BSC

Design Calculation or Analysis Cover Sheet

Complete only applicable items.

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2. Page 1

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Attachment D	125

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DISCLAIMER

The calculations contained in this document were developed by Bechtel SAIC Company, LLC (BSC) and are intended solely for the use of BSC in its work for the Yucca Mountain Project.

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ACRONYMS

3D	three-dimensional
BDBGM	Beyond Design Base Ground Motion
CD	Compact Disc
D/C	Demand / Capacity
DBGM	Design Base Ground Motion
FE	finite elements
FEM	finite element model
RF	Receipt Facility
C.G.	Center of Gravity
ft	Feet

1. PURPOSE

The purpose of this calculation is to perform a preliminary basemat reinforcement design and stability analysis for the Receipt Facility (RF). The shear and flexural reinforcements for the basemat will be determined in this calculation. Building stability against overturning and sliding due to seismic loads will also be evaluated in this calculation.

2. REFERENCES

2.1 PROJECT PROCEDURES / DIRECTIVES

2.1.1 EG-PRO-3DP-G04B-00037, Rev.007, ICN 0. *Calculations and Analyses*. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070122.0010.

2.1.2 IT-PRO-0011 Rev. 003, ICN 0. *Software Management.* Las Vegas, Nevada, Bechtel SAIC Company. ACC: DOC.20061221.0003.

2.1.3 ORD (Office of Repository Development) 2007. *Repository Project Management Automation Plan.* 000-PLN-MGR0-00200-000, Rev. 00E. Las Vegas, Nevada: U.S. Department of Energy, Office of Repository Development. ACC: ENG.20070326.0019

2.2 DESIGN INPUTS

2.2.1 BSC (Bechtel SAIC Company) 2006. *Project Design Criteria Document.* 000-3DR-MGR0-00100-000-006. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20061201.0005.

2.2.2 BSC (Bechtel SAIC Company) 2006. *Basis of Design for the TAD Canister–Based Repository Design Concept.* 000-3DR-MGR0-00300-000-000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG 20061023.0002.

2.2.3 BSC (Bechtel SAIC Company) 2007. *RF Seismic Analysis.* 200-SYC-RF00-00400-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070307.0003.

2.2.4 BSC (Bechtel SAIC Company) 2007. *Receipt Facility: Soil Springs and Damping.* 200-SYC-RF00-00300-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070117.0011.

2.2.5 BSC (Bechtel SAIC Company) 2006. *Receipt Facility (RF) Mass Properties.* 200-SYC-RF00-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20061206.0001.

2.2.6 ACI 349-01. 2001. *Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-01).* Farmington Hills, Michigan: American Concrete Institute. TIC: 252732. [DIRS **158833**]

2.2.7 ASCE 4-98. 2000. *Seismic Analysis of Safety-Related Nuclear Structures and Commentary.* Reston, Virginia: American Society of Civil Engineers. TIC: 253158. [DIRS **159618**]

2.2.8 ASCE / SEI 43-05. *Seismic Design Criteria for Structures, Systems ,and Components in Nuclear Facilities.* Reston, Virginia: American Society of Civil Engineers. TIC: 257275 [DIRS **173805**]

2.2.9 Bowles, J.E. 1996. *Foundation Analysis and Design.* 5th Edition. New York, New York: McGraw-Hill. TIC: 247039. [DIRS **157929**]

2.2.10 MO0411SDSTMHIS.006. Seismic Design Spectra and Time Histories for the Surface Facilities Area (Point D/E) at 5E-4 Annual Exceedance Frequency. Submittal date: 11/16/2004. [DIRS **172426**]

2.2.11 DOE (U.S. Department of Energy) 2007. *Software Validation Report for: SAP2000 Version 9.1.4.* Document ID: 11198-SVR-9.1.4-01-WinXP. Las Vegas, Nevada: U.S. Department of Energy, Office of Repository Development. ACC: MOL.20070118.0264. [DIRS **179105**]

2.2.12 BSC (Bechtel SAIC Company) 2006. *Seismic Analysis and Design Approach Document.* 000-30R-MGR0-02000-000-000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20061214.0008.

2.3 DESIGN CONSTRAINTS

None

2.4 DESIGN OUTPUTS

Results of this calculation will be used in developing the RF foundation concrete drawings. Document numbers have not been assigned to these drawings.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

There are no assumptions requiring verification used in this calculation.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 **Basemat sliding on a level surface**.

Assumption is made that the basemat is an unanchored rigid body on level surface.

Rationale-Although, basemat is embedded in to the ground, conservatively, for purpose of calculating the approximate sliding distance (Eq. A-1, Ref. 2.2.8), basemat is sliding on a level surface.

Where used: Section 6.6.1.2

3.2.2 Stress Contour Plots for reinforcing design

Stress Contour Plots generated by SAP2000 using nodal averaging will be used in the design of the required reinforcing steel.

Rationale: Reinforced concrete is a composite material comprised of concrete and reinforcing bars. While peak element forces exceed the average values shown on the contour plots (Attachment D) it is recognized that as concrete cracks and reinforcing bars yield that peak resultants are redistributed over adjacent elements. Utilizing force resultants based on nodal averaging accounts for the redistribution and is appropriate for use in reinforcement concrete design.

Where used: Section 6.5

4. METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation was prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Ref. 2.1.1). Section 6.1.2 of the *Basis of Design for the TAD Canister–Based Repository Design Concept* (Ref. 2.2.2) classifies the RF structure as Important to Safety (ITS), therefore, the approved version of this calculation is designated as QA: QA.

4.2 USE OF SOFTWARE

Excel 2000 and Word 2000, which are part of the Microsoft Office 2000 Professional suite of programs, were used in this calculation from page 1-54 and Excel 2003 and Word 2003, which are part of the Microsoft Office 2003 Professional suite of programs, were used in this calculation from page 55-119. Microsoft Office 2000 and 2003 Professional as used in this calculation are classified as Level 2 software usage as defined in IT-PRO-0011 (Ref. 2.1.2, Attachment 12). Microsoft Office 2000 is listed on the current Software Report (SW Tracking Number 610236-2000-00) and Microsoft Office 2003 is listed on the current Software Report (SW Tracking Number 610236-2003-00). Both are listed in The *Repository Project Management Automation Plan* (Ref. 2.1.3, Table 6-1).

The above software were executed on a PC system running Microsoft Windows 2000 and 2003 operating system. Results were confirmed by visual inspection and by performing hand calculations. Excel 2000 was used to generate twelve load combinations and Excel 2003 was used to generate vertical and horizontal spring stiffness. Both Excel spreadsheets were used to generate SAP2000 model. Word 2000 was used in the text preparation of this document; no calculations functions contained in Word were used in this document.

SAP2000, Version 9.1.4 as used in this calculation is classified as Level 1 software usage as defined in IT-PRO-0011 (Ref. 2.1.2). This software is a commercially available computer program qualified to perform static and dynamic analysis of structural systems. This software is listed in the Qualified and Controlled Software Report and is qualified with Software Tracking Number 11198-9.1.4-01. The software is operated on a PC system running the Windows XP Professional operating system. The SAP2000 Validation Report is contained in Ref. 2.2.11.

4.3 DESCRIPTION OF CALCULATION APPROACH

As stated in Section 1, this calculation investigates the flexural and shear reinforcing requirements for the RF basemat. The foundation stability against overturning and sliding is also evaluated in this calculation. The Liquid Low Level Waste Collection Pit currently planned for information in the LLW Staging Room is not considered in this calculation. This will be evaluated in the Tier 2 analysis.

A finite element model of the RF basemat is developed and coupled to the tier-1 "beam-stick" model, developed in the RF seismic analysis (Ref. 2.2.3). The result is a finite element model of the basemat with the stiffening effects of the walls included. Non-linear (compression only) springs are used to model the soil underlying the basemat. Dead, live and seismic loads were applied to the model and loading combinations were developed that maximize the soil pressures on each corner of the structure. Since a non-linear spring element is utilized to model the soil stiffness, a non-linear analysis is required for each loading combination (i.e. the principle of super position does not apply to non-linear analysis). In each analysis case SAP2000 obtains a solution and then verifies that all of the spring elements are in compression. If tension exists in any spring elements SAP2000 will remove those springs and re-solve the problem. SAP2000 continues this process until the solution converges and no tension exists in any spring elements.

Having completed the non-linear analysis cases described above SAP2000 is utilized to generate moment and shear contour plots, which will be used in designing the shear and flexural reinforcing in the basemat. In designing the flexural reinforcing a standard rebar pattern is selected and the corresponding moment capacity resulting from that reinforcing is computed. The contour plots will then be utilized to identify areas that may require additional reinforcing above the standard reinforcement pattern. In evaluating the shear reinforcing requirements in the basemat the shear capacity of the concrete (without any shear reinforcing) is computed and the shear contour plots are utilized to determine areas of the basemat requiring transverse shear reinforcing. Transverse shear reinforcing will then be designed to provide the additional capacity required above the capacity provided by the concrete.

After completing the reinforcing design of the basemat, the overall stability of the RF structure against sliding and overturning is evaluated. Because of the high seismic accelerations associated with the DBGM-2 ground motions, it is not possible to compute a static factor of safety against sliding for the RF structure under DBGM-2 seismic input motions. Therefore this calculation will utilize energy balance methods discussed in ASCE 43-05 (Ref. 2.2.8) to compute the maximum predicted sliding displacement. Any umbilical (i.e. utility piping, electrical raceway, etc) connecting to the RF from outside the structure will need to be designed to accommodate the sliding displacement with suitablesafety factor

Details of the finite element analysis of the basemat and the stability calculations are discussed in Section 6.

5. LIST OF ATTACHMENTS

		Number of Pages
Attachment A.	Basemat Plan at EL 0’-0”	2
Attachment B.	SAP2000 Input File	1 Page + CD
Attachment C.	SAP2000 Output Using Upper Bound 35 Soil Springs	1 Page + CD
Attachment D.	SAP2000 Output – Moment and Shear Contours	125

6. BODY OF CALCULATION

6.1 DETERMINE NON-LINEAR SPRING CONSTANTS

A finite element model of the RF basemat was created using SAP 2000. The RF basemat consists of shell elements with a mean size of 5 ft. by 5 ft. Actual mesh sizes vary from this nominal size as required to maintain the correct location of the shear walls. The coordinate system and global origin chosen for this model coincides with the coordinate system and global origin used in the RF “beam-stick” model used in the seismic analysis (Ref. 2.2.3). The origin and orientation of the global axes are shown on Attachment A.

The shell elements used to model the basemat were located at a Z coordinate corresponding to the bottom of the basemat. In this case a 7 ft. thick slab is considered for the main basemat and 4 ft thick slabs are considered for east and west wings (operations area and LLW room respectively) (Ref. 2.2.5), thus the Z coordinate origin of the finite element mesh is located at Z=-7 ft. for main basemat and Z=-4 ft. for the wings. See also the plan at the RF foundation in Attachment A. By modeling the basemat at this elevation, the proper soil pressures are computed since the mat will rotate about a bottom corner of the slab.

Shell elements were also used to model the shear walls from the slab elevations up to elevation 0 ft. These walls will serve to stiffen the basemat from the resulting soil pressures computed in the analysis. The “beam-stick” model developed in the RF seismic analysis (Ref. 2.2.3) is then coupled to the finite element mesh of the walls by using the SAP2000 rigid constraint definition. The resulting model yields an accurate representation of the basemat with the stiffening effects of the shear walls included in the model. Figure 6.1.1 shows an isometric view of the RF basemat with the “beam-stick” model coupled to it. An elevation example of a “beam-stick” element coupled to wall finite elements is shown in Figure 6.1.3. Figure 6.1.2 shows the basemat finite element mesh.

It should be noted that in this model the lower walls span from –7 ft to 32 ft and from –4 ft to 32 ft. In reality, the walls span from the top of the basemat at 0 ft to 32 ft. Since the use of this model is for designing the basemat, the walls are represented here only to stiffen the basemat, which is adequately represented in this model.

To simulate the stiffness properties of the soil underlying the basemat, a series of non-linear (compression only) springs were computed. The soil spring stiffness is computed using the 35 ft. upper bound soil springs computed in the RF soil spring calculation (Ref. 2.2.4). This is the critical soil spring case as determined in the seismic analysis (Ref. 2.2.3) In this calculation a series of global springs, 3 translational and 3 rotational, were computed. This calculation uses these global springs to compute "local" springs to be placed under each node in the basemat mesh. The method of determining these "local" springs is discussed in the Seismic Analysis and Design Approach document (Ref. 2.2.12). Details of the soil spring calculation are given in Section 6.2.

The vertical compression only springs were included in the SAP2000 model using a 2 joint link element. The gap element option in the SAP2000 link definition was used such that the link had a stiffness in compression as defined above and had 0 stiffness when the gap element is open, i.e. in tension. To create the 2 joints used to define the link element the nodes used to define the foundation finite element mesh were copied down to an arbitrary elevation of –17 ft. The joint id's at this location were assigned joint numbers g01, g02, g03…g12260. The joint numbers on the foundation mesh were assigned id's b01, b02, b03…b12260. Such that g01 and b01 have the same X and Y coordinate and thus are located along the same vertical line. Link elements would then connect g01-b01, g02-b02, g03-b03, g12260-b12260.

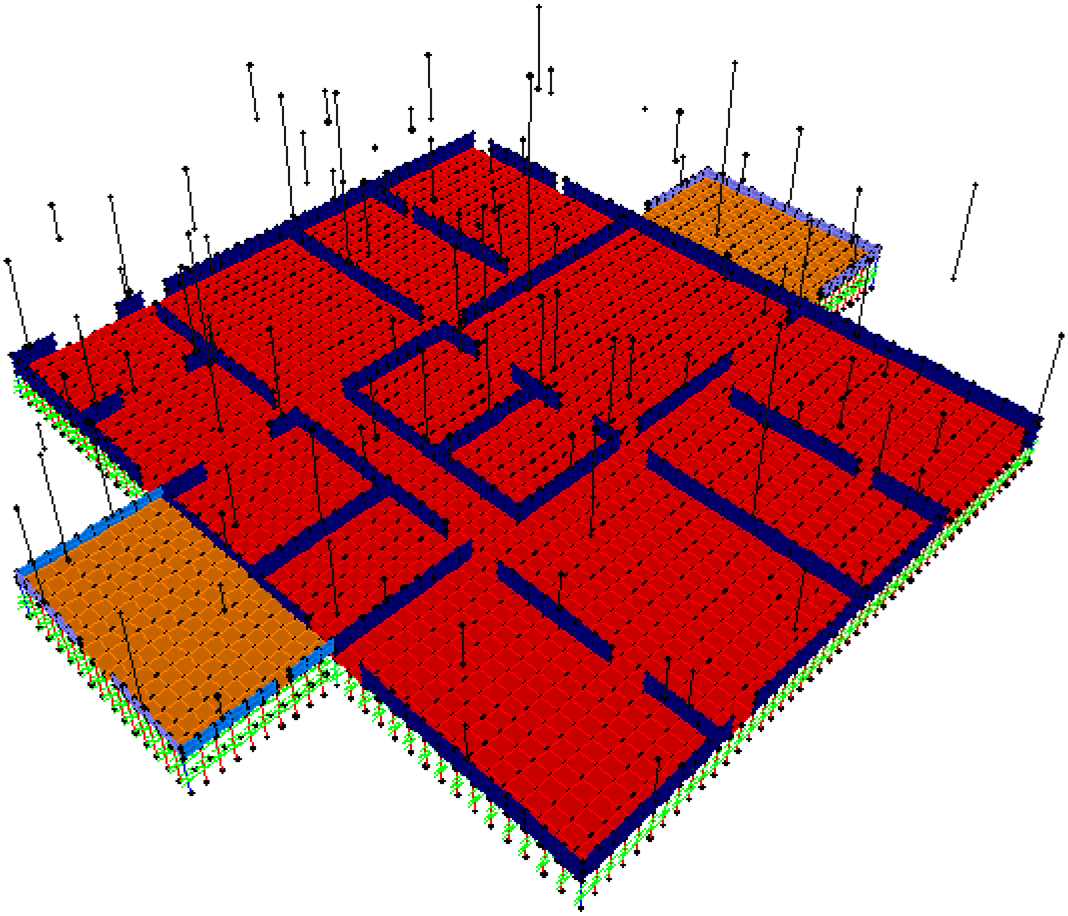
In order to model the effective horizontal stiffness of the soil, the soil springs are calculated for DBGM-2 ground motion (Ref. 2.2.2, Section 6.2.3.1.6). Horizontal stiffness from the upper bound 35 ft alluvium case governs the design of the RF structure (Ref. 2.2.3, Section 7.2). Since the primary load path for lateral loads is under the basemat (neglecting passive pressure at the foundation boundry), the horizontal soil springs are located at the foundation mesh nodes, b01 - b12260 at elevation –7 ft and –4 ft. These springs are linear springs and are calculated in Section 6.2. An example of the soil springs is shown in Figure 6.1.3.

Concrete material properties used in this finite model are taken from Section 4.2.11.6.6 of the Project Design Criteria (Ref. 2.2.1) and are consistent with those used in the RF seismic analysis (Ref. 2.2.3).

In the "beam-stick" seismic model (Ref. 2.2.3), the foundation mass and lower half of the wall mass was lumped at the center of gravity of the basemat. In this analysis, the basemat and lower walls are included in the model and thus their masses are included in the model through the density assigned to the concrete shell elements. Since only 7 ft. of wall height in the main basemat area and 4 ft. of wall height in the east and west wings are included in this model, but the lower half of the actual wall is 16 ft. The density assigned to the wall elements needs to be factored to obtain the correct wall weights. Thus the normal concrete density of 150 lbs./cubic ft. (Ref. 2.2.1, Section 4.2.11.6.6) is multiplied by a factor equal to 16 ft/7 ft or 2.29 resulting in a value of 150*2.29 = 343 lbs./cubic ft. for the main basemat and 16/4 or 4.0, which results in a value of 150*4.0 = 600 lbs./cubic ft. for the wing areas, are used to define the wall element concrete densities.

The SAP2000 model input files are included in Attachment B.

SAP2000 graphics show the model configuration. The basemat elements and wall stick elements, overlaid on the foundation plan, are included in Figure-6.1.1; the basemat finite element mesh is shown in Figure-6.1.2, and the elevation of Walls, Stick, and Link elements are shown in Figure-6.1.3.



RF Foundation Model Coupled to Multi-Stick Seismic Model

Figure 6.1.1. Isometric View of the Model

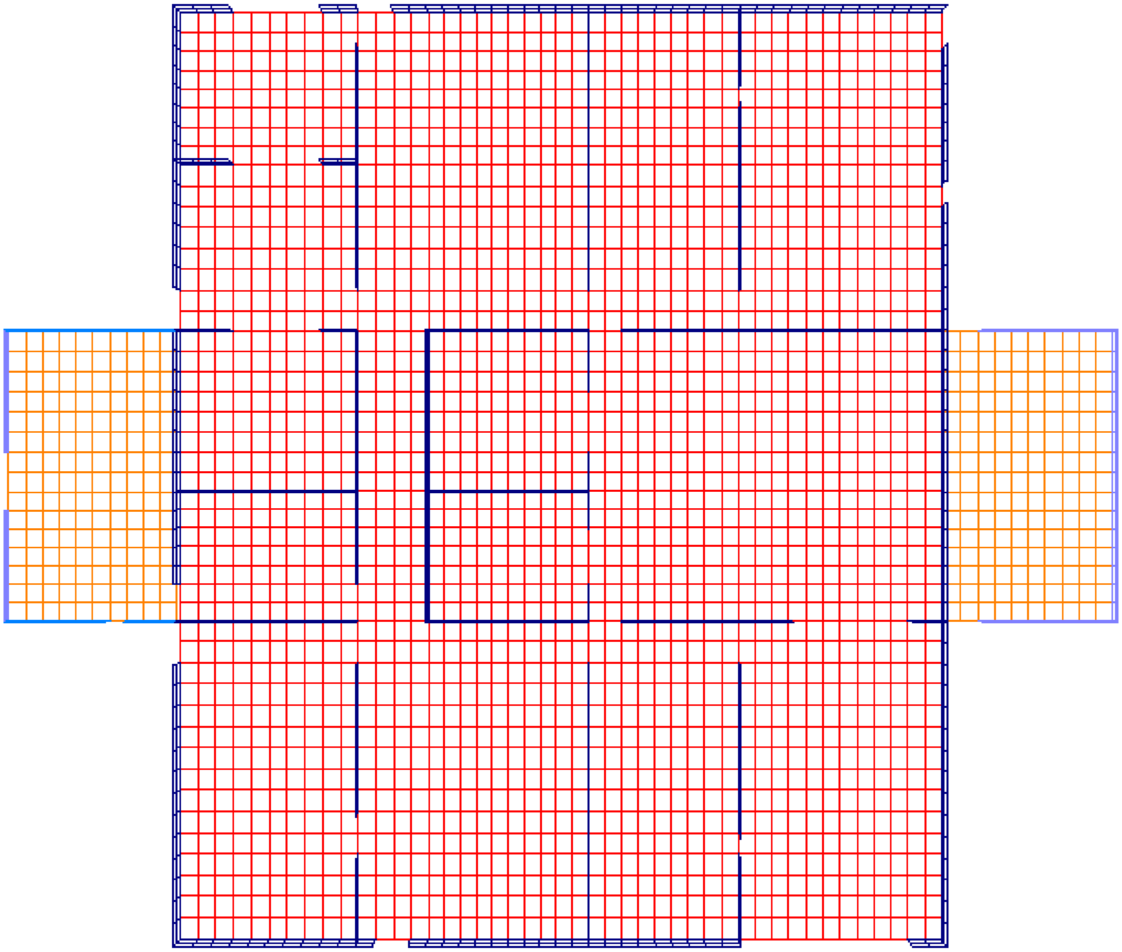
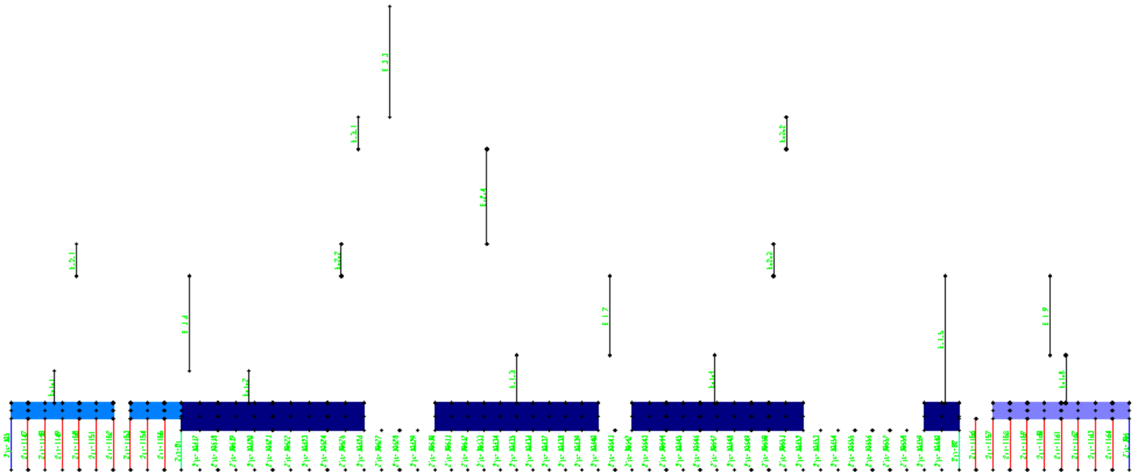


Figure 6.1.2. Basemat Finite Element Mesh



Elevation View

Figure 6.1.3. Wall, Stick, and Link Elements

6.2 SOIL SPRINGS

As stated in Section 6.1, for vertical loads, the boundary condition for the basemat was modeled using non-linear compression –only springs, while linear springs model the horizontal stiffness. The spring stiffness values are based on the upper bound 35 ft alluvium case (Reference 2.2.4). The soil springs used in the seismic analysis (Reference 2.2.3) were global springs, meaning that only one support point was used in the seismic analysis model to model the stiffness of the supporting soil. The basemat finite element model will have a support point located at each node of the basemat mesh. Therefore, the global spring must be converted into individual springs applied to each node of the foundation finite element mesh. This section contains the joint spring calculation.

For DBGM-2 (5E-4 Event) ground motions, the global upper bound 35 ft alluvium spring constants from design calculation for Receipt Facility: Soil Springs: 200-SYC-RF00-00300-000-00A (Reference 2.2.4, Table 7.1.1, Case 3) are listed below. (Note: the coordinate system used in the Soil Spring calculation is same as used in this calculation.)

Global Translational Spring constants (units of kips/ft) (Ref. 2.2.4, Table 7.1.1, Case 3)

Soil Spring Coordinate System	Value
KX (Horizontal)	2.984E+07
KY (Horizontal)	3.175E+07
KZ (Vertical)	3.838E+07

Global Rotational Spring Constants (units of ft-kips/radian) (Ref. 2.2.4, Table 7.1.1, Case 3)

Soil Spring Coordinate System	Value
$K\Psi X$ (Rocking)	4.424E+11
$K\Psi Y$ (Rocking)	4.931E+11
$K\Psi Z$ (Torsional)	6.661E+11

The Seismic Analysis and Design Approach Document (Reference 2.2.12) Appendix C1.2 suggests two equations for calculating vertical soil springs per unit area from global spring values.

1) $k_v = K_V / A$ where k_v is vertical global spring per unit area and K_V is the global vertical spring KZ and A is area of the basemat. (Ref. 2.2.12, Eq. C-2)

2) $k_v = K_\Phi / I_A$ where, K_Φ is the rotational (rocking) spring stiffness ($K\Psi X$ and $K\Psi Y$ in above table) and I_A (I_{XX} and I_{YY} shown below) is the moment of inertia of the basemat area with respect to its centroidal axis. (Ref. 2.2.12, Eq. C-3)

Basemat Area A= (200*242) + 2(42*78) = 54.952E+03 ft^2 (Ref. 2.2.4, Section 6.1.1, pg.20)

I_{XX} = 2.395E+08 ft^4 (Ref. 2.2.4, Section 6.1.1, pg.20)

I_{YY} = 2.582E+08 ft^4 (Ref. 2.2.4, Section 6.1.1, pg.20)

Substituting,

k_v = 3.838E+07 / 54.952E+03 = 698 kips/ ft^3 for vertical about Z axis (Ref. 2.2.12, Eq. C-2)

k_v = 4.931E+11 / 2.582E+08 = 1910 kips/ ft^3 for rocking about Y axis (Ref. 2.2.12, Eq. C-3)

k_v = 4.424E+11/ 2.395E+08 = 1847 kips/ ft^3 for rocking about X axis (Ref. 2.2.12, Eq. C-3)

These values show that the vertical spring values based on global rotational (rocking) springs are higher (stiffer) than the one derived from global vertical spring. For a given load condition the stiffer spring will yield lower bending moment and shear forces in the basemat. For this reason the stiffness value from Equation C-2 of Ref. 2.2.12 will be used for the analysis of the RF basemat.

Therefore use 698 kips / ft^3 which will give more conservative (upper bound) design forces for the basemat design.

The area of the basemat mesh element = Area/total number of shell element = 54952 sq.ft/2370 = 23.2 sq. ft or use nominal of 5ft by 5ft =25 sqft.

The nominal vertical spring values at an internal node = k_v times the tributary area of each node = 698 * 25 = 17,450 kips per foot.

Since the basemat mesh is generated between the walls the area elements nodes are not equally spaced resulting in varying tributary areas. For simplicity the global spring value is distributed to 2482 nodes (see Figure 6.2.1) as follows.

