Pile-Axial Capacity) = (Rfa/RI4)
ST 151 H	8 Leg - Grouted Single Battered K Braced 30" dia. piles 175' penetration	137 ft. 1964	Base Case (All Failure Modes)	3,560	2,680	2,900	-	3,140	3,240	-	-	3,250	Failure of KT joints; First yielding of all piles; Fully plastic section in the bottom horizontals	0.91	1.21	-	-
			Case-1 (Only Jacket - Super Structure Failure Modes)	3,560	2,680	-	-	-	3,140	-	-	3,250	Failure of KT joints and fully plastic sections in the bottom horizontals	0.91	1.21	-	-
			Case-2 (Only Pile Foundation Yield/Hinge failure Modes)	3,560	-	3,120	3,830	-	-	3,970	-	4,070	Fully plastic sections in all 8 piles at two levels	1.14	-	1.04	-
			Case-3 (Only Pile Foundation Pullout/Plunging Failure Modes)	3,560	-	-	-	3,240	-	-	3,580	3,600	Three piles pullout and two piles plunge	1.01	-	-	1.10
ST 130A	8 Leg - Grouted Single Battered K Braced 30" dia. piles 175' penetration	142 ft. 1958	Base Case (All Failure Modes)	1,990	2,230	1,300	1,720	2,500	2,380	1,830	-	2,500	First yielding in all piles; fully plastic section in piles and legs; pullout of piles	1.26	1.92	-	-
			Case-1 (Only Jacket - Super Structure Failure Modes)	1,990	2,000 2,790	(strut) (joints)	-	-	2,400 2,930	(struts) (joints)	-	2,930	3-K joints fail; 6 struts buckle/yield; fully plastic leg sections	1.47	1.20 1.05	(struts) (joints)	-
			Case-2 (Only Pile Foundation Yield/Hinge failure Modes)	1,990	-	1,360	1,620	-	-	1,800	-	1,800	Fully plastic sections in all 8 piles below jacket leg extensions	0.90	-	1.11	-
			Case-3 (Only Pile Foundation Pullout/Plunging Failure Modes)	1,990	-	-	-	2,500	-	-	2,860	2,880	Three piles pullout and four piles plunge	1.45	-	-	1.14
ST52 (T21)	4 Leg - Grouted Double Battered K Braced 36" dia. piles 170' penetration 15' leg extension	61 ft. 1969	Base Case (All Failure Modes)	1,380								(#2) 1900 (Phase 1)						
			Case-1 (Only Jacket - Super Structure Failure Modes)	1,380		-	-	-		-	-	(#2)					
			Case-2 (Only Pile Foundation Yield/Hinge failure Modes)	1,380	-	2,114	2,600	-	-	3,250	-	3,250	All four piles with fully plastic sections at two levels	2.36	-	1.25	-
			Case-3 (Only Pile Foundation Pullout/Plunging Failure Modes)	1,380	-	-	-	2,700	-	-	2,700	2,770	Two piles pullout	2.01	-	-	1.00

Notes: (#1): RI the lesser of RI1, RI2, and RI3.

(#2): K and KT braces same in both T21 and T25 platforms; in T25 brace capacity governed ultimate capacity; T21 with stiffer legs than T25 is likely to have higher capacity than 1,640 kips for T25.

Table 4-5: Capacity Analysis Results for Caisson Cases [from API/MMS Foundation Study]

Platform	Platform Characteristics		Analysis Case	Expected Maximum Hindcast Base Shear (kips)	Base Shear (Kips) from Static Pushover Analysis			Displacement		Ratio	System Factor
	Configuration	Water Depth/ Year Installed			at First yield of Ist Section (#1) (kips)	at Fully Plastic Ist Section (kips)	at Ultimate Capacity (#2) (kips)	at Deck Level (ft.)	at Seabed level (ft.)	Ult. Cap./ Andrew BS	Ult. Cap./ BS at First member failure (#2) / (#1)
SPelto 10	30" dia. 180' penetration 12 degree lean	35 ft. 1985	Base Case	65	38 at 35' below	44	48	5.63	1.2	0.74	1.26
			Su increased by 100 %	65	54	69	-	-	-	-	-
SS113	48" dia. 100' penetration 5 degree leaning Max. t = 1.75"	47 ft. 1990	Base Case	138	186 in 1.75" section	214	235	7.3	1.67	1.70	1.26
SS135	48" dia. 95' penetration 15 degree leaning Max. t = 2"	53 ft. 1983	Base Case	132	119 at 40'-50' below	128 in 1" section	148	7.2	-	1.12	1.24
			Su increased 50 %	132	129	142	165	-	-	1.25	1.28
			Su increased 100%	132	138	154	178	-	-	1.35	1.29
SS136	48" dia. 100' penetration 30 degree leaning	50 ft. 1983	Base Case (upper bound)	139	173	197	224	7.24	1.96	1.61	1.29
			Ignored Sand layer	139	150	153	161	6.78	2.05	1.30	1.21

Capacity Analysis - Summary

Andrew JIP- Phase II

Superstructure Failure Modes Included

- Dominant Failure Modes:
  - » K, KT joints yielding to failure
  - » Buckling of diagonal braces
  - » Horizontal braces full plasticity
  - » Yielding/hinging of leg sections
- Ratios of Load Levels at Multiple to First Failure Events
  - » 1.03 to 1.54 for 8-leg platforms
  - » 1.02 to 1.31 for 4-leg platforms

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Capacity Analysis - Summary

Andrew JIP- Phase II

Foundation failure Modes

- Low Displacements at Pileheads
- Pile Lateral Capacity, System Factor
  - » 1.03 to 1.12 for six 8 leg platforms
  - » 1.08 to 1.36 for three 4-leg platforms
- Pile Axial Capacity, System factor
  - » 1.10 to 1.17 for five 8-leg Platforms
  - » 1.63 for one 8-leg platform strengthened with two tripods
  - » 1.0 to 1.23 for 4-leg Platforms
- Pullout/Plunging for 8-leg Platforms Investigated Predicted at Lower Loads

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Capacity Analysis - Summary

Andrew JIP- Phase II

Comparison With Andrew Phase I Results

- Ratios of Expected Maximum Base Shear
  - » 0.63 to 0.85 of Andrew I
- Ratios of Ultimate Capacity (Base Case)
  - » 1.1 of Andrew I for Survival Cases
  - » 0.9 to 1.2 of Andrew I for Damage Cases
  - » 0.8 of Andrew I for Failure Cases
- Ratios of Ultimate Capacity (Base Case) to Base Shear
  - » 1.4 of Andrew I for Survival Cases
  - » 1.1 to 2.0 of Andrew I for Damage Cases
  - » 1.0 to 1.2 of Andrew I for Failure Cases

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Capacity Analysis - Summary

Andrew JIP- Phase II

Caissons (from API/MMS Foundation Study)

- Three Caissons Considered
- Site-Specific Soil not Available for All Caissons
- Soil Strata Based on Adjacent Blocks for 1 Case
- Two Platforms have Much Higher Capacities than Andrew Load Level
- System Factor Varies from 1.21 to 1.29

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