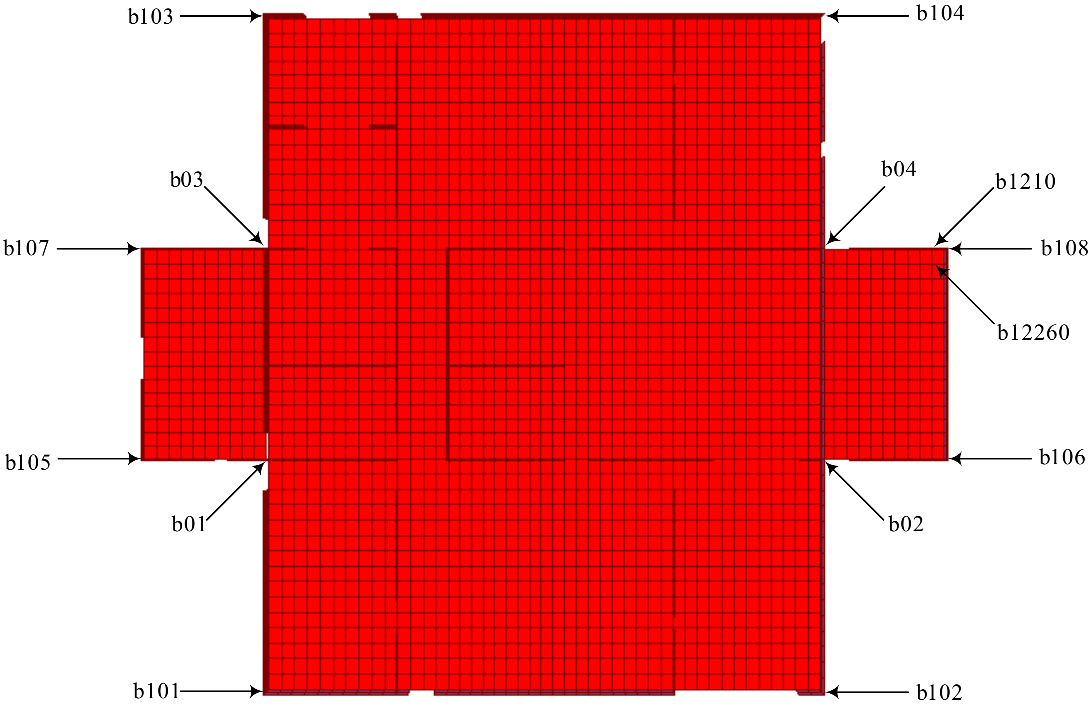


Figure 6.2.1. Base Nodes

Location	Number of Nodes	Base Node	Link Name	Ground Node
Interior of base	2260	b10001 - b12260	2jt-10001 - 2jt-12260	g10001 - g12260
Edge of base	210	b1001 - b1210	2jt-1001 - 2jt-1210	g1001 - g1210
Outside Corner	8	b101 - b108	2jt-101 - 2jt-108	g101 - g108
Inside Corner	4	b01 - b04	2jt-01 - 2jt-04	g01 - g04

For the 8 outside corner nodes (Node b101, b102, b103, b104, b105, b106, b107 and b108) with a nominal tributary area of 25% of the interior node assigned spring value will be ¼ of the interior node spring.

For the 4 inside corner nodes at b01, b02, b03, and b04 with a nominal tributary area of 75% of the interior node the assigned spring value will be ¾ of the spring values of the interior node.

For the 210 (b1001 – b1210) perimeter nodes with a nominal tributary area of 50% of an interior node, the assigned spring value will be 50% of that of the interior node.

Therefore number of interior nodes = 2482-210-4-8 = 2260

For the 2260 (b10001 – b12260) interior nodes the assigned spring value is 100%

Letting X = spring value of the interior node, the total spring value can be computed as

KZ (Vertical) = 2260X+ 210*0.5 X + 8 * 0.25X + 4*0.75X = 2370X

X = 3.838E+07/ 2370 = 16,194 kips/ft (for KZ (Vertical) see top of page 16)

At 210 perimeter (edge) external nodes =1/2(16,194) = 8,097 kips/ft

At 8 corner nodes = ¼ (16,194) = 4,049 kips/ ft

At 4 corner nodes = ¾(16,194) = 12,146 kips/ft

These values are input in SAP2000 as link property assignments and Link Property definitions.

Example: For corner link at node b01,

Link Property Assignments

Link #	**Link Type**	**Link Joint**	**Link Property**
2jt-01	Gap	Two Joint	Base (75%)

Link Property Definition

Link Property	**DOF**	**Fixed**	**Nonlinear**	**Translation Stiffness**
Base (75%)	U1	No	Yes	12,146 kips/ft

Similarly, the translational springs are derived from global values as follows.

Horizontal Springs in X direction: (for KX (Horizontal) see top of page 16)

- At 2260 interior nodes: 2.984E+07 / 2370 =12,591 k/ft
- At 210 perimeter wall nodes (1/2): 6,295 k/ft
- At 8 corner nodes (¼): 3,148 k/ft
- At 4 corner nodes (3/4): 9,443 k/ft

Horizontal Springs in Y direction: (for KY (Horizontal) see top of page 16)

- At 2260 interior nodes: 3.175E+07 / 2370 =13,397 k/ft
- At 210 perimeter wall nodes (1/2): 6,698 k/ft
- At 8 corner nodes (¼): 3,349 k/ft
- At 4 corner nodes (3/4): 10,047 k/ft

These values are input as Joint Spring Assignments in the global X and Y directions at foundation mesh nodes.

6.3 LOADS AND LOADING COMBINATIONS

6.3.1 Loading Combination based on 100-40-40 component factor method

The forces and moments in the basemat will be determined based on a combination of the three global directions considered in the seismic analysis, which are; HX, HY, and VZ as well as the self-weight of the structure. HX (east west) and HY (north south) represent both orthogonal horizontal directions and VZ represents the vertical direction. Self-weight is in the negative VZ direction. To account for non-orthogonal seismic effects, the loading combinations to be considered are based on the 100-40-40 component factor method from ASCE 4-98 (Reference 2.2.7), which uses 100% seismic loading in one direction, combined with 40% seismic in the remaining two directions. The 100-40-40 component factor method (Reference 2.2.7) yields three basic load combinations:

- ± 1.0 HX ± 0.4 HY ± 0.4 VZ
- ± 0.4 HX ± 1.0 HY ± 0.4 VZ
- ± 0.4 HX ± 0.4 HY ± 1.0 VZ

Manipulating the above combinations (using the plus and minus signs) yields 24 loading permutations:

Global Directions	This calculation	Seismic calc (Ref. 2.2.3)
East-West	HX	$D35U_X$
North-South	HY	$D35U_Y$
Vertical	VZ	$D35U_Z$

1: + 1.0 HX + 0.4 HY + 0.4 VZ
2: + 1.0 HX + 0.4 HY - 0.4 VZ
3: + 1.0 HX - 0.4 HY + 0.4 VZ
4: + 1.0 HX - 0.4 HY - 0.4 VZ
5: - 1.0 HX + 0.4 HY + 0.4 VZ
6: - 1.0 HX + 0.4 HY - 0.4 VZ
7: - 1.0 HX - 0.4 HY + 0.4 VZ
8: - 1.0 HX - 0.4 HY - 0.4 VZ
9: + 0.4 HX + 1.0 HY + 0.4 VZ
10: + 0.4 HX + 1.0 HY - 0.4 VZ
11: - 0.4 HX + 1.0 HY + 0.4 VZ
12: - 0.4 HX + 1.0 HY - 0.4 VZ
13: + 0.4 HX - 1.0 HY + 0.4 VZ
14: + 0.4 HX - 1.0 HY - 0.4 VZ
15: - 0.4 HX - 1.0 HY + 0.4 VZ
16: - 0.4 HX - 1.0 HY - 0.4 VZ
17: + 0.4 HX + 0.4 HY + 1.0 VZ
18: + 0.4 HX - 0.4 HY + 1.0 VZ
19: - 0.4 HX + 0.4 HY + 1.0 VZ
20: - 0.4 HX - 0.4 HY + 1.0 VZ
21: + 0.4 HX + 0.4 HY - 1.0 VZ
22: + 0.4 HX - 0.4 HY - 1.0 VZ
23: - 0.4 HX + 0.4 HY - 1.0 VZ
24: - 0.4 HX - 0.4 HY - 1.0 VZ

The RF basemat and wall layout is almost symmetrical with respect to global X-axis (except for walls on column line D and a few wall openings). Thus, the maximum foundation pressure at the northeast corner will be same as the maximum foundation pressure at the southeast corner. Similarly, the maximum foundation pressure at the northwest corner will be same as the pressure at the southwest corner. Therefore, 12 combinations with negative HY force component will be similar to the twelve combinations with positive HY force components. There fore the following 12 load combinations will provide the required foundation loads for design.

1: DL + 1.0 HX + 0.4 HY + 0.4 VZ
2: DL + 0.4 HX + 1.0 HY + 0.4 VZ
3: DL + 0.4 HX + 0.4 HY + 1.0 VZ
4: DL + 1.0 HX + 0.4 HY - 0.4 VZ
5: DL + 0.4 HX + 1.0 HY - 0.4 VZ
6: DL - 0.4 HX + 1.0 HY - 0.4 VZ
7: DL - 0.4 HX + 0.4 HY + 1.0 VZ
8: DL - 0.4 HX + 0.4 HY - 1.0 VZ
9: DL + 0.4 HX + 0.4 HY - 1.0 VZ
10: DL - 1.0 HX + 0.4 HY -0.4 VZ
11: DL - 1.0 HX + 0.4 HY + 0.4 VZ
12: DL - 0.4 HX + 1.0 HY + 0.4 VZ

DL = Non-seismic loads which include wall and floor dead loads and 25% of floor design live loads. These loads are calculated in Ref. 2.2.5.
Note: Live load considered in combination with seismic loads is 25% of floor design live load per Ref. 2.2.12, Section 8.3.1.

6.3.2 Non Seismic Loads (DL)

The floor and wall dead loads are applied at center of mass of each floor. These loads are taken directly from calculation 200-SYC-RF00-00100-000-00A, Receipt Facility (RF) Mass Properties (Ref. 2.2.5, Table-Summary of Mass and Center of Mass). The center of mass nodes and corresponding loads are listed below.

Floor El.	Node	Load in –Z direction (Kips)
32'-0"	399	60166
64'-0"	599	36334
72'-0"	699	2819
100'-0"	799	6426

The self-weight of the basemat and first 16 ft of wall weight are applied as distributed element loads in the finite element model. The self-weight of these elements is accounted for by specifying unit weight, thickness, and gravity multipliers (-1.0 for vertical loads). The weight of the 16 ft wall is accounted for by specifying a weight modifier for wall elements. The heights of the two wall elements are 7 feet for the main basemat and 4 feet for the wings on east and west side, therefore weight modifier, of 16/7 =2.29 and 16/4 =4.00 is applied to the 4 ft and 2 ft thick wall elements respectively to include 16 ft height wall weights in 7 ft and 4 ft of element height.

These loads are combined with seismic loads to form combinations listed in Section 6.3.1

6.3.3 Seismic Loads

Floor level seismic loads are derived from accelerations extracted from the calculation 200-SYC-RF00-00400-000-00A, RF Seismic Analysis (Ref. 2.2.3).

The base level and floor level accelerations for 35' alluvium upper bound analysis case (Ref. 2.2.3 Attachment D) were used to calculate seismic loads. As demonstrated in Ref. 2.2.3 the upper bound 35' soil case was found to be the bounding seismic load condition.

In the following table, HX is the seismic load in X direction, HY is the seismic load in Y direction and VZ is the seismic load in Z direction.

Ux, Uy and Uz are joint accelerations in ft/sec^2 in X, Y, and Z directions respectively due to HX, HY and VZ. It is noted that because of eccentricities between the center of mass and center of rigidity, HX seismic loading produces accelerations in the X, Y, and Z directions. Similar behavior is seen for HY and VZ seismic loading.

Table 6.3.3.1 Design Basis in Structure Accelerations

35' Alluvium, Upper Bound HX Response Accelerations				
Floor El.	Node	Ux ft/sec^2	Uy ft/sec^2	Uz ft/sec^2
0'-0"	99	16.4695	0.7109	0.5657
32'-0"	399	22.9512	0.6026	0.5637
64'-0"	599	29.7089	0.7383	0.7614
72'-0"	699	31.2376	2.3853	4.9466
100'-0"	799	46.4974	3.8748	3.378

35' Alluvium, Upper Bound HY Response Accelerations				
Floor El.	Node	Ux ft/sec^2	Uy ft/sec^2	Uz ft/sec^2
0'-0"	99	0.7564	14.7307	0.1161
32'-0"	399	0.5879	22.1241	0.1387
64'-0"	599	0.7472	30.6566	0.206
72'-0"	699	1.2182	36.4698	0.282
100'-0"	799	2.3604	51.4414	0.2356

35' Alluvium, Upper Bound VZ Response Accelerations				
Floor El.	Node	Ux ft/sec^2	Uy ft/sec^2	Uz ft/sec^2
0'-0"	99	0.6221	0.1166	19.032
32'-0"	399	0.5204	0.1343	21.7175
64'-0"	599	0.5137	0.1238	23.1706
72'-0"	699	0.5398	0.1810	22.6058
100'-0"	799	1.1775	0.3061	25.2941

Source: Attachment D (Ref. 2.2.3)

The seismic load at each joint is calculated from the joint dead load listed above and converting it to mass and then multiplying by the acceleration. (F= m*a)

Example Calculation:

- Determine seismic load due to HX at joint 799.
  Dead load at joint 799 = 6426 kips and g =32.2 ft/sec^2 (Acceleration due to gravity)
- Mass at 799 = 6426/ 32.2 =199.57 kip-sec^2/ft
  Joint load in X direction due to HX = Mass at 799* acceleration in X direction
- Joint Load in X direction due to HX = 199.57 *Ux
  = 199.57*46.4974 =9279.5 kips
- Joint Load in Y direction due to HX = 199.57 *Uy
  =199.57 * 3.8748 =773.3 kips
- Joint Load in Z direction due to HX = 199.57 *Uz
  =199.57 *3.378 =674.15 kips

Similar joint loads due to seismic load in X; Y and Z direction are calculated and presented in the following table.

Also, the Seismic load due to basemat weight and first 16 ft of wall will be distributed to each area element by using gravity multipliers in SAP2000 area element load input. Gravity multiplier is derived by dividing tabulated accelerations at floor elevation 0.0 ft (Joint 99) by acceleration due to gravity (32.2 ft/sec^2).

Example: Gravity multipliers for basemat and wall elements due to HY

- X direction = 0.7564 /32.2 = 0.0235
- Y direction = 14.7307 /32.2 = 0.4575
- Z direction = 0.1161 /32.2 = 0.0036

These results are also presented in the next table.

Table 6.3.3.2 Equivalent Static Seismic Loads

HX Response Loads			
	Area Element Gravity Multiplier		
	X direction	Y direction	Z direction
	0.5115	0.0221	0.0176
		Joint Loads (kips)	
Joint	X direction	Y direction	Z direction
399	42885	1126	1053
599	33523	833	859
699	2735	209	433
799	9279	773	674

HY Response Loads			
	Area Element Gravity Multiplier		
	X direction	Y direction	Z direction
	0.0235	0.4575	0.0036
		Joint Loads (kips)	
Joint	X direction	Y direction	Z direction
399	1098	41339	259
599	843	34592	232
699	107	3193	25
799	471	10266	47

VZ Response Loads			
	Area Element Gravity Multiplier		
	X direction	Y direction	Z direction
	0.0193	0.0036	0.5911
		Joint Loads (kips)	
Joint	X direction	Y direction	Z direction
399	972	251	40579
599	580	140	26145
699	47	16	1979
799	235	61	5048

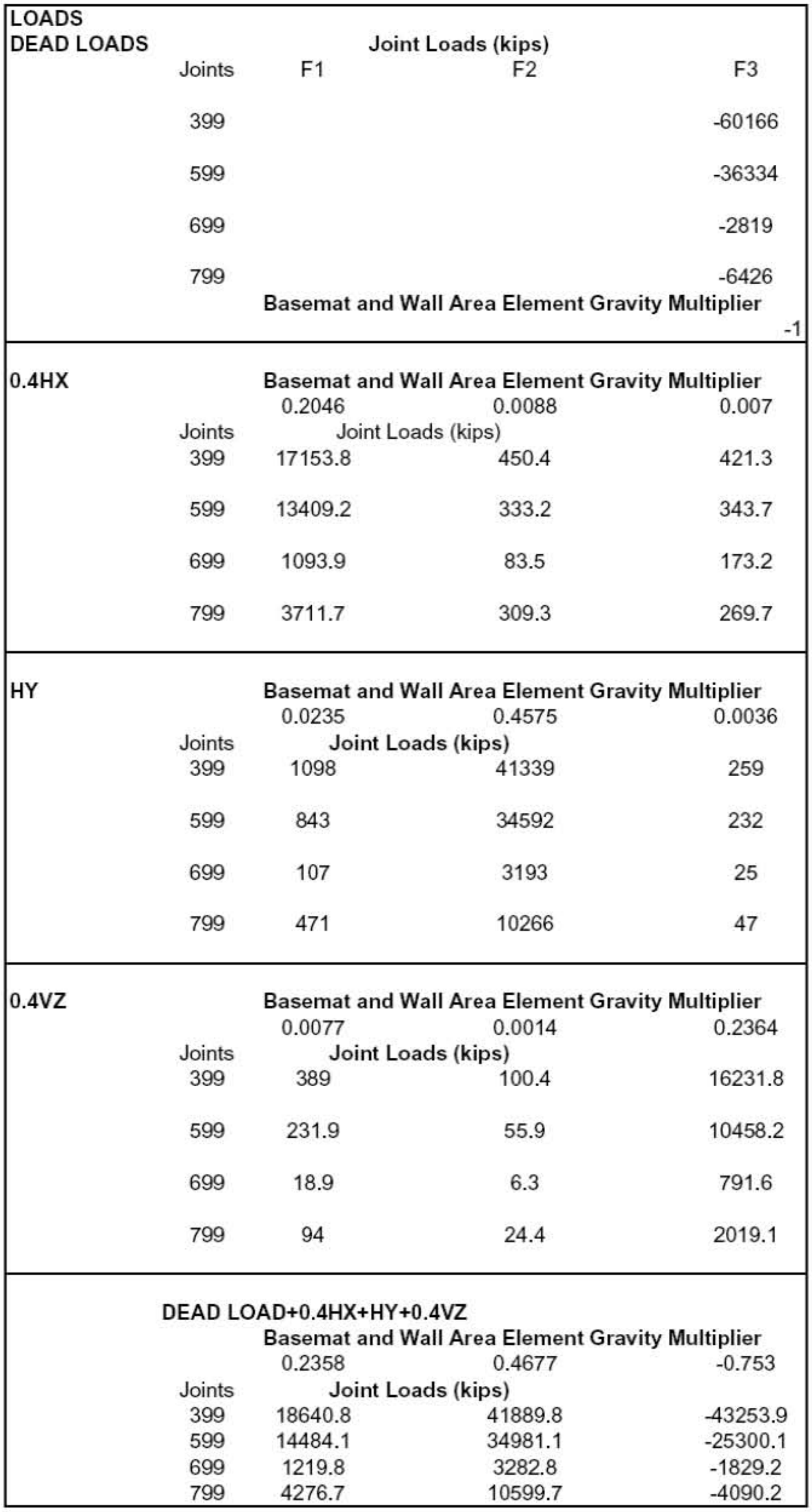
6.3.4 Load Combinations

From dead load and seismic loads twelve combinations as described in Section 6.3.1 are developed by simple additions as shown in the following tables. These joint loads and gravity multipliers were directly input as nonlinear load cases in SAP2000 foundation model.

Table 6.3.4.1 Combination 1 DL+HX+0.4HY+0.4VZ

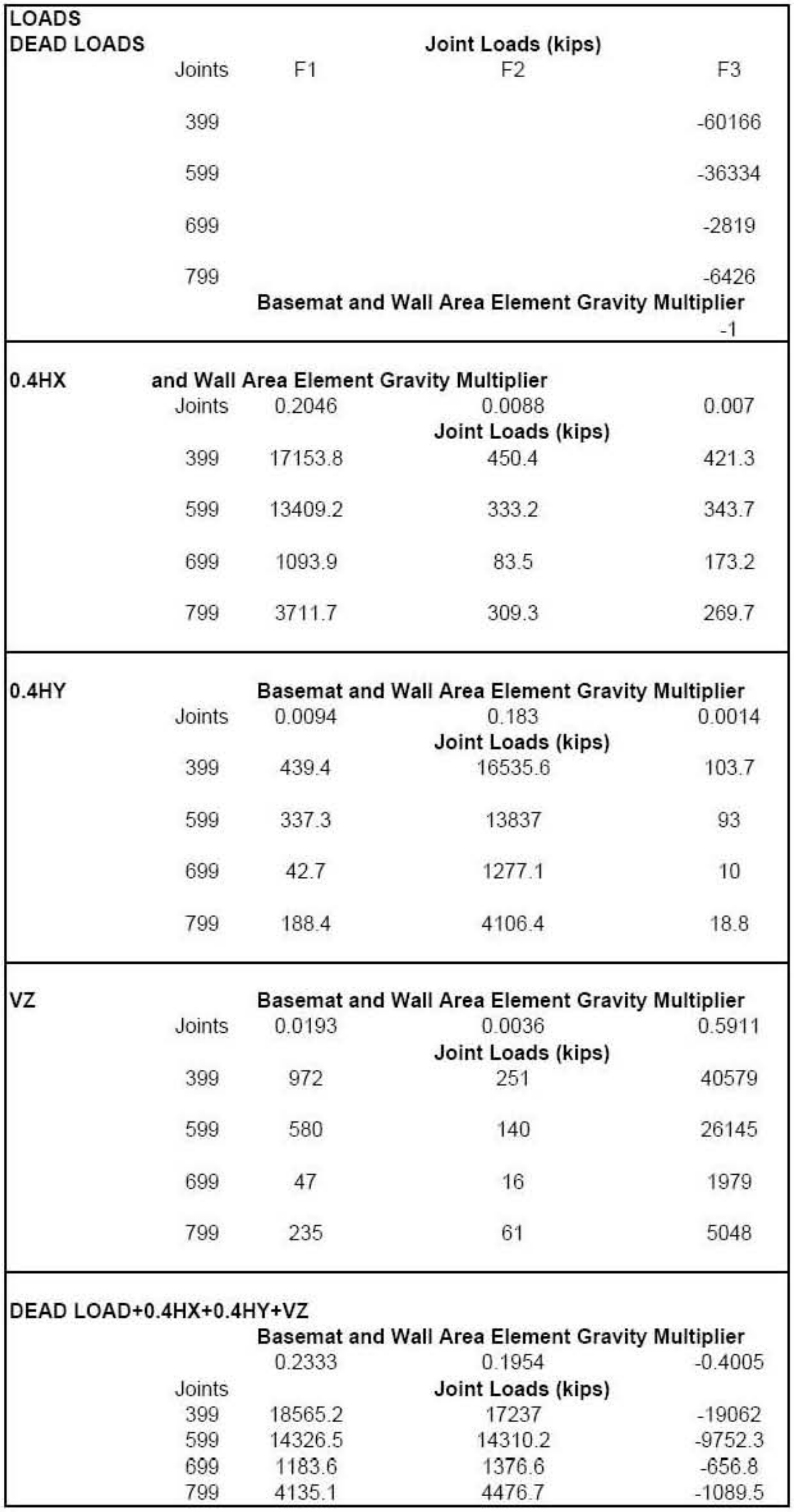
LOADS				
DEAD LOADS			**Joint Loads (kips)**	
	Joints	F1	F2	F3
	399			-60166
	599			-36334
	699			-2819
	799			-6426
		Basemat and Wall Area Element Gravity Multiplier		
				-1
HX		**Basemat and Wall Area Element Gravity Multiplier**		
		0.5115	0.0221	0.0176
	Joints		**Joint Loads (kips)**	
	399	42885	1126	1053
	599	33523	833	859
	699	2735	209	433
	799	9279	773	674
0.4HY		**Basemat and Wall Area Element Gravity Multiplier**		
		0.0094	0.183	0.0014
	Joints		**Joint Loads (kips)**	
	399	439.4	16535.6	103.7
	599	337.3	13837	93
	699	42.7	1277.1	10
	799	188.4	4106.4	18.8
0.4VZ		**Basemat and Wall Area Element Gravity Multiplier**		
		0.0077	0.0014	0.2364
	Joints		**Joint Loads (kips)**	
	399	389	100.4	16231.8
	599	231.9	55.9	10458.2
	699	18.9	6.3	791.6
	799	94	24.4	2019.1
DEAD LOAD +HX +0.4HY +0.4VZ				
		Basemat and Wall Area Element Gravity Multiplier		
		0.5286	0.2065	-0.7446
	Joints		**Joint Loads (kips)**	
	399	43713.4	17762	-42777.5
	599	34092.2	14725.9	-24923.8
	699	2796.6	1492.4	-1584.4
	799	9561.4	4903.8	-3714.1

Table 6.3.4.2 Combination 2 DL+0.4HX+HY+0.4VZ



LOADS				
DEAD LOADS			**Joint Loads (kips)**	
	Joints	F1	F2	F3
	399			-60166
	599			-36334
	699			-2819
	799			-6426
		Basemat and Wall Area Element Gravity Multiplier		
				-1
0.4HX		**Basemat and Wall Area Element Gravity Multiplier**		
		0.2046	0.0088	0.007
	Joints	Joint Loads (kips)		
	399	17153.8	450.4	421.3
	599	13409.2	333.2	343.7
	699	1093.9	83.5	173.2
	799	3711.7	309.3	269.7
HY		**Basemat and Wall Area Element Gravity Multiplier**		
		0.0235	0.4575	0.0036
	Joints	**Joint Loads (kips)**		
	399	1098	41339	259
	599	843	34592	232
	699	107	3193	25
	799	471	10266	47
0.4VZ		**Basemat and Wall Area Element Gravity Multiplier**		
		0.0077	0.0014	0.2364
	Joints	**Joint Loads (kips)**		
	399	389	100.4	16231.8
	599	231.9	55.9	10458.2
	699	18.9	6.3	791.6
	799	94	24.4	2019.1
	DEAD LOAD+0.4HX+HY+0.4VZ			
		Basemat and Wall Area Element Gravity Multiplier		
		0.2358	0.4677	-0.753
	Joints	**Joint Loads (kips)**		
	399	18640.8	41889.8	-43253.9
	599	14484.1	34981.1	-25300.1
	699	1219.8	3282.8	-1829.2
	799	4276.7	10599.7	-4090.2

Table 6.3.4.3 Combination 3 DL+0.4HX+0.4HY+VZ

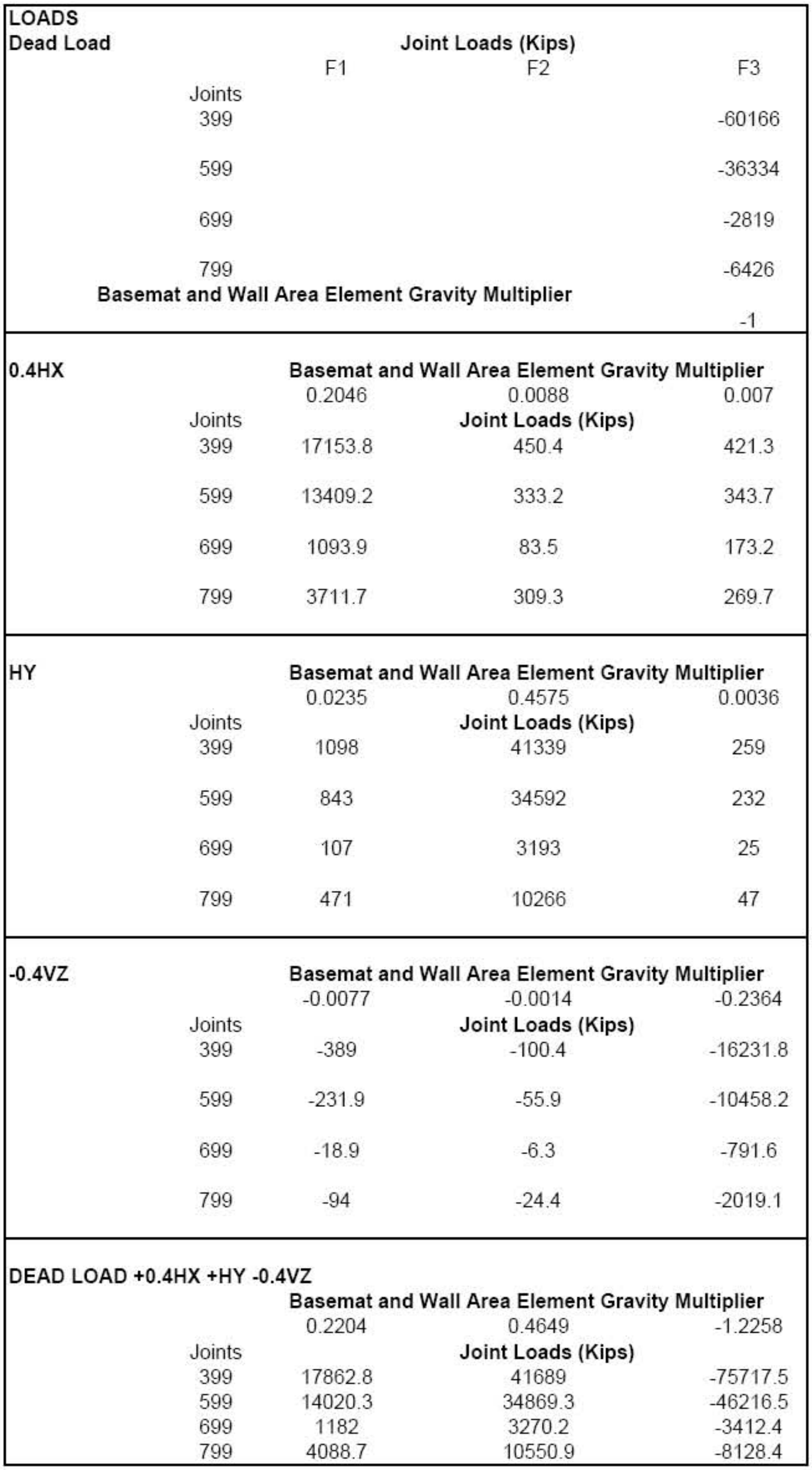


LOADS				
DEAD LOADS			**Joint Loads (kips)**	
	Joints	F1	F2	F3
	399			-60166
	599			-36334
	699			-2819
	799			-6426
		Basemat and Wall Area Element Gravity Multiplier		
				-1
0.4HX	**and Wall Area Element Gravity Multiplier**			
	Joints	0.2046	0.0088	0.007
			Joint Loads (kips)	
	399	17153.8	450.4	421.3
	599	13409.2	333.2	343.7
	699	1093.9	83.5	173.2
	799	3711.7	309.3	269.7
0.4HY		**Basemat and Wall Area Element Gravity Multiplier**		
	Joints	0.0094	0.183	0.0014
			Joint Loads (kips)	
	399	439.4	16535.6	103.7
	599	337.3	13837	93
	699	42.7	1277.1	10
	799	188.4	4106.4	18.8
VZ		**Basemat and Wall Area Element Gravity Multiplier**		
	Joints	0.0193	0.0036	0.5911
			Joint Loads (kips)	
	399	972	251	40579
	599	580	140	26145
	699	47	16	1979
	799	235	61	5048
DEAD LOAD+0.4HX+0.4HY+VZ				
		Basemat and Wall Area Element Gravity Multiplier		
		0.2333	0.1954	-0.4005
	Joints		**Joint Loads (kips)**	
	399	18565.2	17237	-19062
	599	14326.5	14310.2	-9752.3
	699	1183.6	1376.6	-656.8
	799	4135.1	4476.7	-1089.5

Table 6.3.4.4 Combination 4 DL+HX+0.4HY-0.4VZ

LOADS			
Dead Load		**Joint Loads (Kips)**	
Joints	F1	F2	F3
399			-60166
599			-36334
699			-2819
799			-6426
Basemat and Wall Area Element Gravity Multiplier			-1
HX		**Basemat and Wall Area Element Gravity Multiplier**	
	0.5115	0.0221	0.0176
Joints		**Joint Loads (Kips)**	
399	42885	1126	1053
599	33523	833	859
699	2735	209	433
799	9279	773	674
0.4HY		**Basemat and Wall Area Element Gravity Multiplier**	
	0.0094	0.183	0.0014
Joints		**Joint Loads (Kips)**	
399	439.4	16535.6	103.7
599	337.3	13837	93
699	42.7	1277.1	10
799	188.4	4106.4	18.8
-0.4VZ		**Basemat and Wall Area Element Gravity Multiplier**	
	-0.0077	-0.0014	-0.2364
Joints		**Joint Loads (Kips)**	
399	-389	-100.4	-16231.8
599	-231.9	-55.9	-10458.2
699	-18.9	-6.3	-791.6
799	-94	-24.4	-2019.1
DEAD LOAD +HX +0.4HY -0.4VZ			
		Basemat and Wall Area Element Gravity Multiplier	
	0.5132	0.2037	-1.2174
Joints		**Joint Loads (Kips)**	
399	42935.4	17561.2	-75241.1
599	33628.4	14614.1	-45840.2
699	2758.8	1479.8	-3167.6
799	9373.4	4855	-7752.3

Table 6.3.4.5 Combination 5 DL+0.4HX+HY-0.4VZ

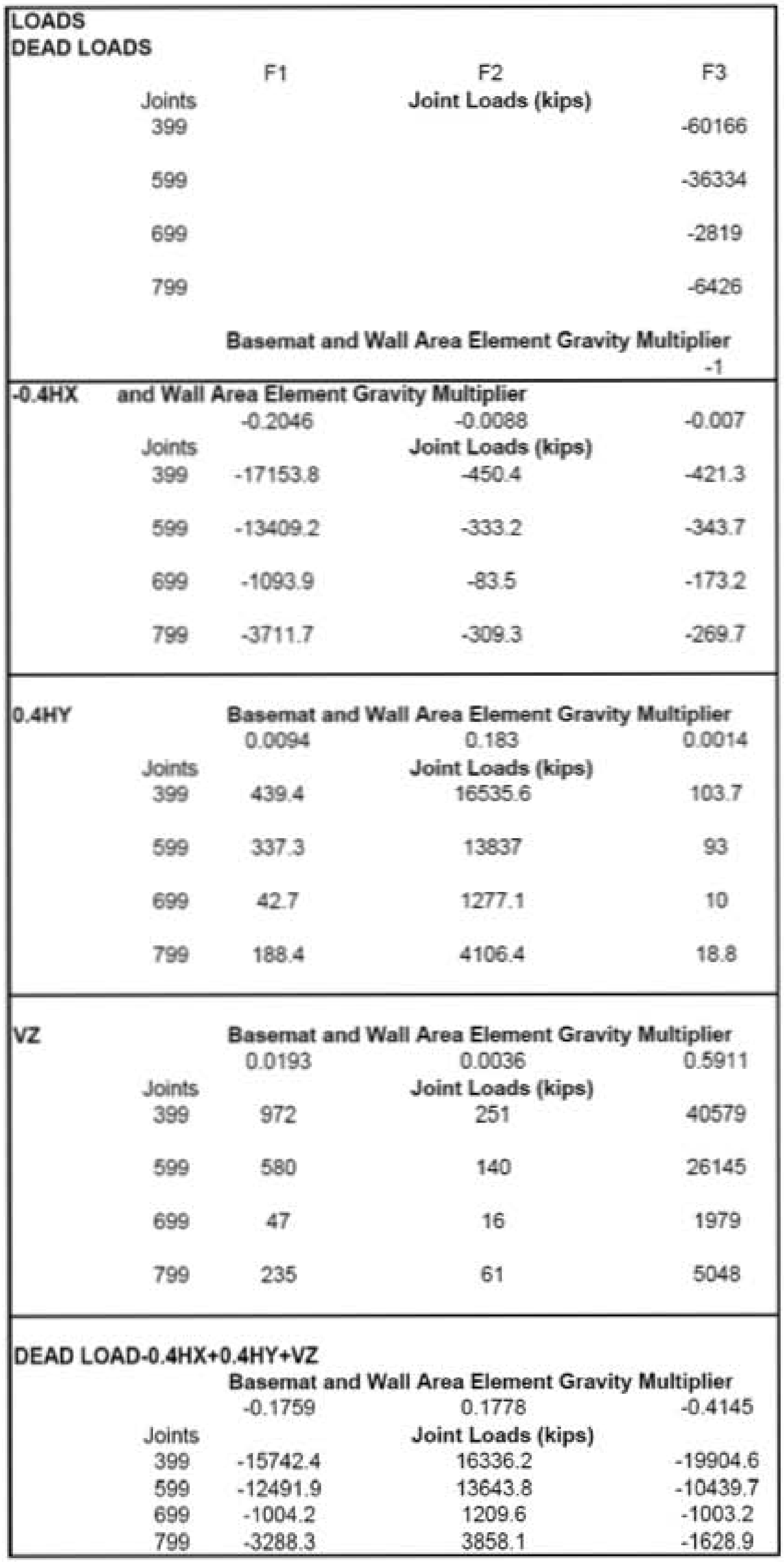


LOADS				
Dead Load			**Joint Loads (Kips)**	
		F1	F2	F3
	Joints			
	399			-60166
	599			-36334
	699			-2819
	799			-6426
	Basemat and Wall Area Element Gravity Multiplier			
				-1
0.4HX		**Basemat and Wall Area Element Gravity Multiplier**		
		0.2046	0.0088	0.007
	Joints		**Joint Loads (Kips)**	
	399	17153.8	450.4	421.3
	599	13409.2	333.2	343.7
	699	1093.9	83.5	173.2
	799	3711.7	309.3	269.7
HY		**Basemat and Wall Area Element Gravity Multiplier**		
		0.0235	0.4575	0.0036
	Joints		**Joint Loads (Kips)**	
	399	1098	41339	259
	599	843	34592	232
	699	107	3193	25
	799	471	10266	47
-0.4VZ		**Basemat and Wall Area Element Gravity Multiplier**		
		-0.0077	-0.0014	-0.2364
	Joints		**Joint Loads (Kips)**	
	399	-389	-100.4	-16231.8
	599	-231.9	-55.9	-10458.2
	699	-18.9	-6.3	-791.6
	799	-94	-24.4	-2019.1
DEAD LOAD +0.4HX +HY -0.4VZ				
		Basemat and Wall Area Element Gravity Multiplier		
		0.2204	0.4649	-1.2258
	Joints		**Joint Loads (Kips)**	
	399	17862.8	41689	-75717.5
	599	14020.3	34869.3	-46216.5
	699	1182	3270.2	-3412.4
	799	4088.7	10550.9	-8128.4

Table 6.3.4.6 Combination 6 DL-0.4HX+HY-0.4VZ

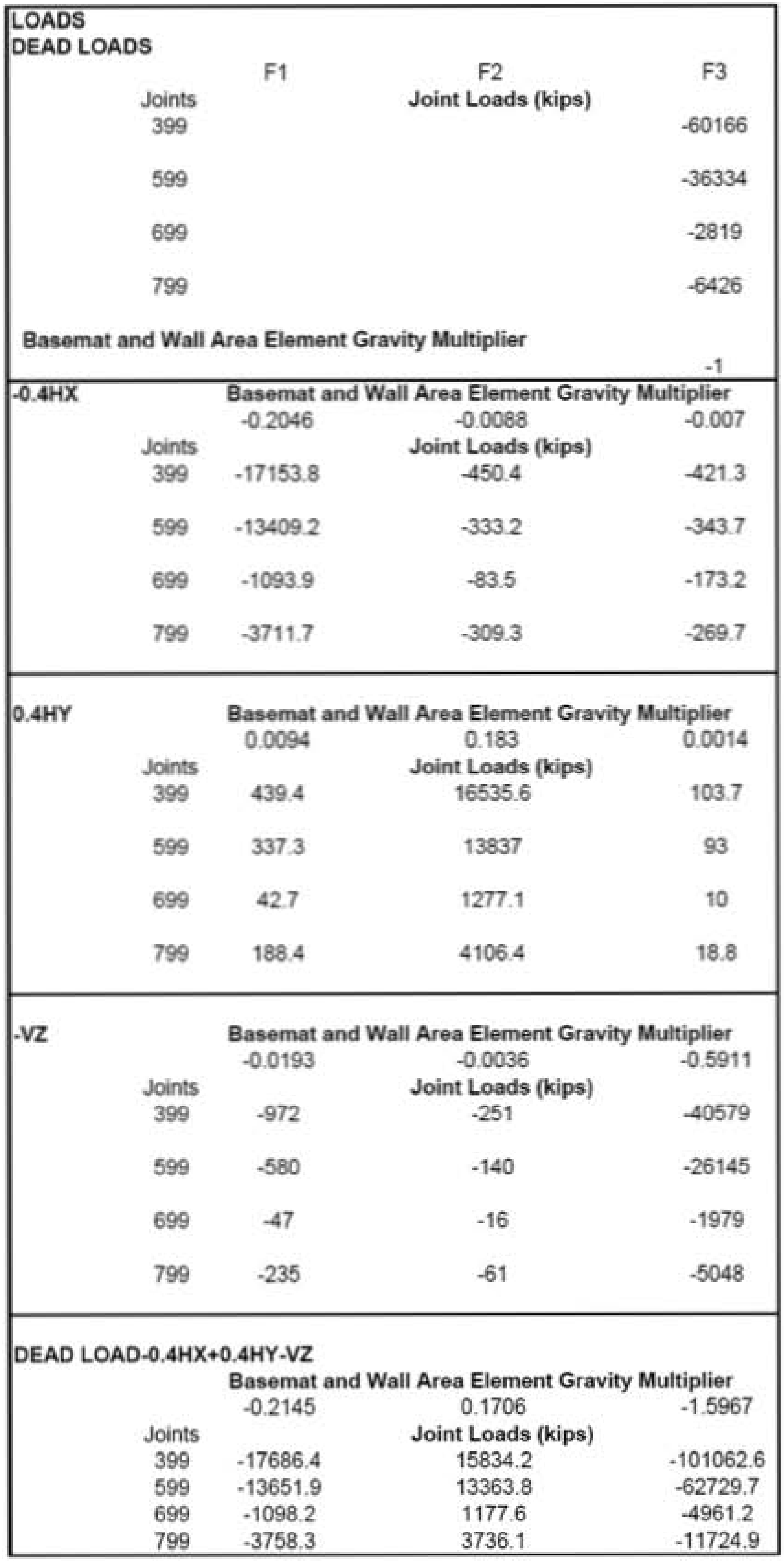
LOADS				
Dead Load			**Joint Loads (Kips)**	
		F1	F2	F3
	Joints		**Joint Loads (Kips)**	
	399			-60166
	599			-36334
	699			-2819
	799			-6426
		Basemat and Wall Area Element Gravity Multiplier		
				-1
-0.4HX		**Basemat and Wall Area Element Gravity Multiplier**		
		-0.2046	-0.0088	-0.007
	Joints		**Joint Loads (Kips)**	
	399	-17153.8	-450.4	-421.3
	599	-13409.2	-333.2	-343.7
	699	-1093.9	-83.5	-173.2
	799	-3711.7	-309.3	-269.7
HY		**Basemat and Wall Area Element Gravity Multiplier**		
		0.0235	0.4575	0.0036
	Joints		**Joint Loads (Kips)**	
	399	1098	41339	259
	599	843	34592	232
	699	107	3193	25
	799	471	10266	47
-0.4VZ		**Basemat and Wall Area Element Gravity Multiplier**		
		-0.0077	-0.0014	-0.2364
	Joints		**Joint Loads (Kips)**	
	399	-389	-100.4	-16231.8
	599	-231.9	-55.9	-10458.2
	699	-18.9	-6.3	-791.6
	799	-94	-24.4	-2019.1
DEAD LOAD -0.4HX +HY -0.4VZ				
		Basemat and Wall Area Element Gravity Multiplier		
		-0.1888	0.4473	-1.2398
	Joints		**Joint Loads (Kips)**	
	399	-16444.8	40788.2	-76560.1
	599	-12798.1	34202.9	-46903.9
	699	-1005.8	3103.2	-3758.8
	799	-3334.7	9932.3	-8667.8

Table 6.3.4.7 Combination 7 DL-0.4HX+0.4HY+VZ



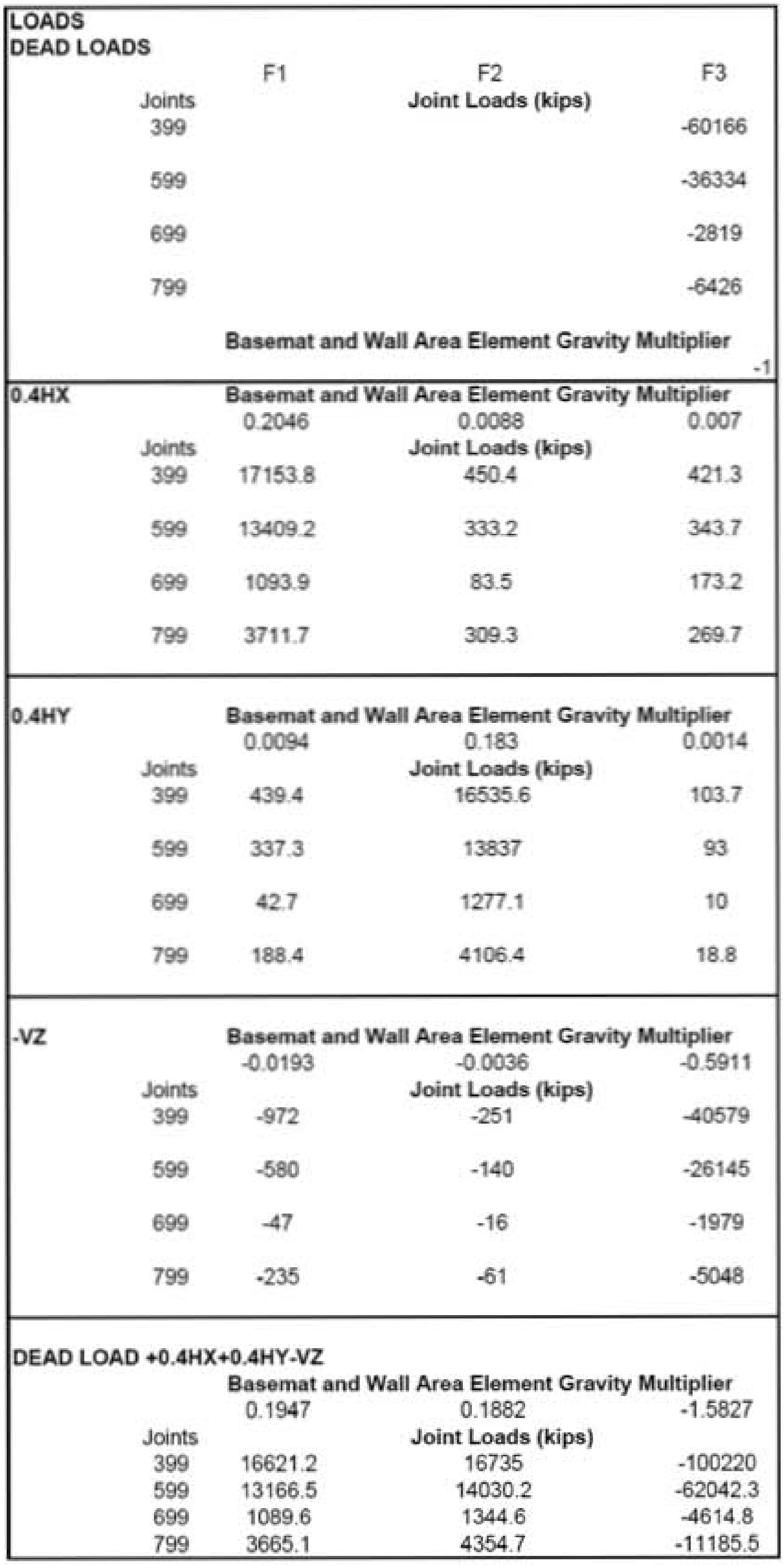
LOADS				
DEAD LOADS				
		F1	F2	F3
	Joints		**Joint Loads (kips)**	
	399			-60166
	599			-36334
	699			-2819
	799			-6426
			Basemat and Wall Area Element Gravity Multiplier	
				-1
-0.4HX		**and Wall Area Element Gravity Multiplier**		
		-0.2046	-0.0088	-0.007
	Joints		**Joint Loads (kips)**	
	399	-17153.8	-450.4	-421.3
	599	-13409.2	-333.2	-343.7
	699	-1093.9	-83.5	-173.2
	799	-3711.7	-309.3	-269.7
0.4HY			**Basemat and Wall Area Element Gravity Multiplier**	
		0.0094	0.183	0.0014
	Joints		**Joint Loads (kips)**	
	399	439.4	16535.6	103.7
	599	337.3	13837	93
	699	42.7	1277.1	10
	799	188.4	4106.4	18.8
VZ			**Basemat and Wall Area Element Gravity Multiplier**	
		0.0193	0.0036	0.5911
	Joints		**Joint Loads (kips)**	
	399	972	251	40579
	599	580	140	26145
	699	47	16	1979
	799	235	61	5048
DEAD LOAD-0.4HX+0.4HY+VZ				
			Basemat and Wall Area Element Gravity Multiplier	
		-0.1759	0.1778	-0.4145
	Joints		**Joint Loads (kips)**	
	399	-15742.4	16336.2	-19904.6
	599	-12491.9	13643.8	-10439.7
	699	-1004.2	1209.6	-1003.2
	799	-3288.3	3858.1	-1628.9

Table 6.3.4.8 Combination 8 DL-0.4HX+0.4HY –VZ



		F1	F2	F3
LOADS				
DEAD LOADS				
	Joints		**Joint Loads (kips)**	
	399			-60166
	599			-36334
	699			-2819
	799			-6426
Basemat and Wall Area Element Gravity Multiplier				-1
-0.4HX		**Basemat and Wall Area Element Gravity Multiplier**		
		-0.2046	-0.0088	-0.007
	Joints		**Joint Loads (kips)**	
	399	-17153.8	-450.4	-421.3
	599	-13409.2	-333.2	-343.7
	699	-1093.9	-83.5	-173.2
	799	-3711.7	-309.3	-269.7
0.4HY		**Basemat and Wall Area Element Gravity Multiplier**		
		0.0094	0.183	0.0014
	Joints		**Joint Loads (kips)**	
	399	439.4	16535.6	103.7
	599	337.3	13837	93
	699	42.7	1277.1	10
	799	188.4	4106.4	18.8
-VZ		**Basemat and Wall Area Element Gravity Multiplier**		
		-0.0193	-0.0036	-0.5911
	Joints		**Joint Loads (kips)**	
	399	-972	-251	-40579
	599	-580	-140	-26145
	699	-47	-16	-1979
	799	-235	-61	-5048
DEAD LOAD-0.4HX+0.4HY-VZ				
		Basemat and Wall Area Element Gravity Multiplier		
		-0.2145	0.1706	-1.5967
	Joints		**Joint Loads (kips)**	
	399	-17686.4	15834.2	-101062.6
	599	-13651.9	13363.8	-62729.7
	699	-1098.2	1177.6	-4961.2
	799	-3758.3	3736.1	-11724.9

Table 6.3.4.9 Combination 9 DL+0.4HX+0.4HY-VZ

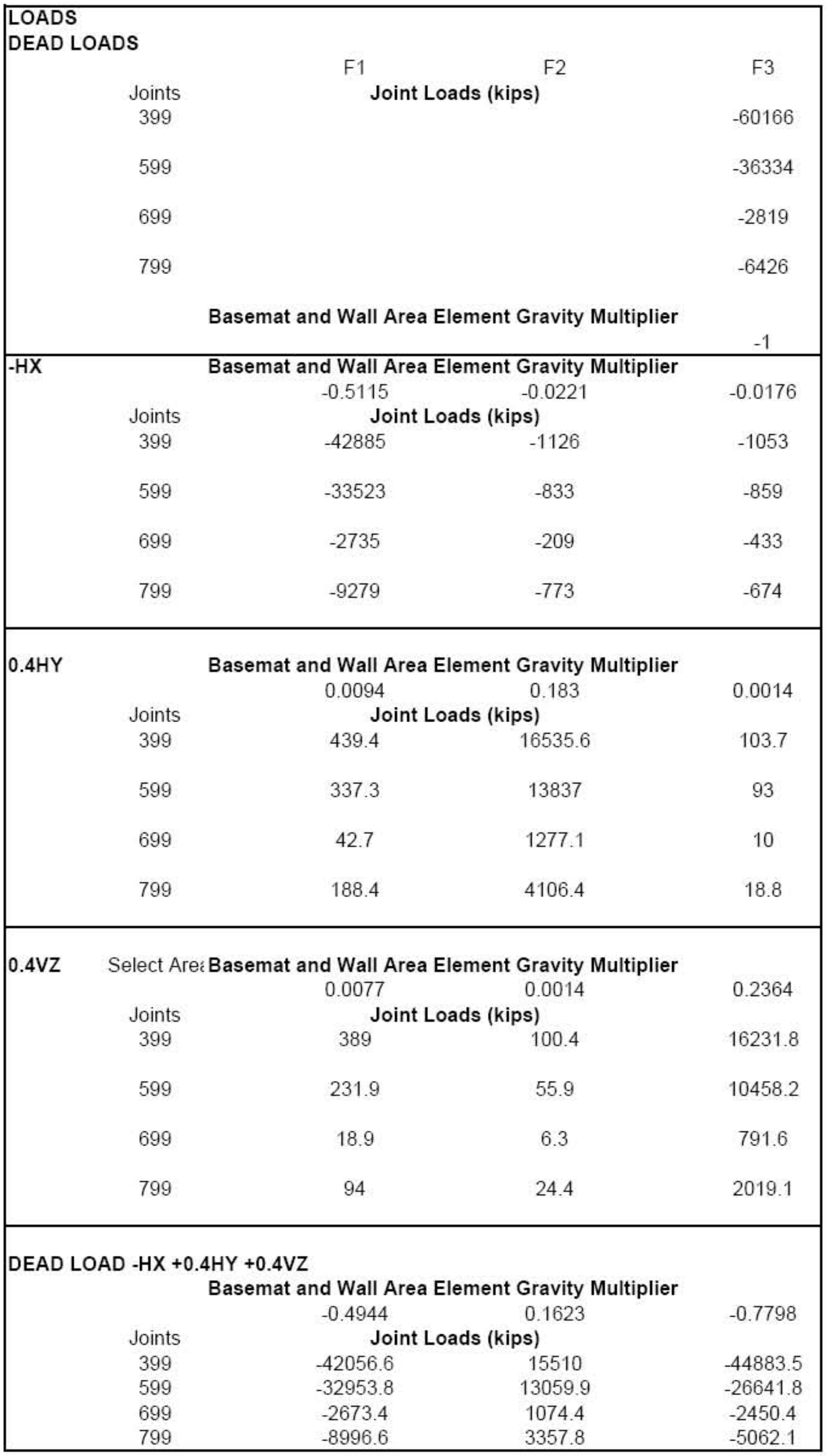


		F1	F2	F3
LOADS				
DEAD LOADS				
	Joints		**Joint Loads (kips)**	
	399			-60166
	599			-36334
	699			-2819
	799			-6426
			Basemat and Wall Area Element Gravity Multiplier	
				-1
0.4HX			**Basemat and Wall Area Element Gravity Multiplier**	
		0.2046	0.0088	0.007
	Joints		**Joint Loads (kips)**	
	399	17153.8	450.4	421.3
	599	13409.2	333.2	343.7
	699	1093.9	83.5	173.2
	799	3711.7	309.3	269.7
0.4HY			**Basemat and Wall Area Element Gravity Multiplier**	
		0.0094	0.183	0.0014
	Joints		**Joint Loads (kips)**	
	399	439.4	16535.6	103.7
	599	337.3	13837	93
	699	42.7	1277.1	10
	799	188.4	4106.4	18.8
-VZ			**Basemat and Wall Area Element Gravity Multiplier**	
		-0.0193	-0.0036	-0.5911
	Joints		**Joint Loads (kips)**	
	399	-972	-251	-40579
	599	-580	-140	-26145
	699	-47	-16	-1979
	799	-235	-61	-5048
DEAD LOAD +0.4HX+0.4HY-VZ				
			Basemat and Wall Area Element Gravity Multiplier	
		0.1947	0.1882	-1.5827
	Joints		**Joint Loads (kips)**	
	399	16621.2	16735	-100220
	599	13166.5	14030.2	-62042.3
	699	1089.6	1344.6	-4614.8
	799	3665.1	4354.7	-11185.5

Table 6.3.4.10 Combination 10 DL-HX+0.4HY–0.4VZ

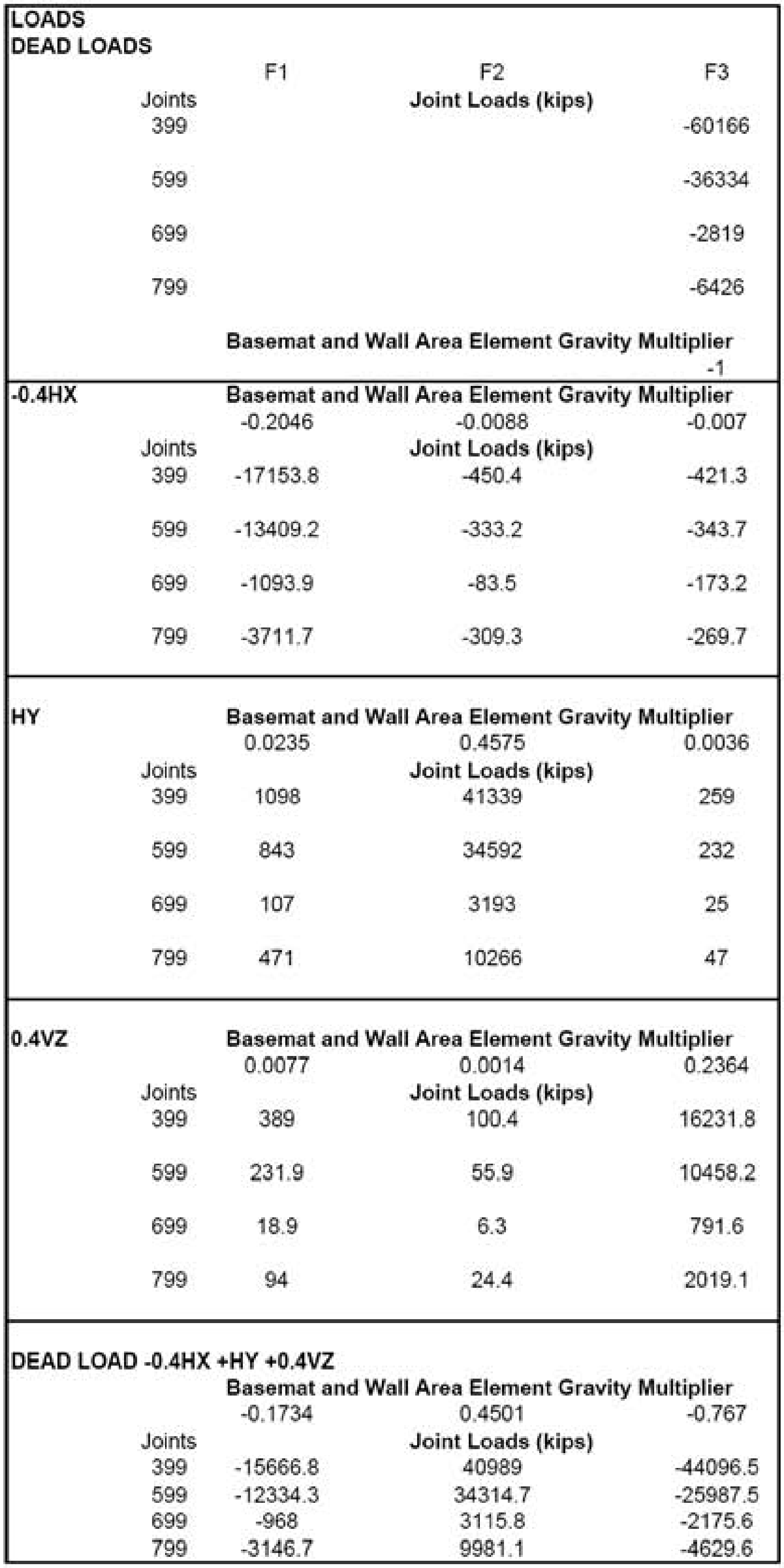
LOADS				
DEAD LOADS				
		F1	F2	F3
	Joints	**Joint Loads (kips)**		
	399			-60166
	599			-36334
	699			-2819
	799			-6426
		Basemat and Wall Area Element Gravity Multiplier		
				-1
-HX		**Basemat and Wall Area Element Gravity Multiplier**		
		-0.5115	-0.0221	-0.0176
	Joint	**Joint Loads (kips)**		
	399	-42885	-1126	-1053
	599	-33523	-833	-859
	699	-2735	-209	-433
	799	-9279	-773	-674
0.4HY		**Basemat and Wall Area Element Gravity Multiplier**		
		0.0094	0.183	0.0014
	Joint	**Joint Loads (kips)**		
	399	439.4	16535.6	103.7
	599	337.3	13837	93
	699	42.7	1277.1	10
	799	188.4	4106.4	18.8
-0.4VZ		**Basemat and Wall Area Element Gravity Multiplier**		
		-0.0077	-0.0014	-0.2364
	Joint	**Joint Loads (kips)**		
	399	-389	-100.4	-16231.8
	599	-231.9	-55.9	-10458.2
	699	-18.9	-6.3	-791.6
	799	-94	-24.4	-2019.1
DEAD LOAD -HX +0.4HY -0.4VZ				
		Basemat and Wall Area Element Gravity Multiplier		
		-0.5098	0.1595	-1.2526
	Joint		**Joint Loads (kips)**	
	399	-42834.6	15309.2	-77347.1
	599	-33417.6	12948.1	-47558.2
	699	-2711.2	1061.8	-4033.6
	799	-9184.6	3309	-9100.3

Table 6.3.4.11 Combination 11 DL-HX+0.4HY+0.4VZ



LOADS				
DEAD LOADS				
		F1	F2	F3
	Joints	**Joint Loads (kips)**		
	399			-60166
	599			-36334
	699			-2819
	799			-6426
		Basemat and Wall Area Element Gravity Multiplier		
				-1
-HX		**Basemat and Wall Area Element Gravity Multiplier**		
		-0.5115	-0.0221	-0.0176
	Joints	**Joint Loads (kips)**		
	399	-42885	-1126	-1053
	599	-33523	-833	-859
	699	-2735	-209	-433
	799	-9279	-773	-674
0.4HY		**Basemat and Wall Area Element Gravity Multiplier**		
		0.0094	0.183	0.0014
	Joints	**Joint Loads (kips)**		
	399	439.4	16535.6	103.7
	599	337.3	13837	93
	699	42.7	1277.1	10
	799	188.4	4106.4	18.8
0.4VZ	Select Are	**Basemat and Wall Area Element Gravity Multiplier**		
		0.0077	0.0014	0.2364
	Joints	**Joint Loads (kips)**		
	399	389	100.4	16231.8
	599	231.9	55.9	10458.2
	699	18.9	6.3	791.6
	799	94	24.4	2019.1
DEAD LOAD -HX +0.4HY +0.4VZ				
		Basemat and Wall Area Element Gravity Multiplier		
		-0.4944	0.1623	-0.7798
	Joints	**Joint Loads (kips)**		
	399	-42056.6	15510	-44883.5
	599	-32953.8	13059.9	-26641.8
	699	-2673.4	1074.4	-2450.4
	799	-8996.6	3357.8	-5062.1

Table 6.3.4.12 Combination 12 DL-0.4HX+HY+0.4VZ

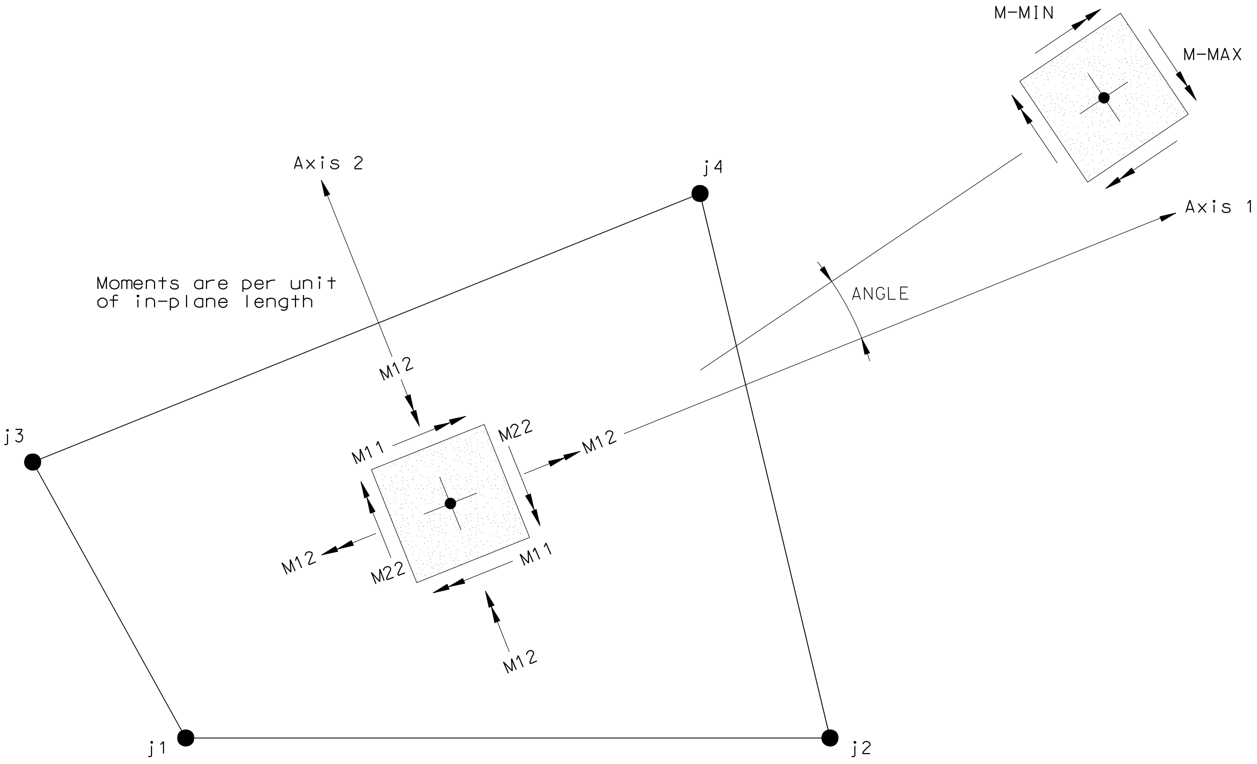


LOADS				
DEAD LOADS				
		F1	F2	F3
	Joints		**Joint Loads (kips)**	
	399			-60166
	599			-36334
	699			-2819
	799			-6426
		Basemat and Wall Area Element Gravity Multiplier		
				-1
-0.4HX		**Basemat and Wall Area Element Gravity Multiplier**		
		-0.2046	-0.0088	-0.007
	Joints		**Joint Loads (kips)**	
	399	-17153.8	-450.4	-421.3
	599	-13409.2	-333.2	-343.7
	699	-1093.9	-83.5	-173.2
	799	-3711.7	-309.3	-269.7
HY		**Basemat and Wall Area Element Gravity Multiplier**		
		0.0235	0.4575	0.0036
	Joints		**Joint Loads (kips)**	
	399	1098	41339	259
	599	843	34592	232
	699	107	3193	25
	799	471	10266	47
0.4VZ		**Basemat and Wall Area Element Gravity Multiplier**		
		0.0077	0.0014	0.2364
	Joints		**Joint Loads (kips)**	
	399	389	100.4	16231.8
	599	231.9	55.9	10458.2
	699	18.9	6.3	791.6
	799	94	24.4	2019.1
DEAD LOAD -0.4HX +HY +0.4VZ				
		Basemat and Wall Area Element Gravity Multiplier		
		-0.1734	0.4501	-0.767
	Joints		**Joint Loads (kips)**	
	399	-15666.8	40989	-44096.5
	599	-12334.3	34314.7	-25987.5
	699	-968	3115.8	-2175.6
	799	-3146.7	9981.1	-4629.6

6.4 SAP2000 ANALYSIS RESULTS

6.4.1 Bending Moments and Shear Forces in Foundation Mat

Stress contour plots for the Four Corners of the basemat are included in Attachment B. The contour plots represent the bending moments M11 (along X-axis) and M22 (along Y-axis), twisting moment M12, and shear forces V13 (along X-axis) and V23 (along Y-axis). For further information on the definitions of M11, M22, M12, V13, and V23, refer to Figure 6.4.1 and Figure 6.4.2.



Axis 3 is out of the paper

Figure 6.4.1. Shell Element Bending and Twisting Moments

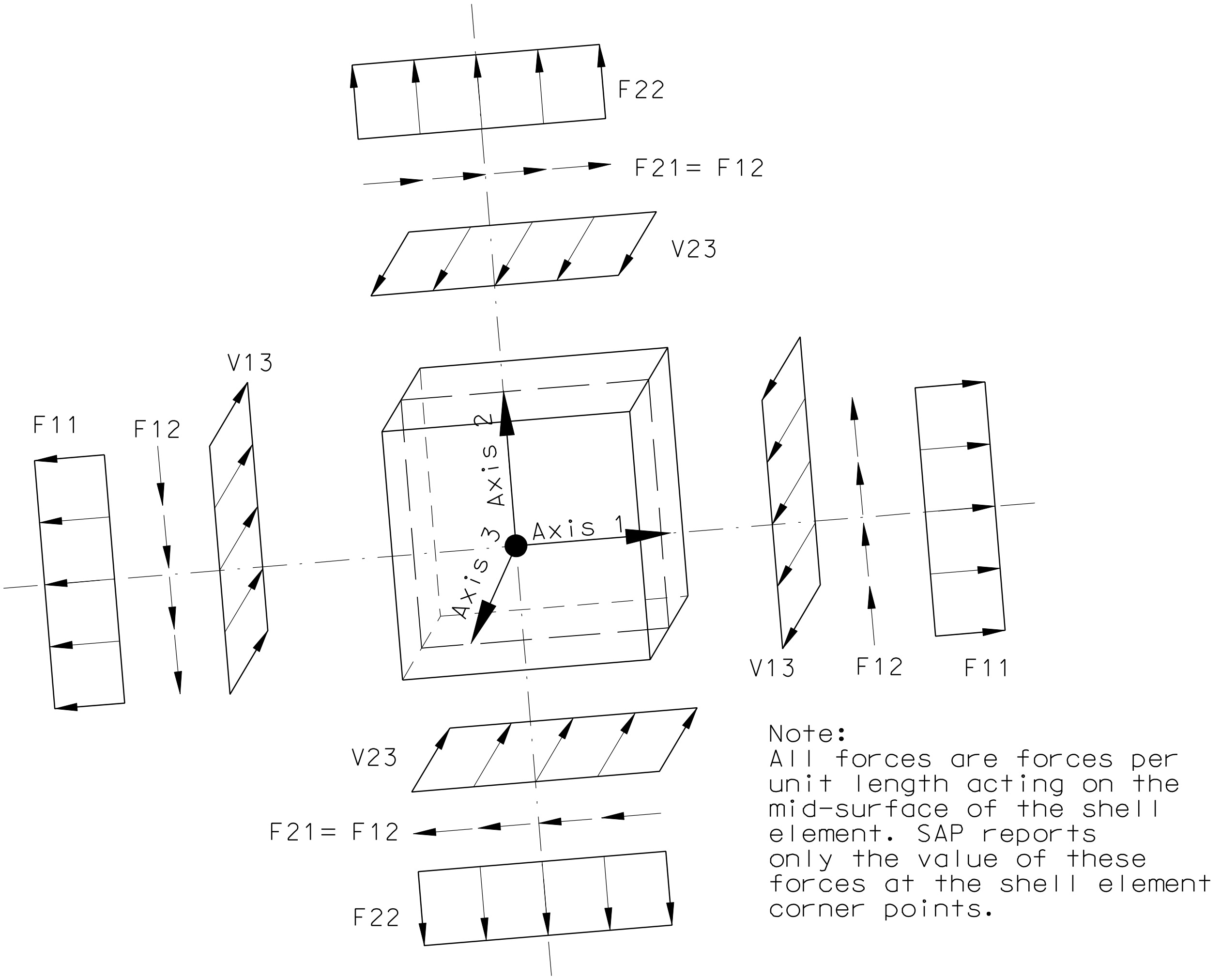


Figure 6.4.2. Shell Element Membrane and Shear Forces

The SAP2000 contour plots included in Attachment D have shear force V23 designated as Vmax and V13 designated as V23. This can be verified by comparing the values of element forces listed for each load combination in Attachment C to the values on the force contour plots.

SAP2000 stress averaging at joints is used to smooth the contour plots. The maximum moment and shear values are derived graphically by visual inspection of the force contours (See assumption 3.2.2).

6.4.2 Maximum Bearing Pressure on Basemat

The Maximum bearing pressure on the mat is determined by dividing the maximum link element reaction force by the tributary area of the link. The maximum link reaction at (link #2jt-12008) the north east corner of the mat is 236.3 kips under load case 5. Therefore the maximum bearing pressure on the mat = 236.3 kips / 23.2 ft^2 = 10.2 kips per square foot, which is less than bearing capacity of 50 ksf for large foundation mat (Ref. 2.2.12, Section 6.2.3).

6.5 REINFORCING DESIGN

The project design criteria document (Reference 2.2.1, Section 4.2.11.6.2) specifies a concrete compressive strength f'_c of 4,000 psi or 5,000 psi for design of surface facilities. A concrete strength of 5,000 psi is used for the design and analysis of the RF structure (Ref. 2.2.3, Table B-3).
Reinforcing steel shall comply with ASTM A706, grade 60 (Ref. 2.2.1, Section 4.2.11.6.2).

Use same effective depth (d) for top and bottom reinforcing. Moments are considered at the face of wall, not under and shear is considered at a distance of "d" from the face of wall.

6.5.1 7 ft thick main basemat

For following notations, see Ref. 2.2.6, Sections 7 thru 11.

Depth of main basemat =7 ft = 84"

Determine the effective structural depth "d" by using one layer of number 18 rebar at 12 in. on-center each-way at top and bottom of basemat:

$d = 84" - 3"(\text{cover}) - 1.5d_b = 84" - 3" - 1.5(2.257") = 77.6"$ (For cover, see Ref. 2.2.6, Section 7.7.1(a))

Calculate the nominal moment capacity by using one layer of number 18 rebar at 12 in. on-center, $A_s = 4.0\ in^2$:

$$\phi M_n = \phi A_s f_y (d - \frac{a}{2}) \geq M_u \quad \text{(Ref. 2.2.9, Eq. 8-2)}$$

ϕ = Strength reduction factor for flexure=0.9 (Ref. 2.2.6, Section 9.3.2.2(a))

Where

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{4\ in^2 (60\ ksi)}{0.85\ (5\ ksi)(12")} = 4.7\ in \quad \text{(Ref. 2.2.9, Eq. 8.1)}$$

$$\phi M_n = \frac{0.9\ (4\ in^2)(60\ ksi)(77.6" - \frac{4.7"}{2})}{12\ in/ft} = 1354.5\ ft - k/ft$$

Determine the shear capacity of concrete requirement per ACI 349-01, Chapter 11 (Reference 2.2.6)

$$\phi V_c = \phi 2 \sqrt{f'_c}\ bd = \frac{0.85\ (2)\sqrt{5000 psi}\ (12\ in/ft)(77.6 in)}{1000 lb/kip} = 111.9\ k/ft \quad \text{(Ref. 2.2.6, Eq. 11-3)}$$

ϕ = Strength reduction factor for out-of-plane shear=0.85 (Ref. 2.2.6, Section 9.3.2.3)

Determine the shear capacity of #5 vertical ties at 12" on center each way:

$$\phi\ V_S = \phi\ A_v * f_y d / s \qquad \text{(Ref. 2.2.6, Eq. 11-15)}$$

s = 12 inches

$$A_v = .31\, in^2 / ft$$

$$\phi\ V_S = 0.85 * 0.31 * 60 * 77.6 / 12 = 102.2 kips / \text{ft}$$

Shear Capacity of concrete + ties, $\phi\ Vn$ = 111.9+102.2 = 214.1 kips / ft

Moment and shear capacity was compared to demand from the contour plots for M11, M22, V13 and V23. The torsional moment M12 was added to demand values for M11 and M22 to determine demand. The following tables summarize the maximum demand for moments and shears in comparison to the capacity.

Table 6.5.1 Maximum Moment D/C Ratios for 7 ft mat (per foot width)

Maximum Moment M (kft)^{**1}	M12 at Max moment (kft)	Total Demand (D) (kft) Mu=M+M12	Capacity (C) (kft) $=\phi M_n$	D/C	Load Combination	For location see Attachment D, page
-M11 -960.0	-195	1155	1354.5	0.85	8	97 & 99
+M11 750.0	+50	800	1354.5	0.59	9	102 & 104
-M22 -560	-195	755	1354.5	0.56	8	98 & 99
+M22 780.0	+100	880	1354.5	0.65	9	103 & 104

$^{**1-}$For maximum moment location, see attachment D

Table 6.5.2 Maximum Shear D/C Ratios for 7 ft mat (per foot width)

Maximum Shear Vu (kips)^{**2}	Capacity (C)=ϕ Vn (kips)	D/C	Load Combination	For location see Attachment D, page
-V13 120	214.1	0.56	8	100
+V13 120	214.1	0.56	8	100
-V23 105	214.1	0.49	9	106
+V23 120	214.1	0.56	8	101

$^{**2-}$For maximum shear location see attachment D

6.5.2 4ft thick basemat for east-west wings

Depth of basemat for east-west wings = 4 ft = 48"

Determine the effective structural depth "d" by using one layer of number 18 rebar at 12 in. on-center each-way at top and bottom of baseman:

$d = 48"-3"(\text{cover}) - 1.5d_b = 48"-3"-1.5(2.257") = 41.6"$ (For cover, see Ref. 2.2.6, section 7.7.1(a))

Calculate the moment capacity by using one layer of number 18 rebar at 12 in. on-center, $A_s = 4.0$ in^2:

$$\phi M_n = \phi A_s f_y (d - \frac{a}{2}) \geq M_u \qquad \text{(Reference 2.2.9, Esq. 8.2)}$$

ϕ = Strength reduction factor for flexure=0.9 (Ref. 2.2.6, Section 9.3.2.2(a)

Where, $$a = \frac{A_s f_y}{0.85 f_c^{'} b} = \frac{4.00\ in^2 (60\ ksi)}{0.85\ (5\ ksi)(12")} = 4.7\ in \qquad \text{(Ref. 2.2.9, Esq. 8.1)}$$

$$\phi M_n = \frac{0.9\ (4.00\ in^2)(60\ ksi)(41.6"-\frac{4.7"}{2})}{12\ in/ft} = 706.5\ ft-k/ft$$

Determine the shear capacity of concrete requirement per ACI 349-01, Chapter 11 (Ref. 2.2.6)

$$\phi V_c = \phi 2 \sqrt{f_c^{'}}\ bd = \frac{0.85\ (2)\ \sqrt{5000 psi}\ (12\ in/ft)(41.6 in)}{1000 lb/kip} = 60.0\ k/ft \qquad \text{(Ref. 2.2.6, Esq. 11-3)}$$

ϕ = strength reduction factor for shear=0.85 (Ref. 2.2.6, Section 9.3.2.3)

Determine the shear capacity of #5 vertical ties at 12" on center each way:

$\phi\ V_S = \phi\ A_v * f_e d / s$ (Ref. 2.2.6, Esq. 11-15)

S = 12 inches

$A_v = .31\ in^2 / ft$

$\phi\ V_S = 0.85 * 0.31 * 60 * 41.6 / 12 = 54.8 kips$ /ft

Shear Capacity of concrete + ties = 60.0+54.8 = 114.8 kips / ft

Moment and shear capacity was compared to demand from the contour plots for M11, M22, V13 and V23. The tensional moment M12 was added to demand values for M11 and M22 to determine demand. The following tables summarize the maximum demand for moments and shears in comparison to the capacity.

Table 6.5.3 Maximum Moment D/C Ratios for 4 ft mat (per foot width)

Maximum Moment M (kit) ^{**1}	M12 at Max moment (kit)	Total Demand (D) (kit) Mud=M+M12	Capacity (C) (Kit) $=\phi M_n$	D/C	Load Combination	For location see Attachment D, page
-M11 -360	-50	410	706.5	0.58	4	137 & 139
+M11 600.0	+50	650	706.5	0.92	4	137 & 139
-M22 -260.0	-100	360	706.5	0.51	5	143 & 144
+M22 130.0	+100	230	706.5	0.33	5	143 & 144

$^{**1-}$For maximum moment location, see attachment D

Table 6.5.4 Maximum Shear D/C Ratios for 4 ft mat (per foot width)

Maximum Shear Vu (kips) ^{**2}	Capacity (C)= ϕ *Van* (kips)	D/C	Load Combination	For location see Attachment D, page
-V13 70	114.8	0.61	4	140
+V13 90	114.8	0.78	9	165
-V23 100	114.8	0.87	10	171
+V23 100	114.8	0.87	10	171

$^{**2-}$For maximum shear location, see attachment D

From the contour plots, the maximum shear V13, does not occur in the same location as maximum V23. Therefore, additional shear reinforcement for V23 is not required beyond what is provided for maximum V13 or V23.

From the contour plots, 11 ft distance from the centerline column was judged to be enough for shear reinforcing. Beyond that actual shear is less than shear for plain concrete

For a foundation plan view and section showing flexural and shear reinforcement, see the following two sheets (Figures 6.5.1 and 6.5.2).

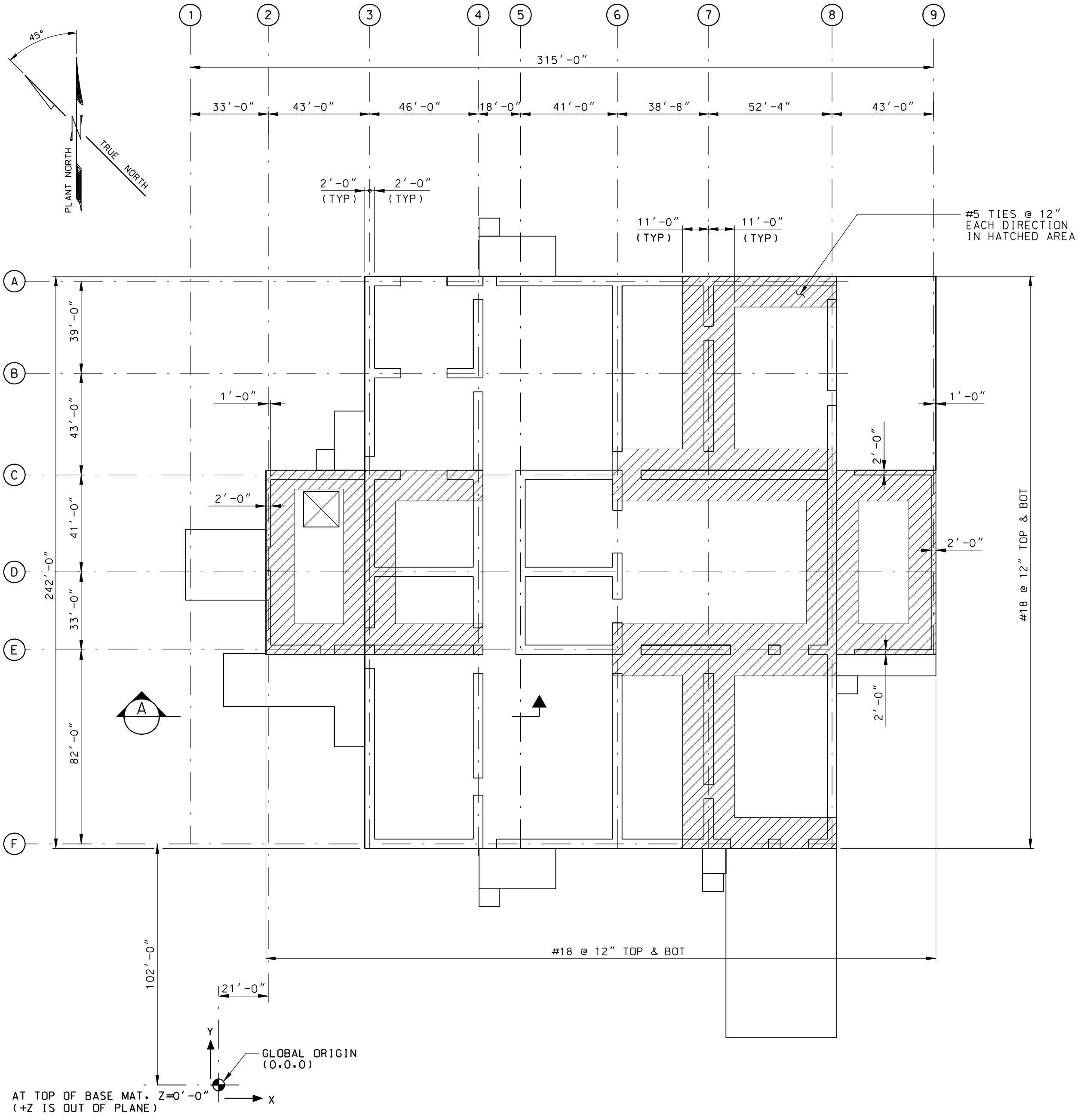


Figure 6.5.1. Basemat Reinforcing-Plan View

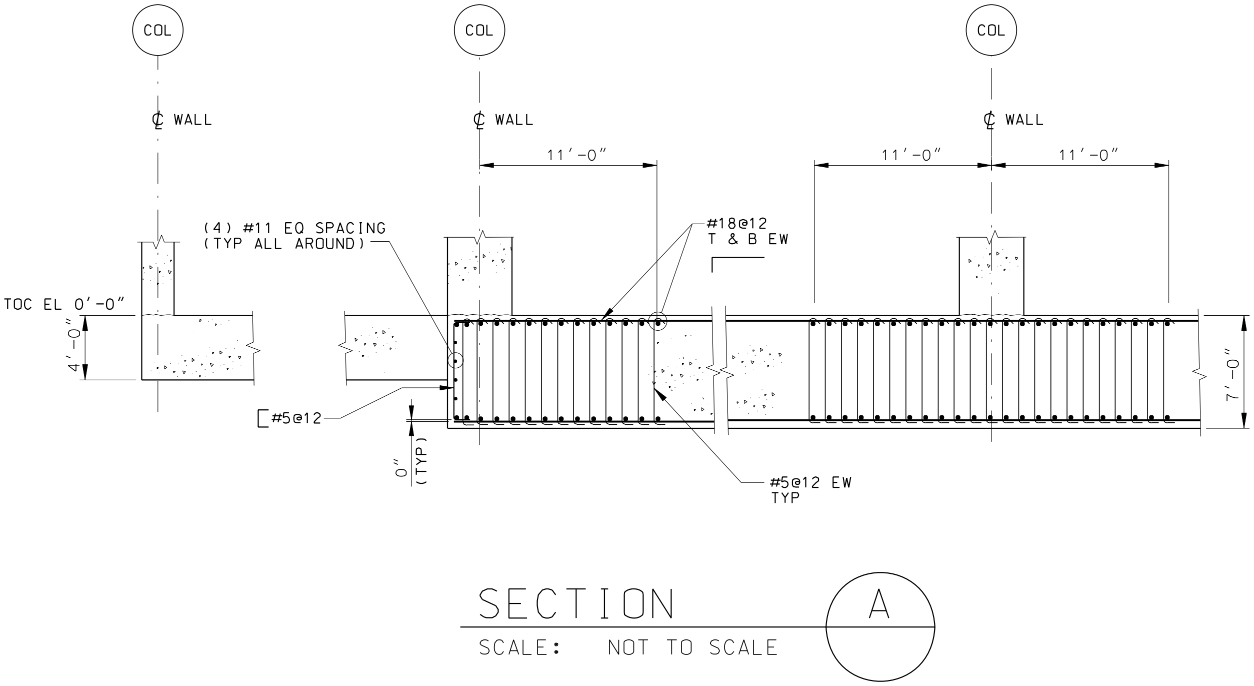


Figure 6.5.2. Basemat Cross Section

6.6 STRUCTURAL STABILITY EVALUATION

This section evaluates the stability of the structure for sliding and overturning under the design basis ground motions. Seismic Analysis and Design approach document (Section 11.1 of Ref. 2.2.12) is used for the evaluation of sliding stability. Sliding displacement is calculated by using the approximate method suggested in Appendix A of the ASCE /SEI 43-05 Seismic Design Criteria for Structures, Systems and components in Nuclear Facilities (Ref. 2.2.8).

6.6.1 Check Sliding Stability

6.6.1.1 Static Check

The static resistance to sliding V_R, is a function of the soil cohesion c, the resistance due to passive soil pressure P_P *L and the available friction force $N\mu$.

Therefore, Total sliding resistance, $V_R = c + N\mu + P_P * L$ (Ref. 2.2.8, Section 7.2.1)

Using c=0 (for granular soils) minimizes the sliding resistance and results in an upper bound value for the computed soil displacement.

N = Normal compressive force = total weight of the RF (Ref. 2.2.5, Table-Summary of Mass and Center of Mass, page 26)

μ = Friction coefficient for alluvium = 0.81 (Table 6-2, Ref. 2.2.12)

L = Length of basemat = 242 ft (Least dimension in N-S direction of the building for max overturning effect and minimum passive soil pressure calculation)

P_P = passive soil pressure on the basemat = $K_P \rho H^2 /2$ (Ref. 2.2.9, Eq. 11-5)

K_P = Coefficient of passive resistance = 4.4 (alluvium, Table 6-2, Ref. 2.2.12)

ρ = Moist Density =114 pcf (alluvium, Table 6-2 Ref. 2.2.12)

H = Effective height for passive pressure = 7 ft. - Finished grade is 6 in. below ground floor and consider top 1 ft as ineffective.

Therefore, effective height for passive pressure is, H= 7 ft-0.5 ft -1.0 ft=5.5 ft

$P_P = 4.4*114*5.5^2 /2 = 7587$ lbs/ft

$P_P L = 7587*242 = 1,836,054$ lbs = 1,836 kips

The total weight of the RF = W = 189,677 kips (Ref. 2.2.5, Section 6, Table-Summary of Mass and Center of Mass, page 26)

V_R (Total) = 189,677 *0.81 + 1,836 = 155,474 kips

Equivalent coefficient of friction = V_R /W = 155,474 /189,677 = 0.820 (Ref. 2.2.8, Eq. 7-4)

Check static factor of safety against sliding for load case 7: Dead load –0.4HX+0.4HY +VZ

This case will have seismic load in vertical up direction minimizing the building weight and therefore resulting in least $V_{R.}$

From analysis output for this case the sum of link reactions (FZ) and spring reactions (FX and FY) are summarized as follows. (Attachment C, Load Combination 7, Table-Joint Reactions)

Σ FZ (Vertical) = 39696 kips

Σ FX (Horizontal, E-W) = 28860 kips

Σ FY (Horizontal, N-S) = 34217 Kips

Resultant lateral force on foundation of main basemat = $(FX^2 + FY^2)^{1/2} = (28860^2 + 34217^2)^{1/2}$

= 44763 kips

$V_R = 0.820 * 39696 = 32551$ kips

The Section 11.1.1 of Ref. 2.2.12 recommends a minimum factor of safety of 1.1.

Factor of safety against sliding in the direction of least dimension (N-S) = Resistance / lateral force = 32551/ 34217 = 0.951 < 1.1

Factor of safety against sliding in the direction of Resultant lateral force= Resistance / lateral force = 32551/ 44763 = 0.727 < 1.1

Therefore, building will slide.

Calculate predicted magnitude of building displacement using ASCE /SEI 43-05 (Ref. 2.2.8)

6.6.1.2 Sliding Displacement

Equivalent coefficient of sliding friction = $\mu = 0.820$

Peak vertical ground acceleration (DBGM-2, site D/E), $A_V = 0.52g$ (Ref. 2.2.10, Table 6-6)

Effective coefficient of friction $\mu_e = \mu\,(1-0.4\,A_V/g) = 0.649$ (Ref. 2.2. 8, Eq. A-1)

Sliding coefficient $C_S = 2\,\mu_e\,g = 1.299g$ (Ref. 2.2. 8, Eq. A-2)

Best estimate of sliding distance, $d_s = C_S / (2\,\pi\,f_{es})^2$ (Ref. 2.2. 8, Eq. A-3)

f_{es} = the lowest natural frequency at which the horizontal 10% damped vector spectral acceleration SA_{VH} equals C_S (Ref. 2.2.8, Section A.1),

$SA_{VH} = [SA_{H1}^2 + (0.16)\,SA_{H2}^2]^{1/2}$ (Ref. 2.2.8, Section A-4)

SA_{H1} and SA_{H2} are the 10% damped spectral accelerations for each of the two orthogonal horizontal components. Since $SA_{H1} = SA_{H2}$ (Ref. 2.2.8, Section A.1)

$SA_{VH} = 1.08\ SA_{H1} = C_S$

$SA_{H1} = 1.299g / 1.08 = 1.206g$

Horizontal spectral accelerations for 10% damped condition are well below 1.299g for all frequency ranges. Therefore, it can be concluded that the building will not slide when subjected to the 10% damped spectral accelerations.

However, an estimate of upper bound displacement value can be made by substituting the natural frequency (first mode frequency) for f_{es}. The natural frequency of RF is determined to be 8.5 Hz for 35' upper bound alluvium case. (Ref. 2.2.3, Table 6)

$$d_s = C_S / (2\pi f_{es})^2 = 1.299g / (2\pi\ 8.5)^2 = 0.015 \text{ ft} = 0.176\text{" say 0.2 inches.}$$

Considering a factor of safety of 2 (Ref. 2.2.8, Section A.1) any connection that enters the structure should have a flexibility of at least 2 ds or 0.4 inches.

6.6.2 Check Overturning Stability

6.6.2.1 Static Check – Overturning

Since the building plan dimension in the north /south (Y) direction of 242 ft is significantly less than east /west (X) direction of 284 ft, therefore, overturning in the Y direction will be the critical condition. The two cases to be considered are: full seismic load in the Y direction coupled with 40% seismic load in the upward (+Z) direction, full seismic load in the upward (+Z) direction with 40% seismic load in the Y direction. The governing load cases are shown below.

- Load combination 7, DEAD LOAD – 0.4HX +0.4HY +VZ will have the least restoring force with associated overturning loads.
- Load combination 12, DEAD LOAD – 0.4HX +HY +0.4VZ will have the maximum overturning loads in the weak direction with associated restoring forces.

The applied joint loads for these two cases are summarized in Tables 6.3.4.7 and 6.3.4.12.

The load due to baseslab weight is determined by multiplying, basemat and 16 ft wall weight by acceleration values (gravity Multiplier) listed for each combination. The weight of basemat including 16 ft of wall is directly taken from calculation 200-SYC-RF00-00100-000-00A (Ref. 2.2.5)

Base slab and wall weight = 83933 kips (Ref. 2.2.5, Table-Weights and Centers of Mass, page 26)

Example: Load Case 12 (DL-0.4HX+HY+0.4VZ)

- F1 (Force in X dir.) due to base slab and wall weight = - 0.1734 *83933 = -14,554 kips
- F2 (Force in Y dir.) due to base slab and wall weight = 0.4501 *83933 = 37,778 kips
- F3 (Vertical Force) due to base slab and wall weight = -0.767 *83933 = -64,377 kips

From these loads the Overturning and restoring moments are calculated with forces applied at top of floor slab and top of basemat for Load cases 7 and 12 as follows.

Load Combination 7 (DL-0.4HX+0.4HY+VZ)

Overturning Moments

Node	Elevation	Moment Arm –h (ft)	F2 (kips)	Moment X (kft)
399	32’	39’	16336.2	637,112
599	64’	71’	13643.8	968,710
699	72’	79’	1209.6	95,558
799	100’	107’	3858.1	412,817
Base Slab		7’	14923*	104,461
Total Overturning Moment				2,218,658

* 83933 kips (Ref. 2.2.5) x 0.1778 (Table 6.3.4.7 of this calc.)

Restoring Moment

Node	Elevation	F3 (kips)	Moment Arm – h** (ft)	Restoring Moment (kipft)
399	32’	-19905	119.20’	2,372,676
599	64’	-10440	117.75’	1,229,310
699	72’	-1003	119.00	119,357
799	100’	-1629	119.00	193,851
Base Slab		-34790*	119.38	4,153,230
Total Restoring Force		-67767		8,068,424

* 83933 kips (Ref. 2.2.5) x -0.4145 (Table 6.3.4.7 of this calc.)

** See Table on page 26 of Ref. 2.2.5

Factor of safety = Restoring moment / Overturning moment = 8,068,424/2,218,658= **3.64** > 1.1

Load Combination 12 (DL-0.4HX+HY+0.4VZ)

Overturning Moments

Node	Elevation	Moment Arm –h (ft)	F2 (kips)	Moment X (kft)
399	32’	39’	40989	1,598,571
599	64’	71’	34314.7	2,436,344
699	72’	79’	3115.8	246,148
799	100’	107’	9981.1	1,067,978
Base Slab		7’	37,778*	264,446
Total Overturning Moment				5,613,487

* 83933 kips (Ref. 2.2.5) x 0.4501 (Table 6.3.4.12 of this calc.)

Restoring Moment

Node	Elevation	F3 (kips)	Moment Arm –h** (ft)	Restoring Moment (kipft)
399	32’	-44097	119.20’	5,256,362
599	64’	-25988	117.75’	3,060,087
699	72’	-2176	119.00	258,944
799	100’	-4630	119.00	550,970
Base Slab		-64,377*	119.38	7,685,326
Total Restoring Force		-141,268		16,811,689

* 83933 kips (Ref. 2.2.5) x -0.767 (Table 6.3.4.12 of this calc.)

** See Table on page 26 of Ref. 2.2.5

Factor of safety = Restoring moment / Overturning moment = 16,811,689/5,613,487

= **2.99** > 1.1

These calculations show that the structure has adequate safety margin against overturning.

7. RESULTS AND CONCLUSIONS

7.1 RESULTS

The primary results of this calculation are:

- Design forces and moments:
  - The contour plots shown in Attachment D represent the shear forces and bending moments that will occur in the RF basemat under the design loading combinations. The contours were used to obtain the design forces for designing the preliminary flexural and shear reinforcement for the RF basemat.
- Basemat flexural reinforcement:
  - The 7 ft basemat was designed for a maximum bending moment, $M_{u,}$ of 1155 ft-k/ft. The preliminary reinforcement selected was #18 bars at 12 inch spacing on center, each way, top and bottom. This reinforcement yields a design moment capacity, ϕM_n, of 1354.5 ft-k/ft. Therefore, the flexural demand/capacity ratio = M_u / ϕM_n = 0.85 < 1.0.
  - The 4 ft basemat was designed for a maximum bending moment, $M_{u,}$ of 650 ft-k/ft. The preliminary reinforcement selected was #18 bars at 12 inch spacing on center, each way, top and bottom. This reinforcement yields a design moment capacity, ϕM_n, of 706.5 ft-k/ft. Therefore, the flexural demand/capacity ratio = M_u / ϕM_n = 0.92 < 1.0.
- Basemat shear reinforcement:
  - The 7 ft basemat was designed for a maximum shear, V_u, of 120 k/ft. This exceeds the concrete capacity, ϕV_c, of 111.9 k/ft, which indicates that shear reinforcement is required in some areas of the mat. The required shear reinforcement is 0.31 in^2/ft. The preliminary shear reinforcement selected was #5 bars at 12 inch spacing on center, which provides 0.31 in^2/ft. The total shear capacity is now 214.1 k/ft Therefore, the shear demand/capacity ratio = $A_{v\ required}$ / $A_{v\ provided}$ = 0.56 < 1.0. Areas requiring shear reinforcement is identified on Figure 6.5.1.
  - The 4 ft basemat was designed for a maximum shear, V_u, of 100 k/ft. This exceeds the concrete capacity, ϕV_c, of 60 k/ft, which indicates that shear reinforcement is required in some areas of the mat. The required shear reinforcement is 0.31 in^2/ft. The shear reinforcement selected was #5 bars at 12 inch spacing on center, which provides 0.31 in^2/ft. The total shear capacity is now 114.8 k/ft. Therefore, the shear demand/capacity ratio = $A_{v\ required}$ / $A_{v\ provided}$ = 0.87 < 1.0. Areas requiring shear reinforcement is identified on Figure 6.5.1.

The mat reinforcement is designed for thickness of both 7 and 4 feet. Where thickness is reduced due to rail or other pockets the slab will be designed to account for local variations during final design.

- Maximum bearing pressure on the foundation mat is 10.2 kips per square foot (see Section 6.4.2).
- Foundation overturning stability check:
  - The structure has a minimum static factor of safety against overturning of about 2.99 (load case 12), which indicates that the structure is stable against overturning.
- Foundation sliding stability check:
  - A static margin of safety against sliding could not be demonstrated for the RF, which means that the structure will slide when subjected to the maximum 2000-year return period earthquake. The sliding stability was then evaluated based on the reserve energy method described in Appendix A.1 of the ASCE /SEI 43-05 (Ref. 2.2.8), to determine the distance d_s that the structure will slide. Although the reserve energy method did not indicate that the RF would slide under DBGM-2 seismic loads, the sliding distance was conservatively calculated to be 0.2 inches.

7.2 CONCLUSIONS

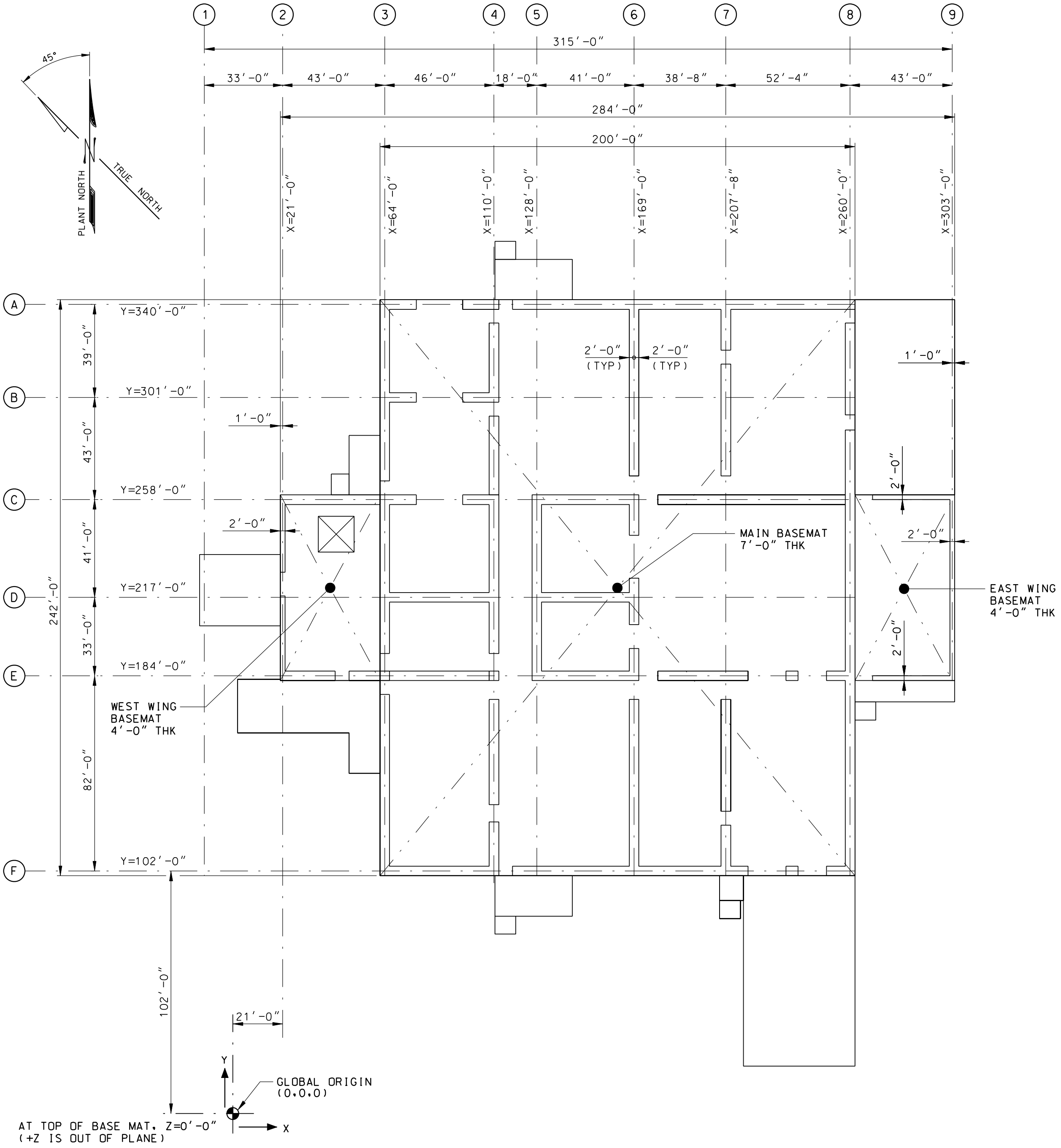
The outputs are reasonable based on the inputs. The maximum shear forces and moments occur at the corner areas of the structure, as expected, due to non-orthogonal effects. The maximum shear forces occur at the face of supports (walls), as expected. The preliminary flexural and shear reinforcement is indicative of the basemat thickness and provides a reasonable design.

The shear demand-capacity ratio for both 7 ft and 4 ft is high. Therefore, in the Tier 2 analysis it is recommended that the 4 ft basemat under the east and west wings be revised to 7 ft thick and shear reinforcement under the high shear areas will be increased.

The structure is stable against overturning.

Based on the reserve energy method described in Appendix A.1 of Reference 2.2.8, the structure may slide when subjected to the maximum 2000-year return period earthquake. A safety factor of two will be applied to the computed sliding displacement d_s of 0.2 inches. Therefore, 0.4 inches ($2d_s$) will be used when evaluating the flexibility of any commodities or utilities entering the structure, or clearance of any adjacent structures such as the Entrance Vestibule. This methodology ensures that no unacceptable interaction will occur between the structures and any ITS commodities entering the structure, or any adjacent structure, under seismic loading conditions.

ATTACHMENT A
BASEMAT PLAN AT EL 0’-0”



GROUND FLOOR PLAN AT EL 0'-0"

NOTE: ALL DIMENSIONS ARE +/- SIX INCHES

ATTACHMENT B
SAP2000 INPUT FILES

<u>SAP File (CD 1 0f 1)</u>

200-DBC-RF00-00300-000-00A.SDB

<u>EXCEL File (CD 1 0f 1)</u>

RF Foundation SAP2000 input.xls

ATTACHMENT C
SAP2000 OUTPUT FILES

(CD 1 0f 1)

Load Combination 1.xls

Load Combination 2.xls

Load Combination 3.xls

Load Combination 4.xls

Load Combination 5.xls

Load Combination 6.xls

Load Combination 7.xls

Load Combination 8.xls

Load Combination 9.xls

Load Combination 10.xls

Load Combination 11.xls

Load Combination 12.xls

ATTACHMENT D
MOMENT AND SHEAR CONTOURS

Attachment D Moment and Shear Contours

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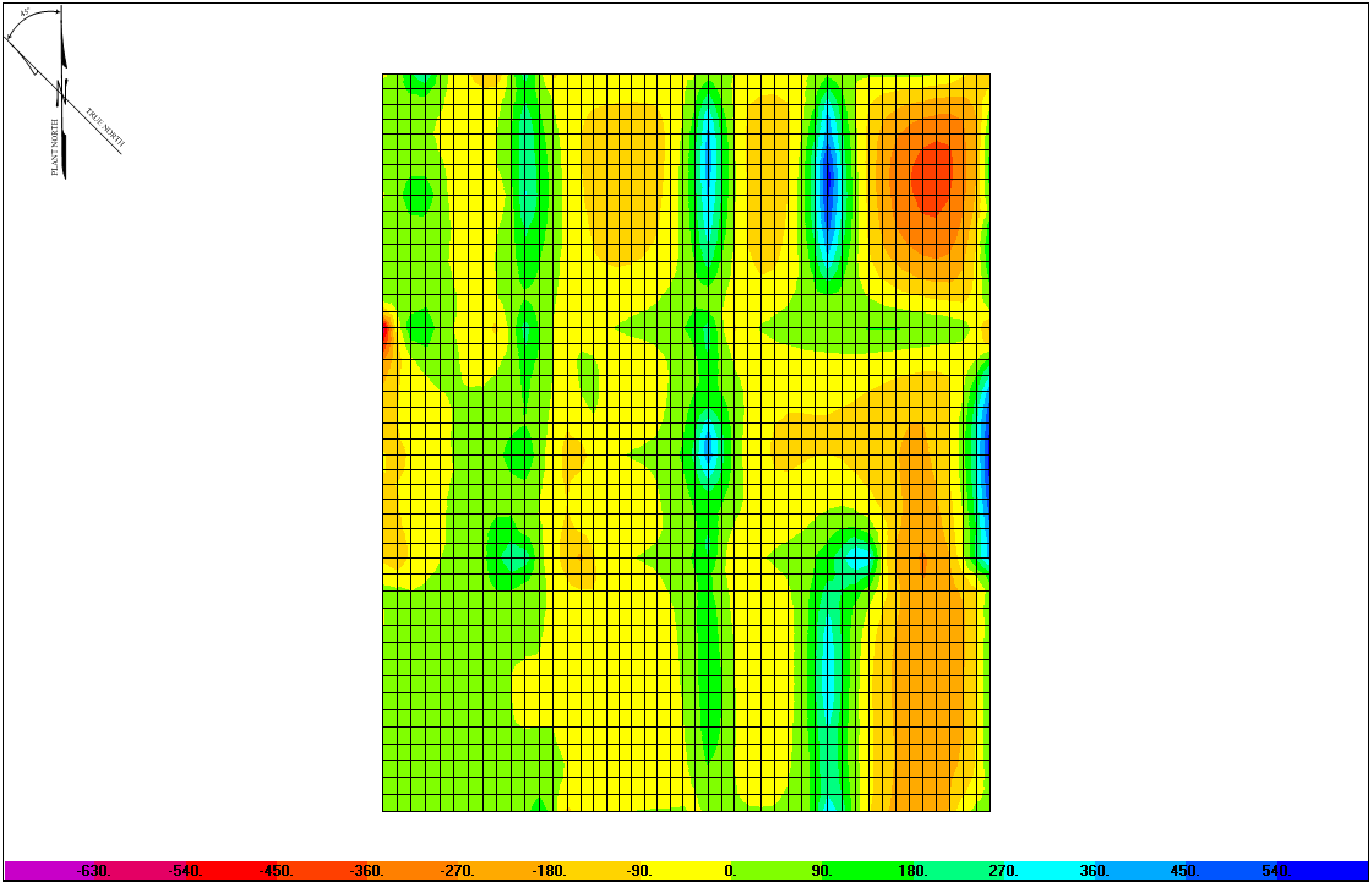
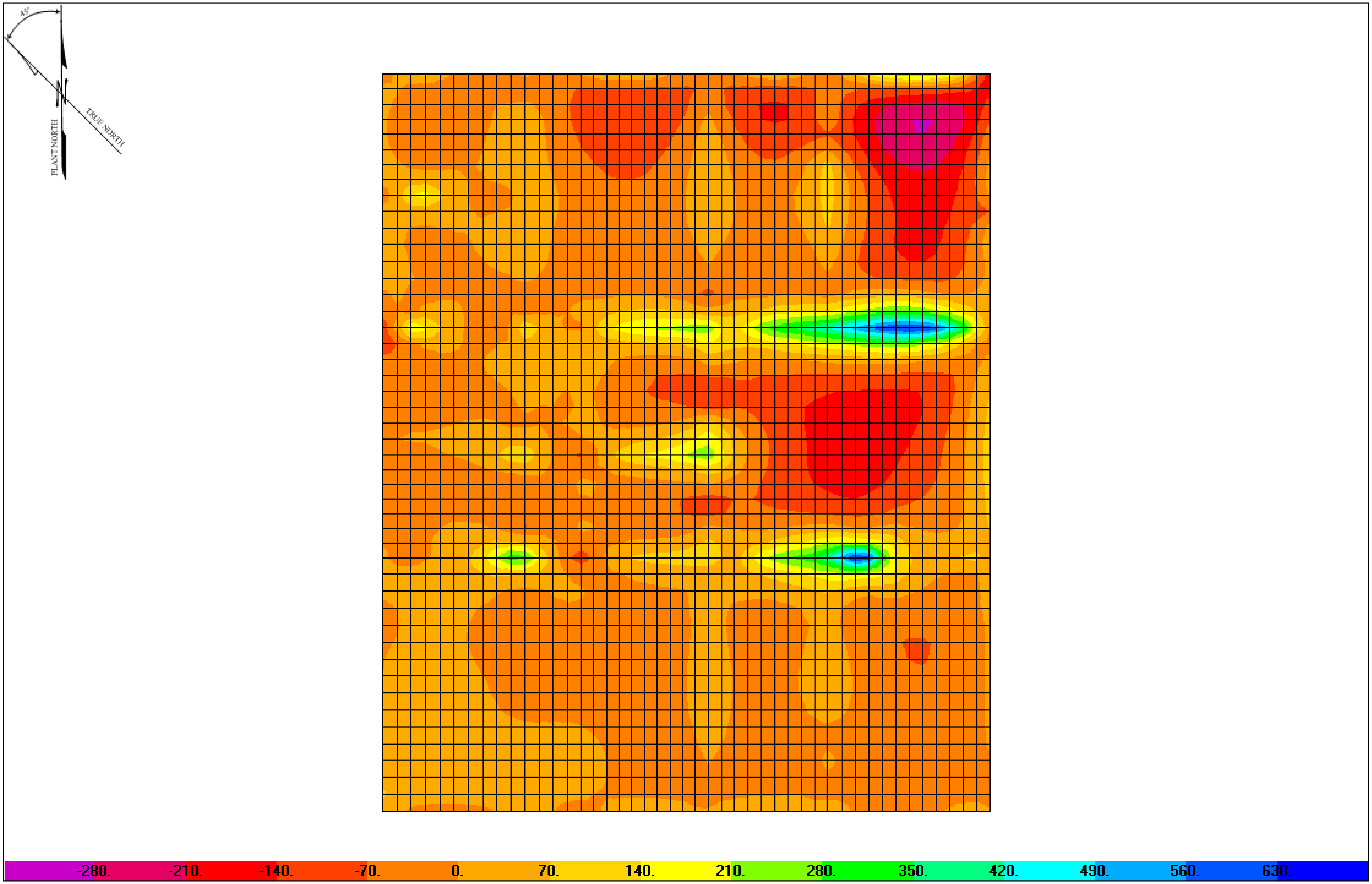
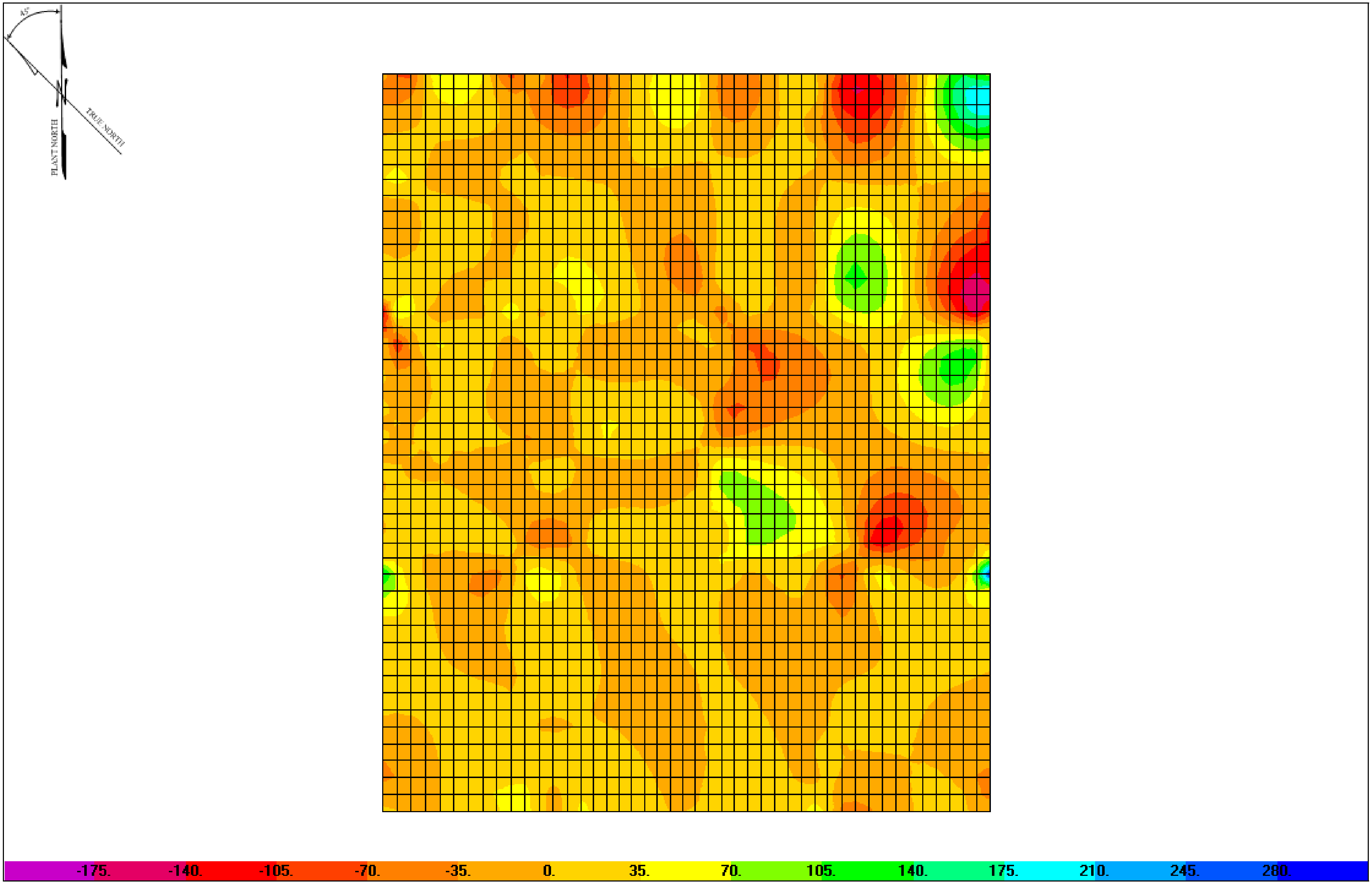


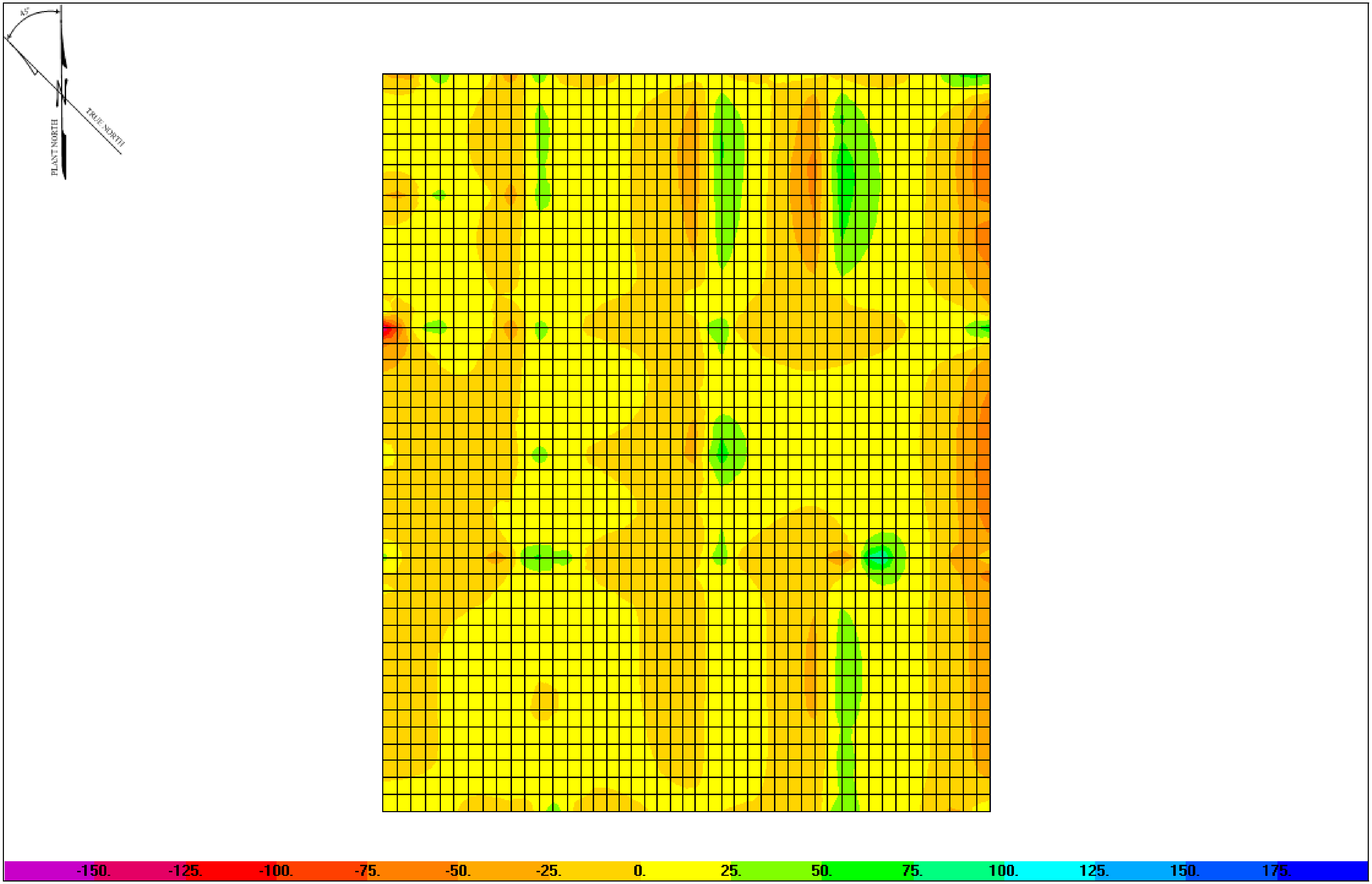
7 ft. Thick Resultant M11 Diagram – Combination 1 (DL+HX+0.4HY+0.4VZ) – kip-ft



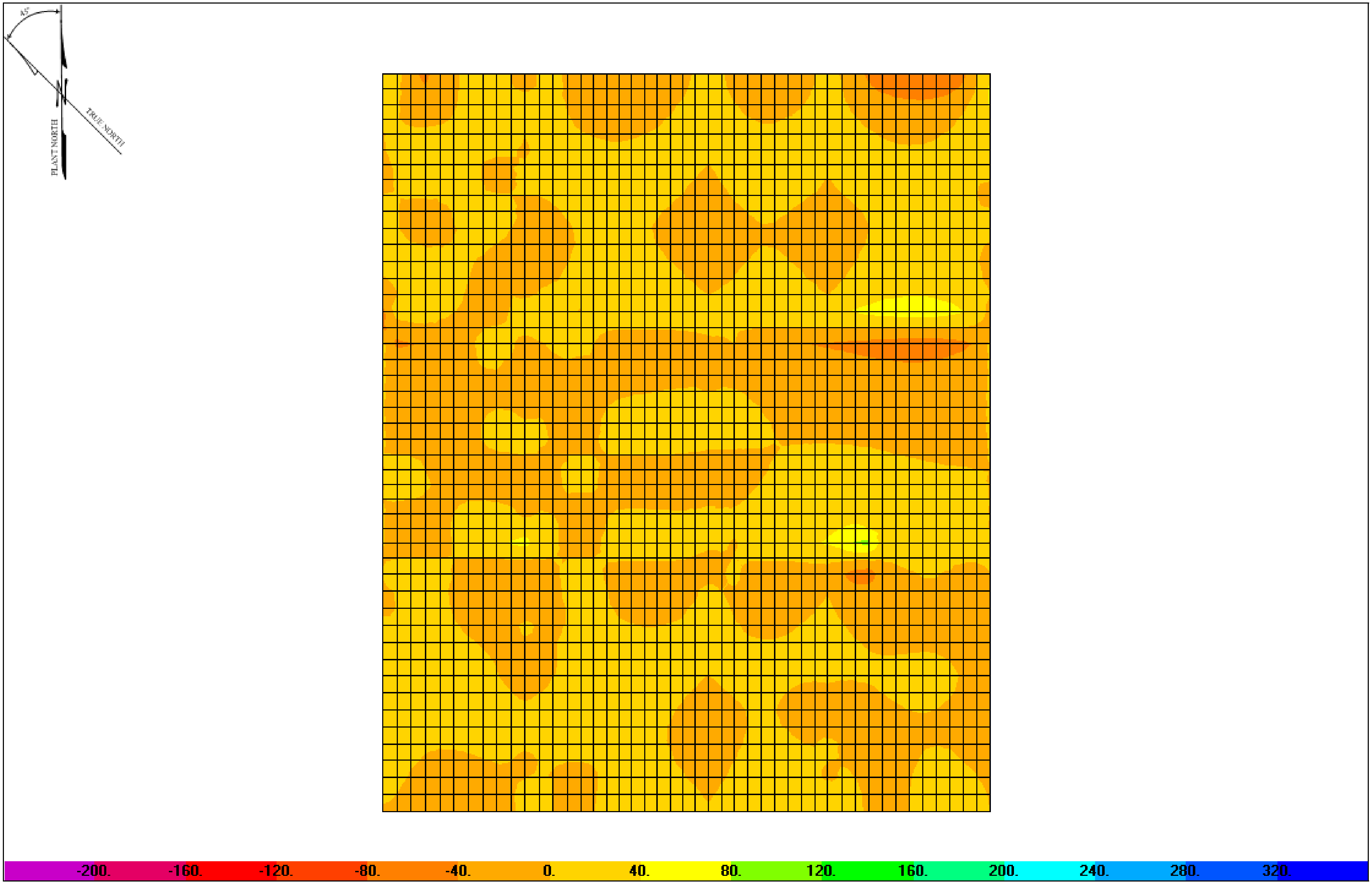
7 ft. Thick Resultant M22 Diagram – Combination 1 (DL+HX+0.4HY+0.4VZ) – kip-ft



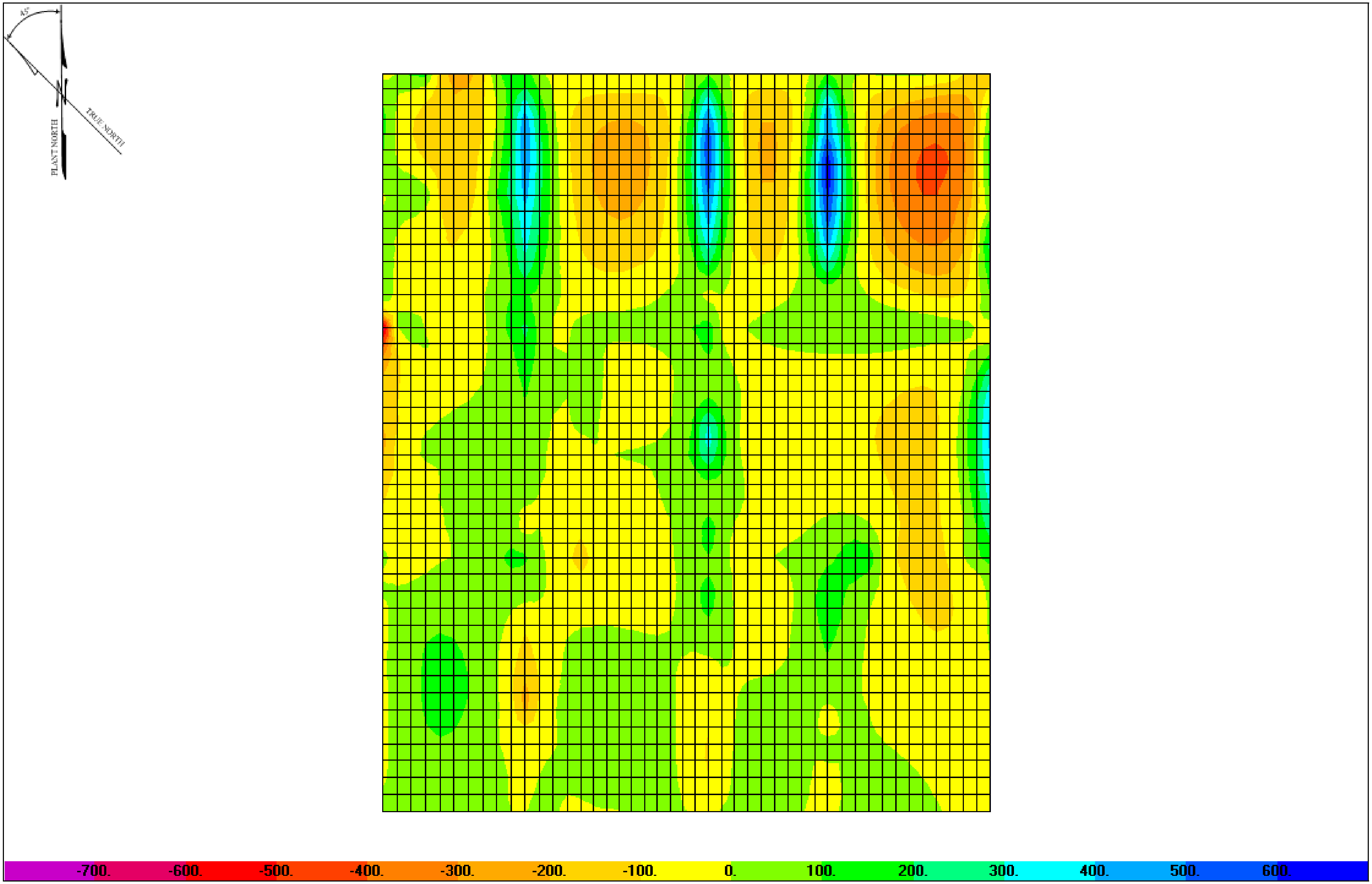
7 ft. Thick Resultant M12 Diagram – Combination 1 (DL+HX+0.4HY+0.4VZ) – kip-ft



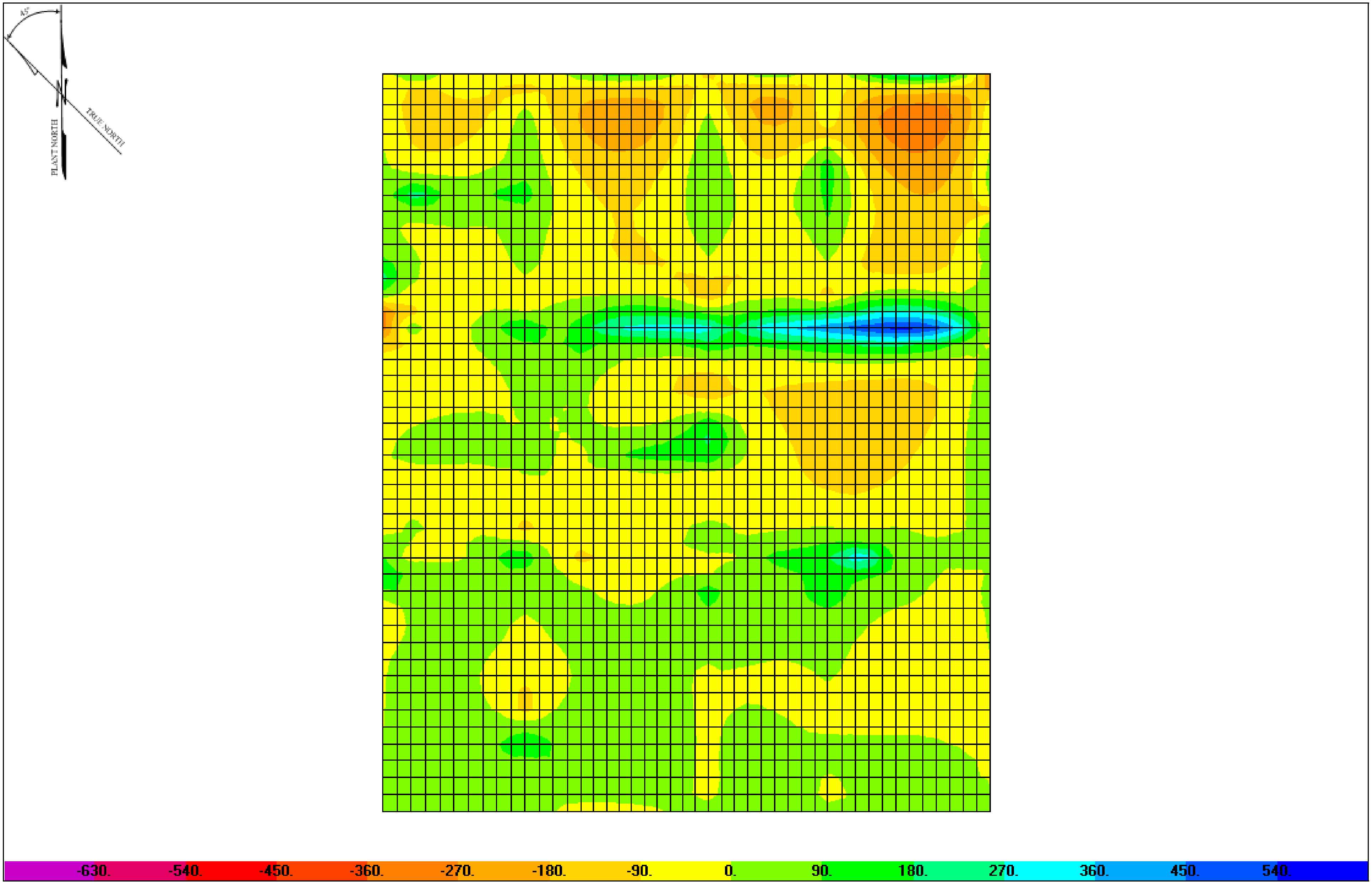
7 ft. Thick Resultant V13 Diagram – Combination 1 (DL+HX+0.4HY+0.4VZ) – kip



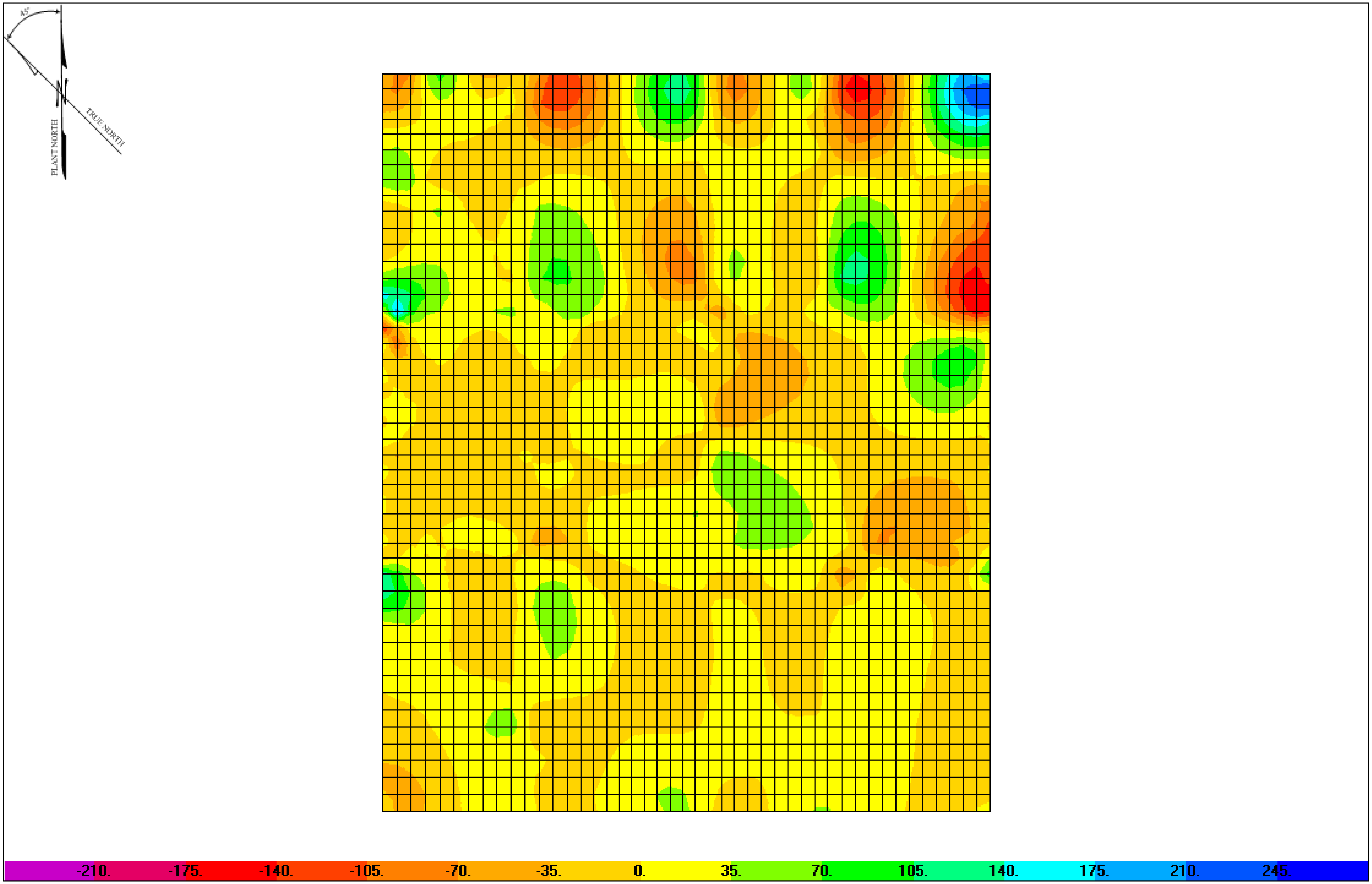
7 ft. Thick Resultant V23 Diagram – Combination 1 (DL+HX+0.4HY+0.4VZ) – kip



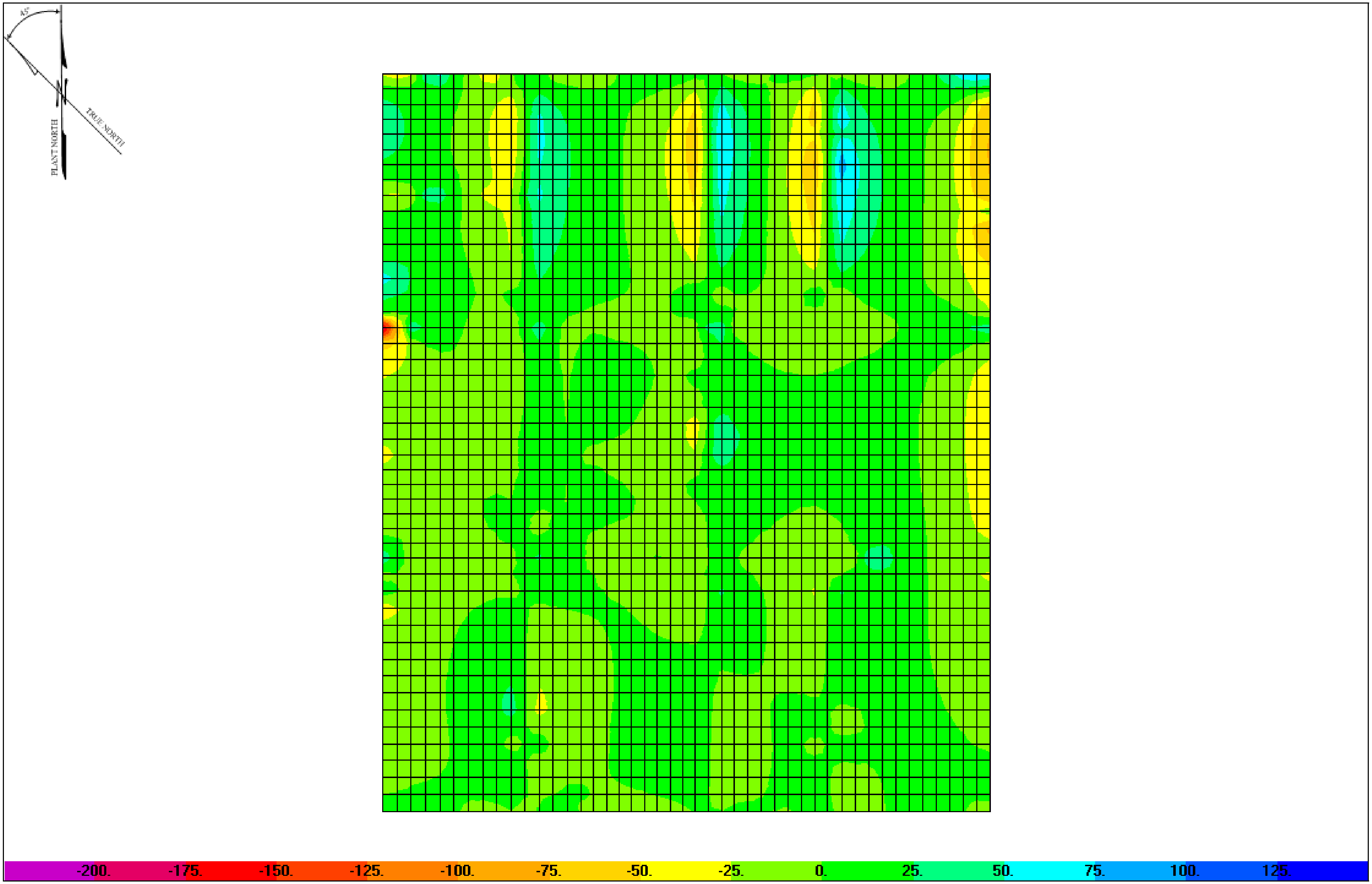
7 ft. Thick Resultant M11 Diagram – Combination 2 (DL+0.4HX+HY+0.4VZ) – kip-ft



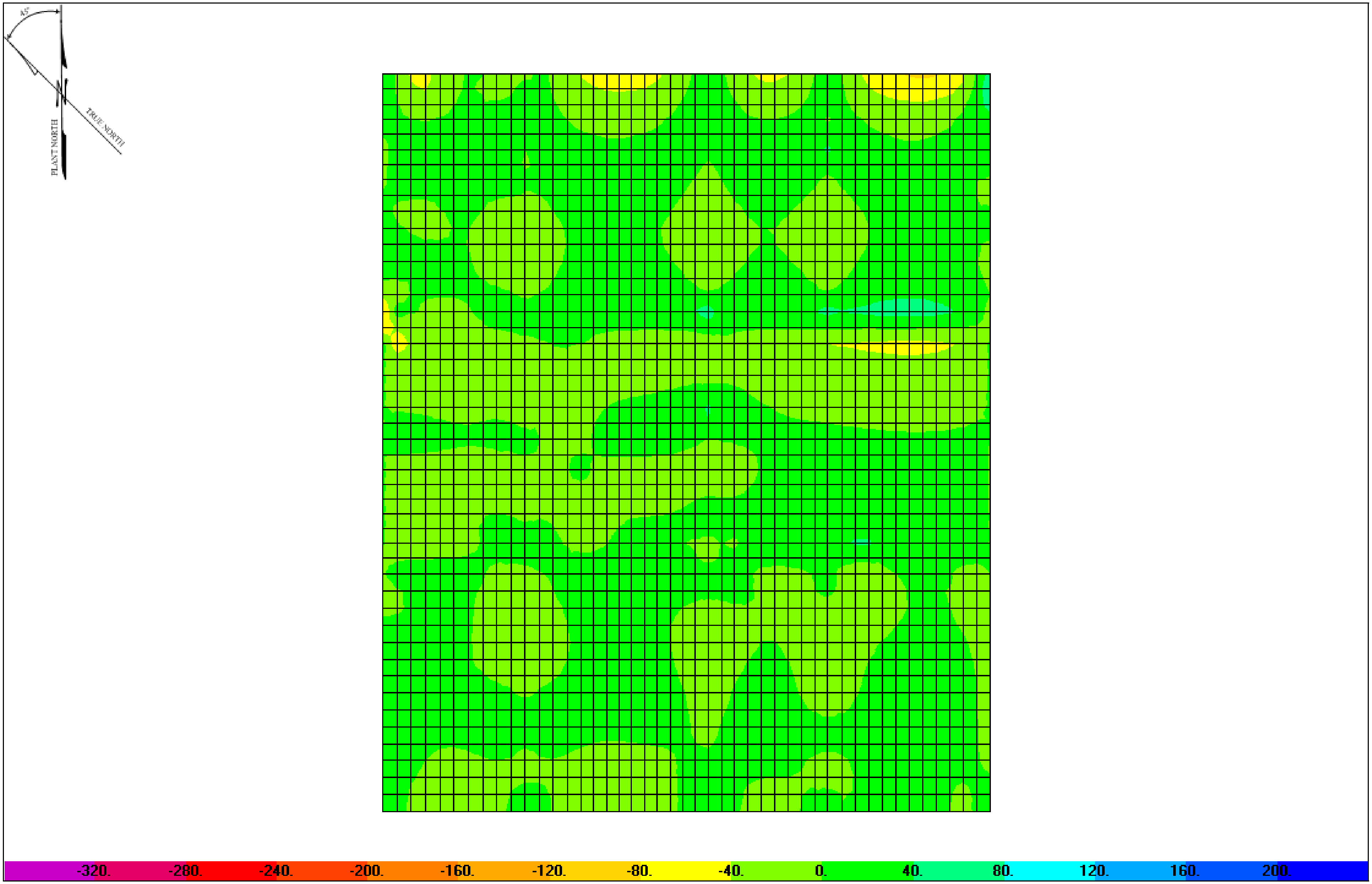
7 ft. Thick Resultant M22 Diagram – Combination 2 (DL+0.4HX+HY+0.4VZ) – kip-ft



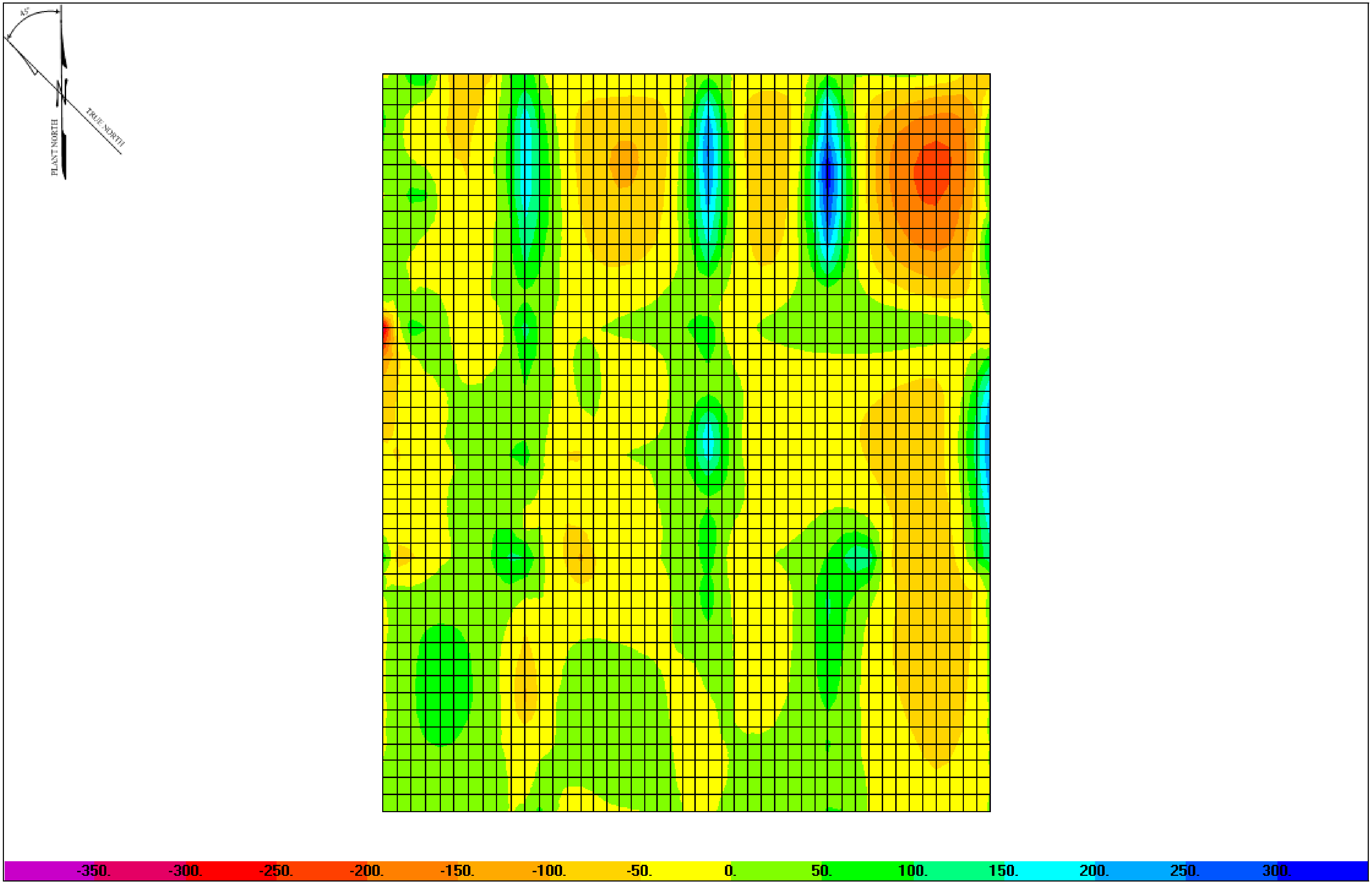
7 ft. Thick Resultant M12 Diagram – Combination 2 (DL+0.4HX+HY+0.4VZ) – kip-ft



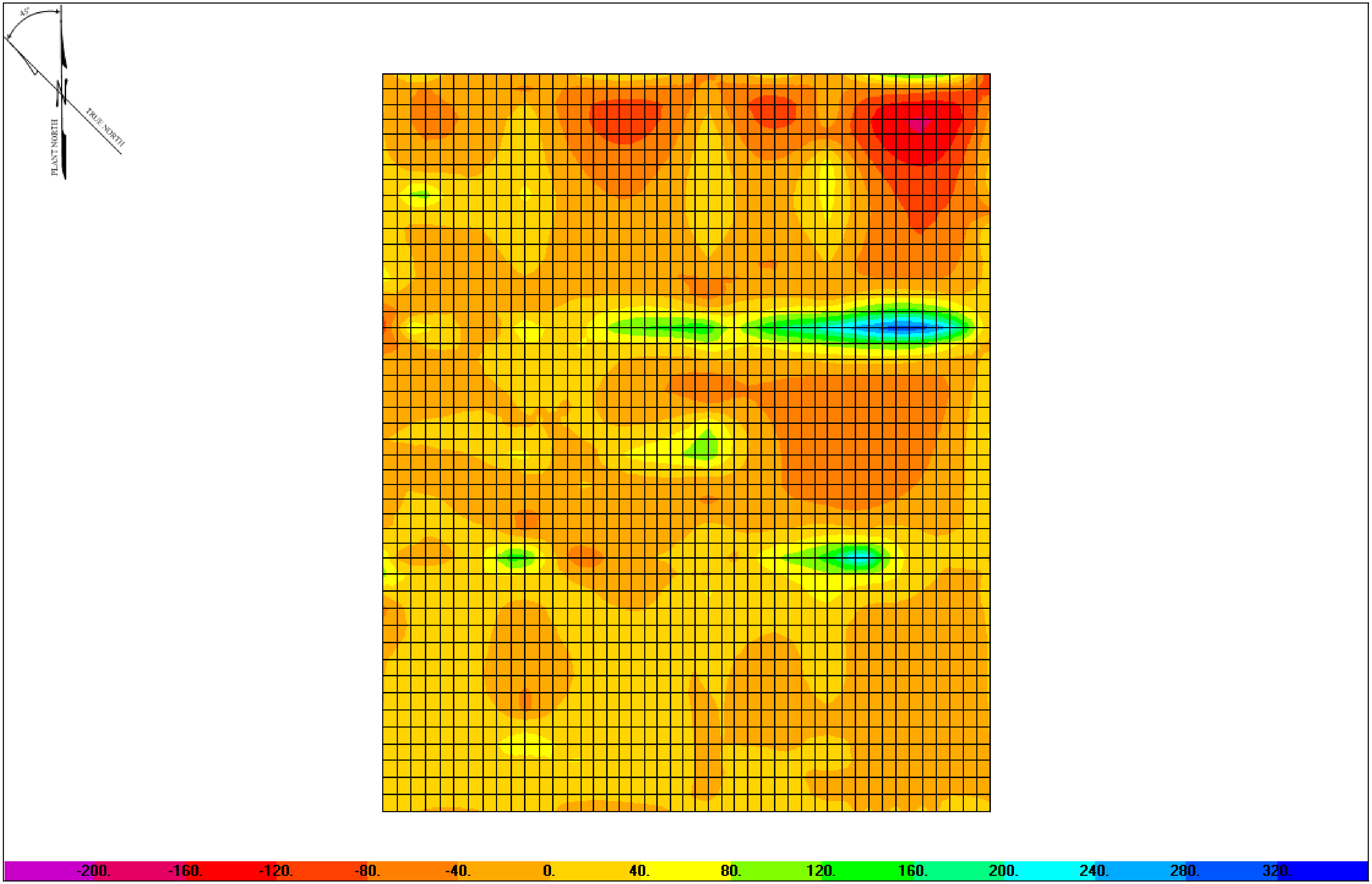
7 ft. Thick Resultant V13 Diagram – Combination 2 (DL+0.4HX+HY+0.4VZ) – kip



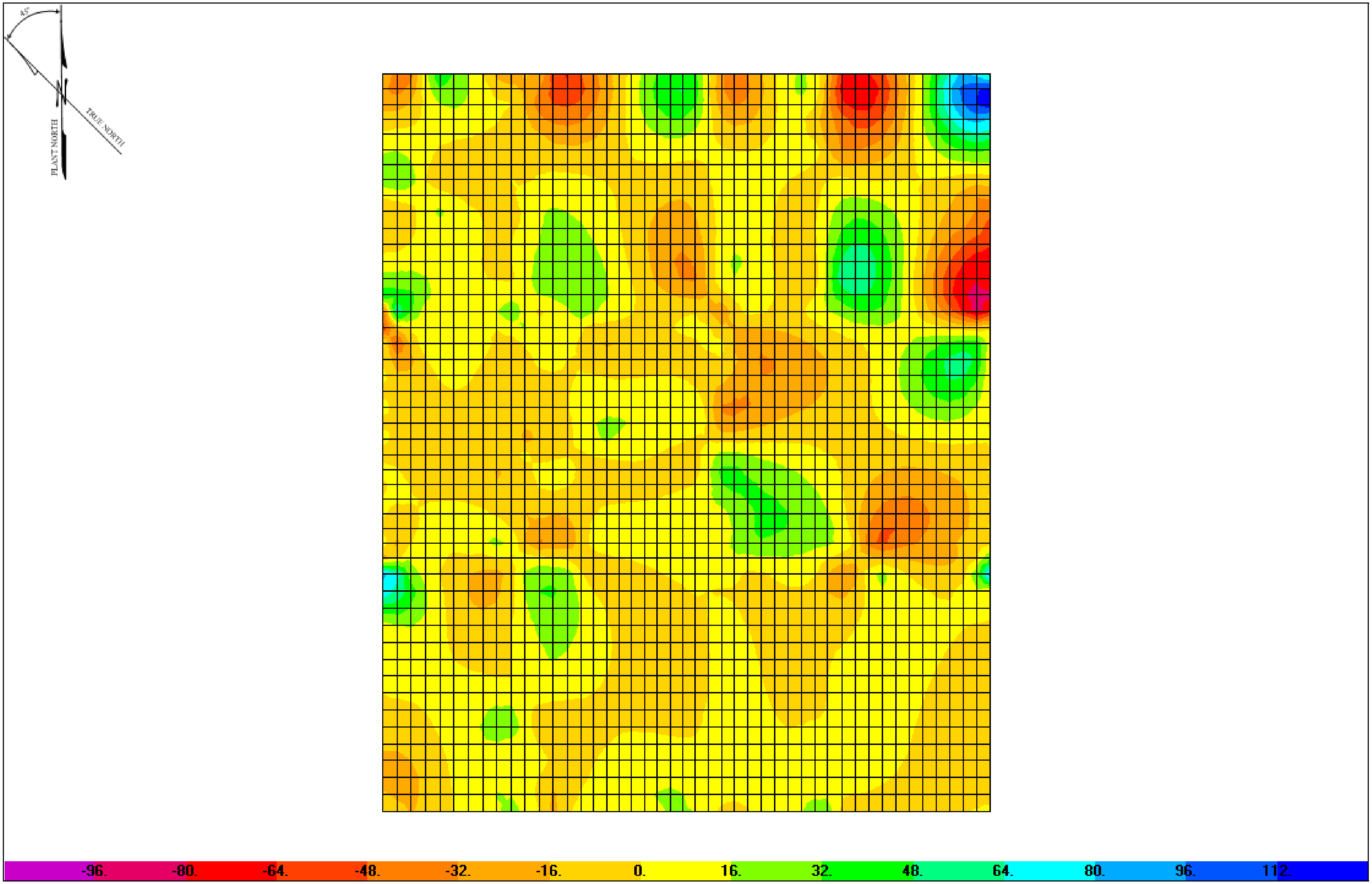
7 ft. Thick Resultant V23 Diagram – Combination 2 (DL+0.4HX+HY+0.4VZ) – kip



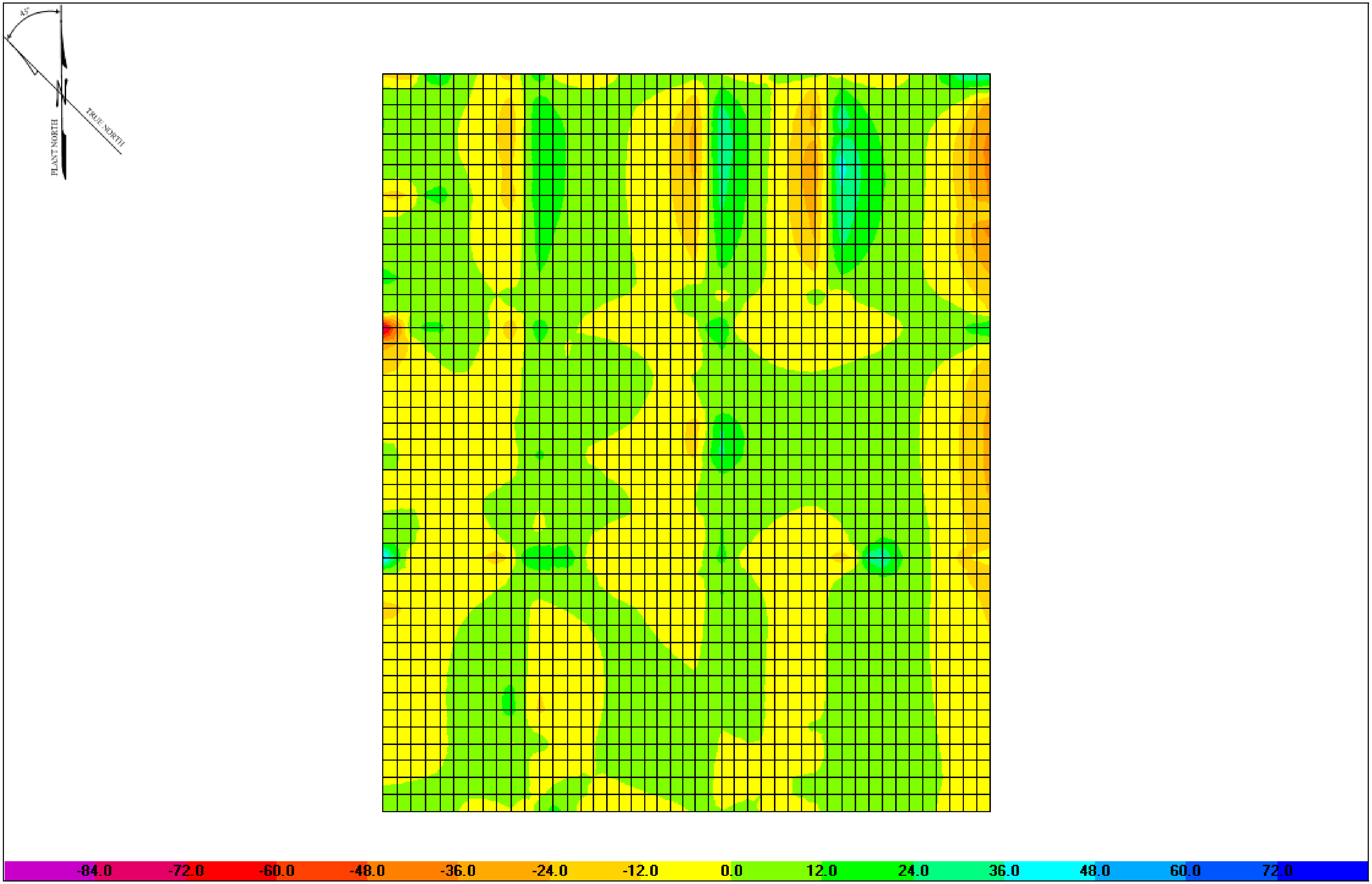
7 ft. Thick Resultant M11 Diagram – Combination 3 (DL+0.4HX+0.4HY+VZ) – kip-ft



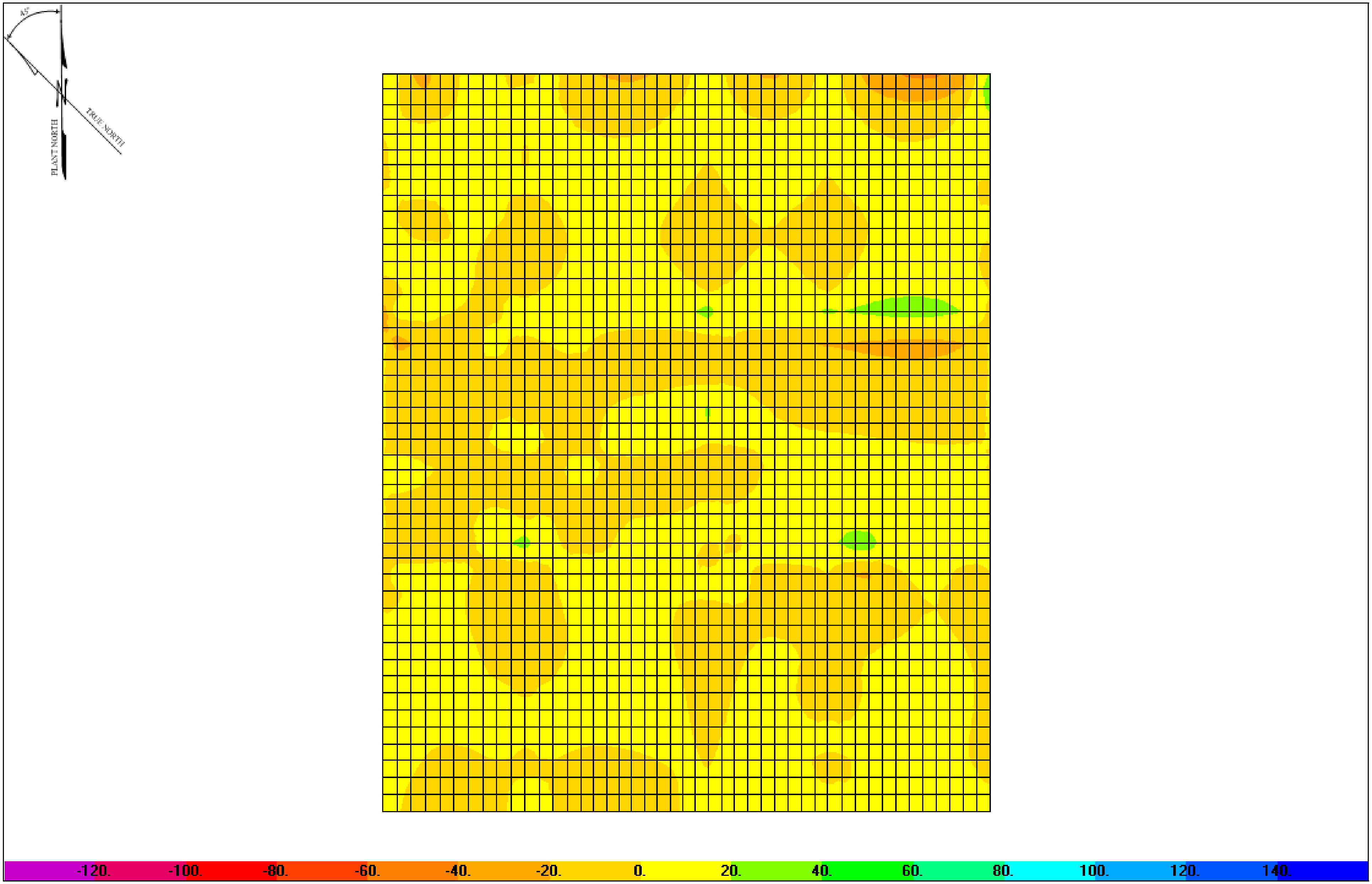
7 ft. Thick Resultant M22 Diagram – Combination 3 (DL+0.4HX+0.4HY+VZ) – kip-ft



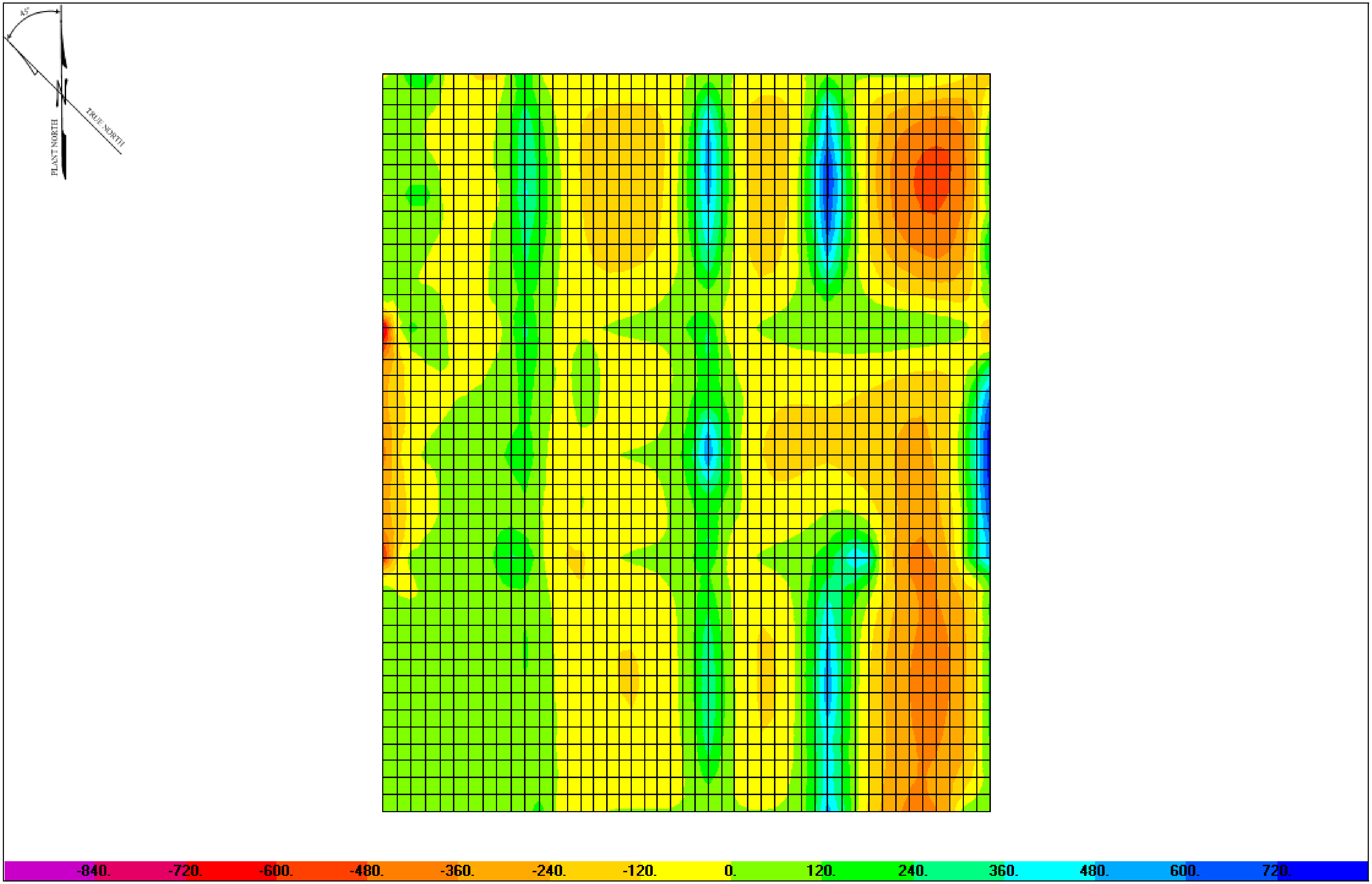
7 ft. Thick Resultant M12 Diagram – Combination 3 (DL+0.4HX+0.4HY+VZ) – kip-ft



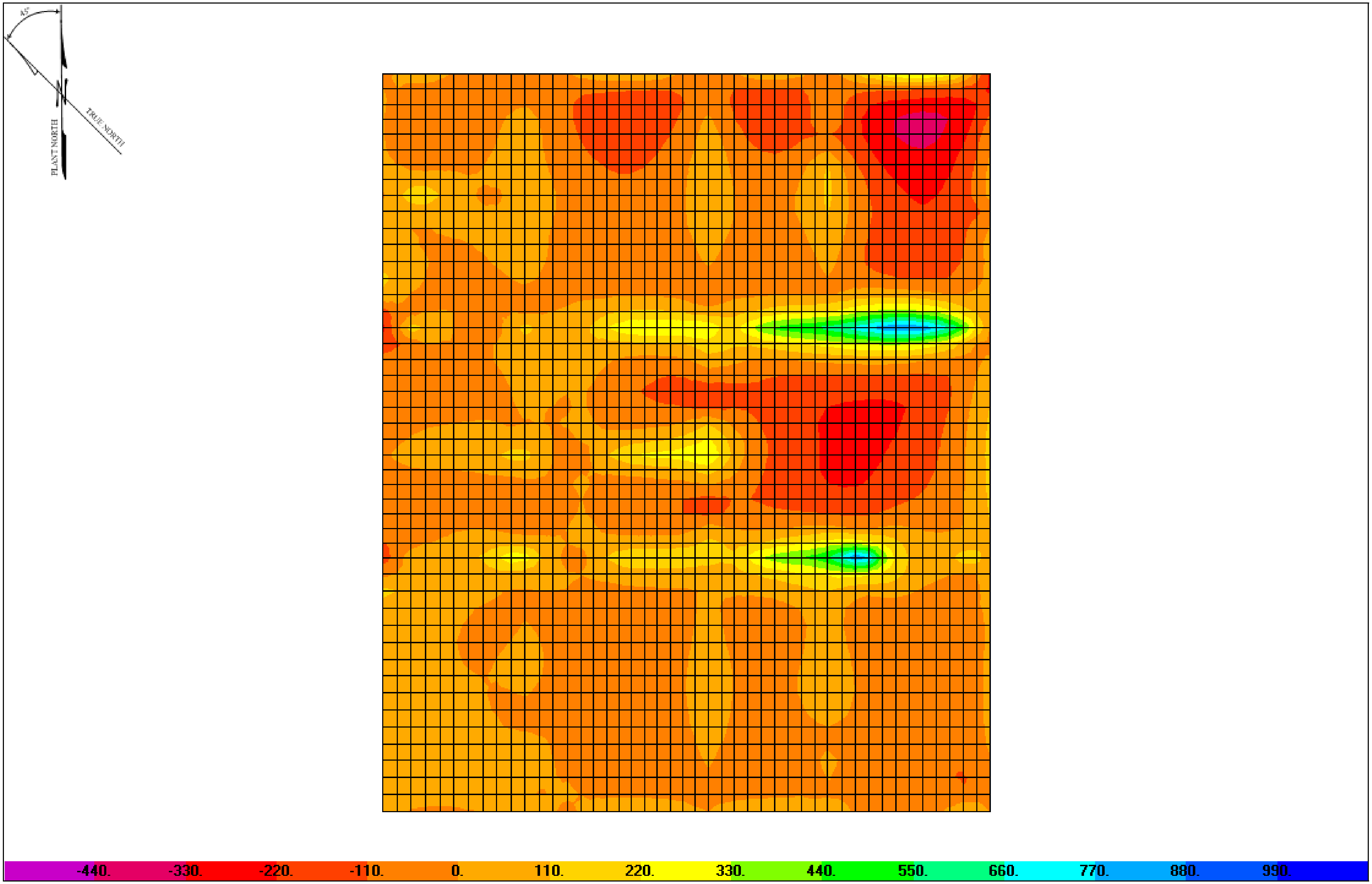
7 ft. Thick Resultant V13 Diagram – Combination 3 (DL+0.4HX+0.4HY+VZ) – kip



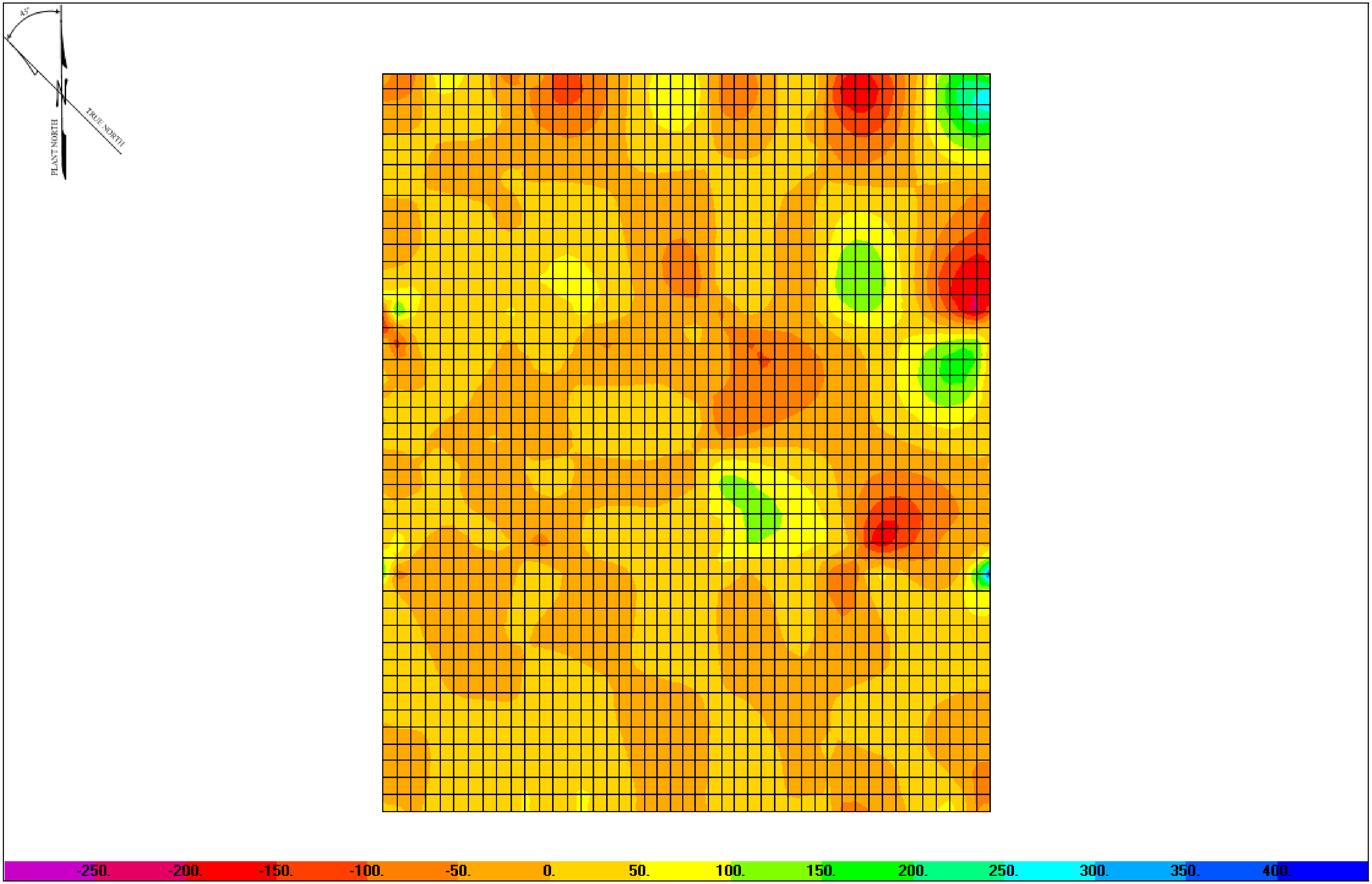
7 ft. Thick Resultant V23 Diagram – Combination 3 (DL+0.4HX+0.4HY+VZ) – kip



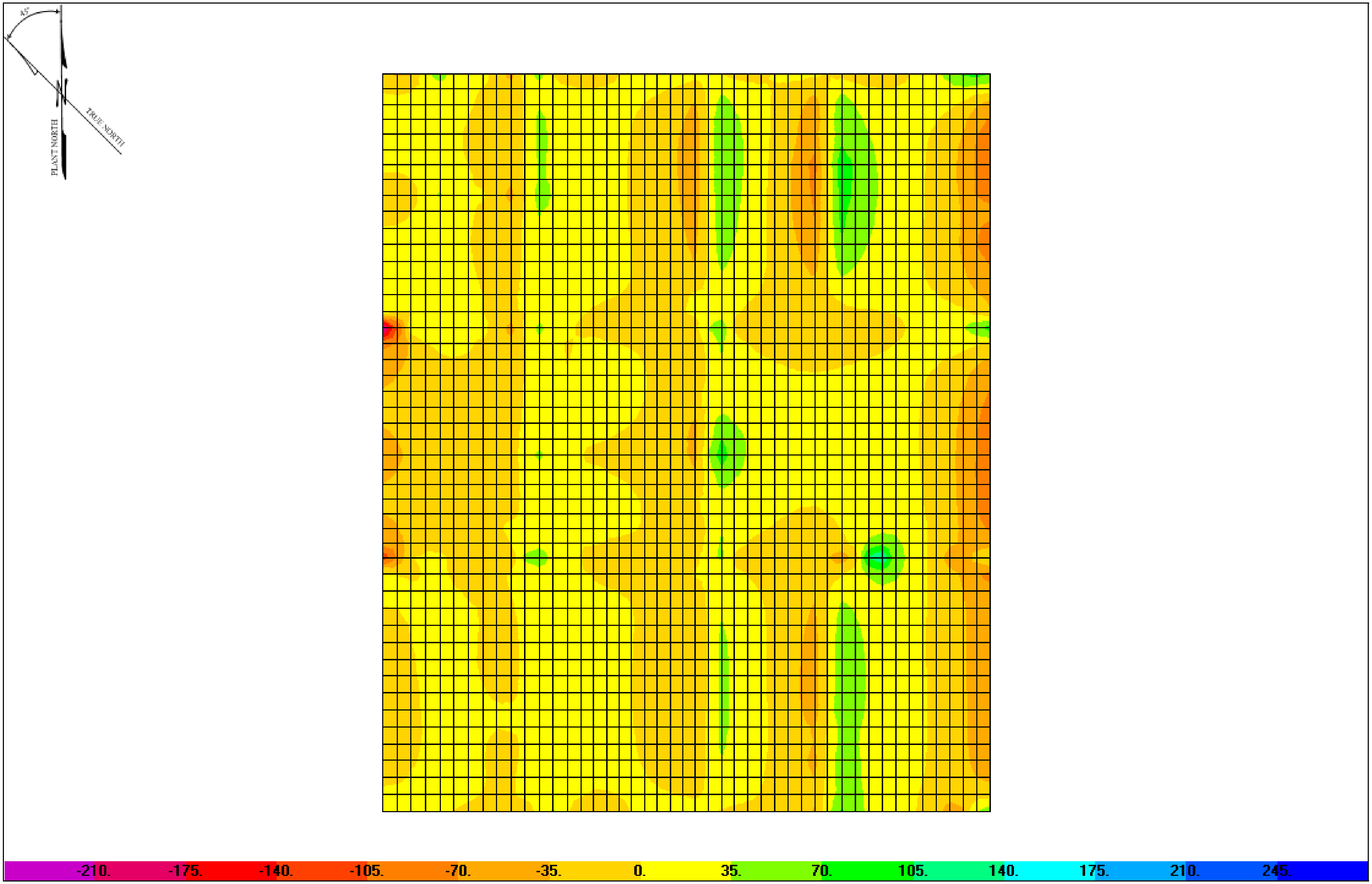
7 ft. Thick Resultant M11 Diagram – Combination 4 (DL+HX+0.4HY-0.4VZ) – kip-ft



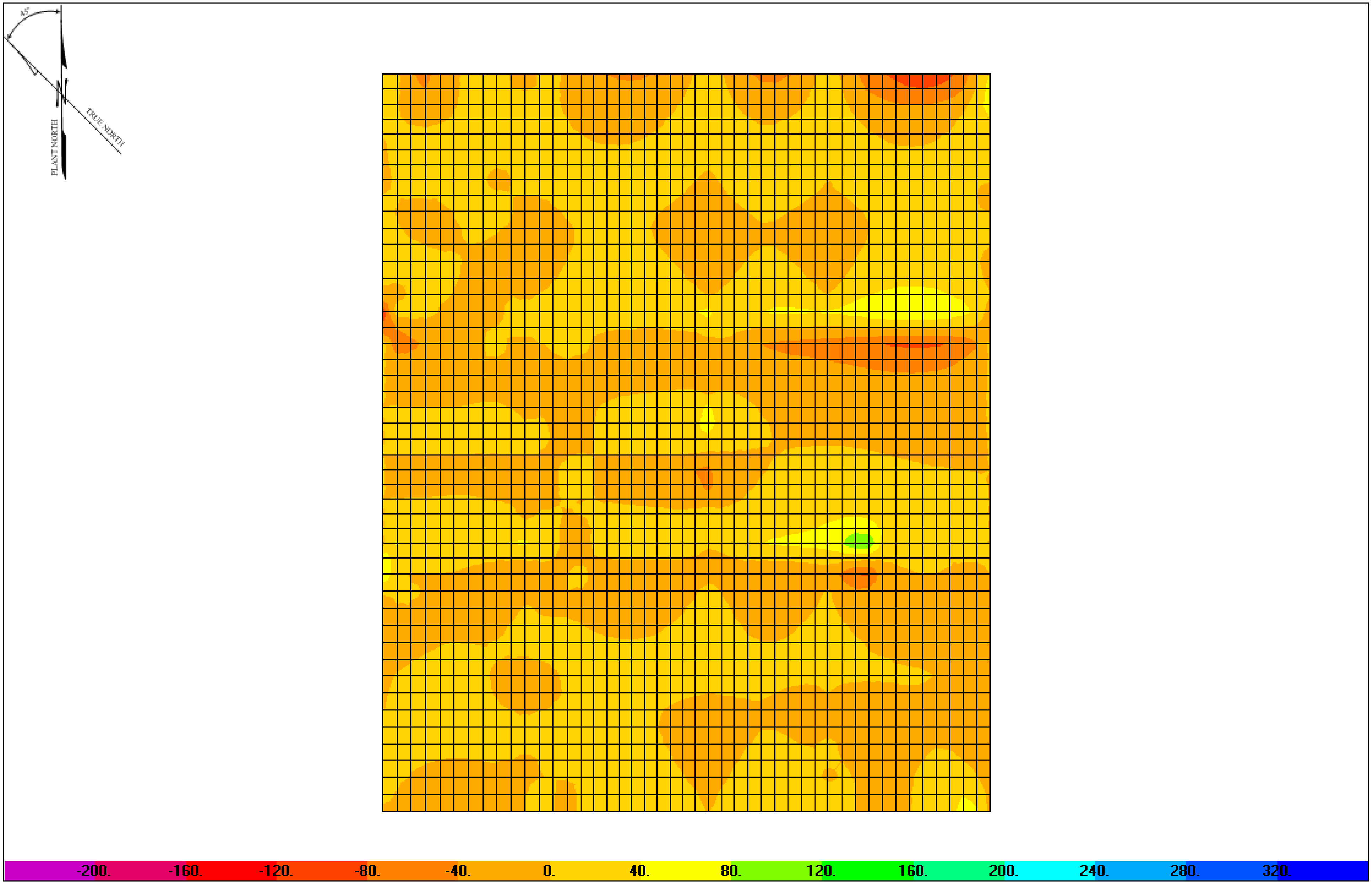
7 ft. Thick Resultant M22 Diagram – Combination 4 (DL+HX+0.4HY-0.4VZ) – kip-ft



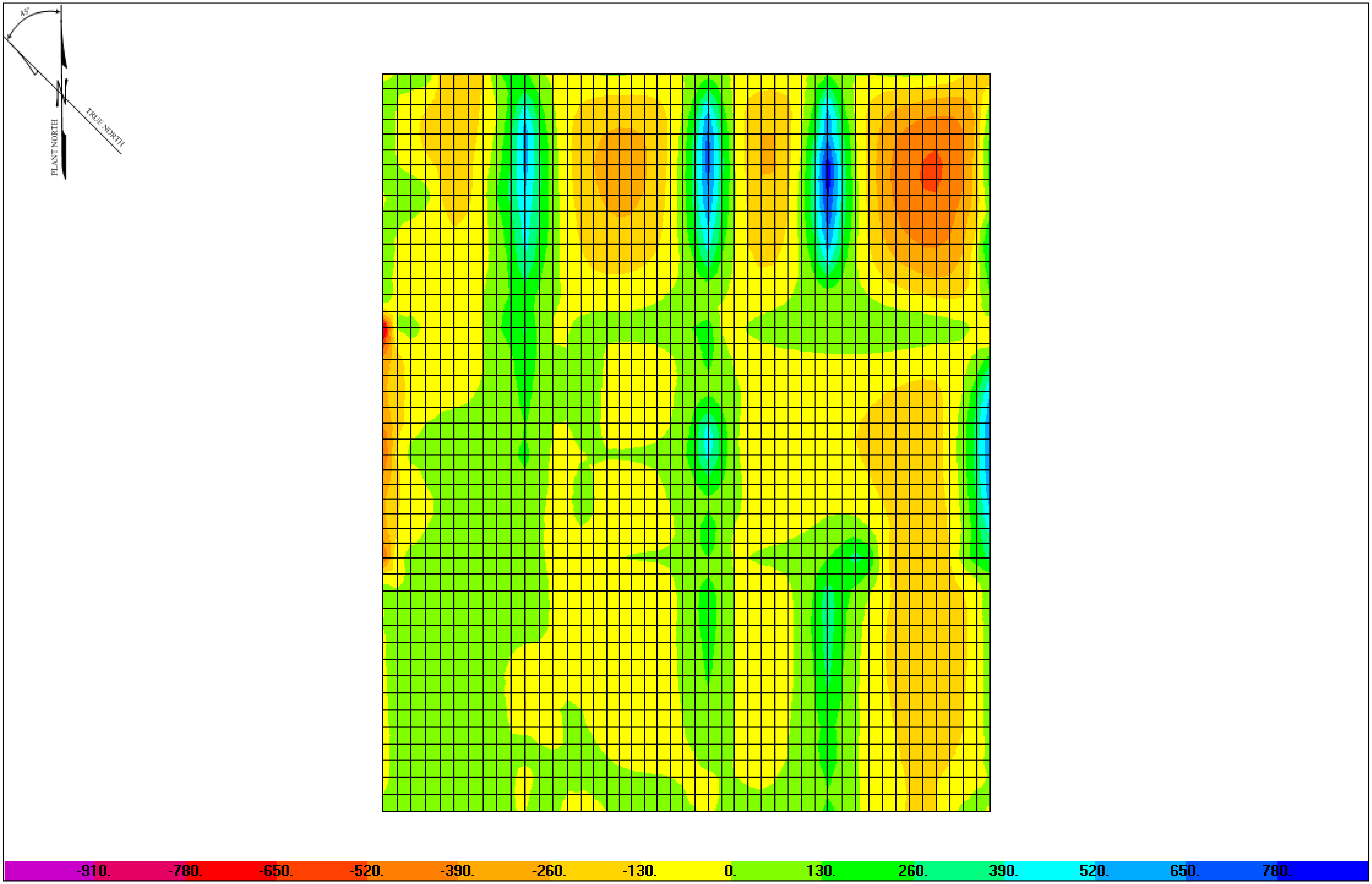
7 ft. Thick Resultant M12 Diagram – Combination 4 (DL+HX+0.4HY-0.4VZ) – kip-ft



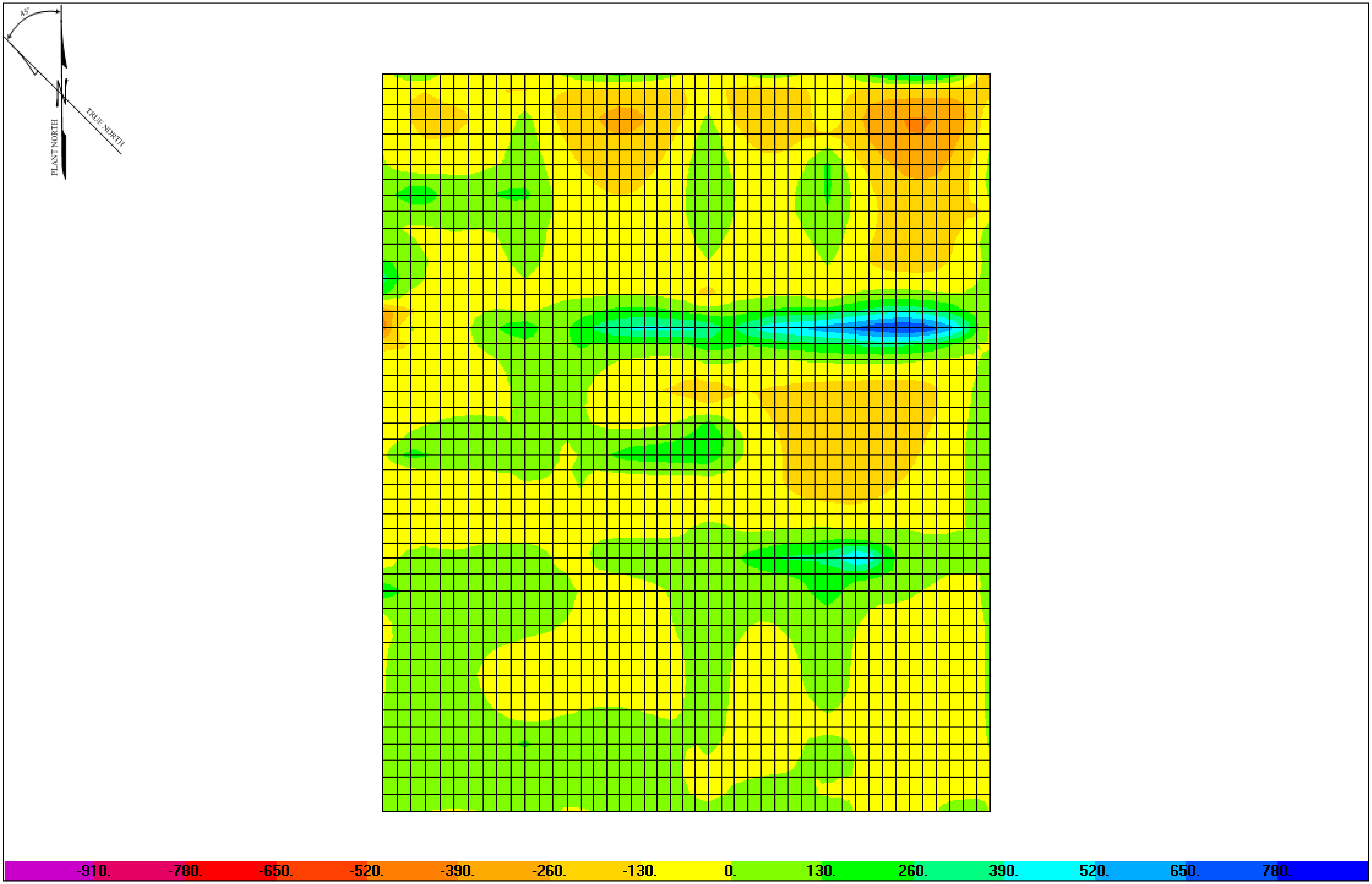
7 ft. Thick Resultant V13 Diagram – Combination 4 (DL+HX+0.4HY-0.4VZ) – kip



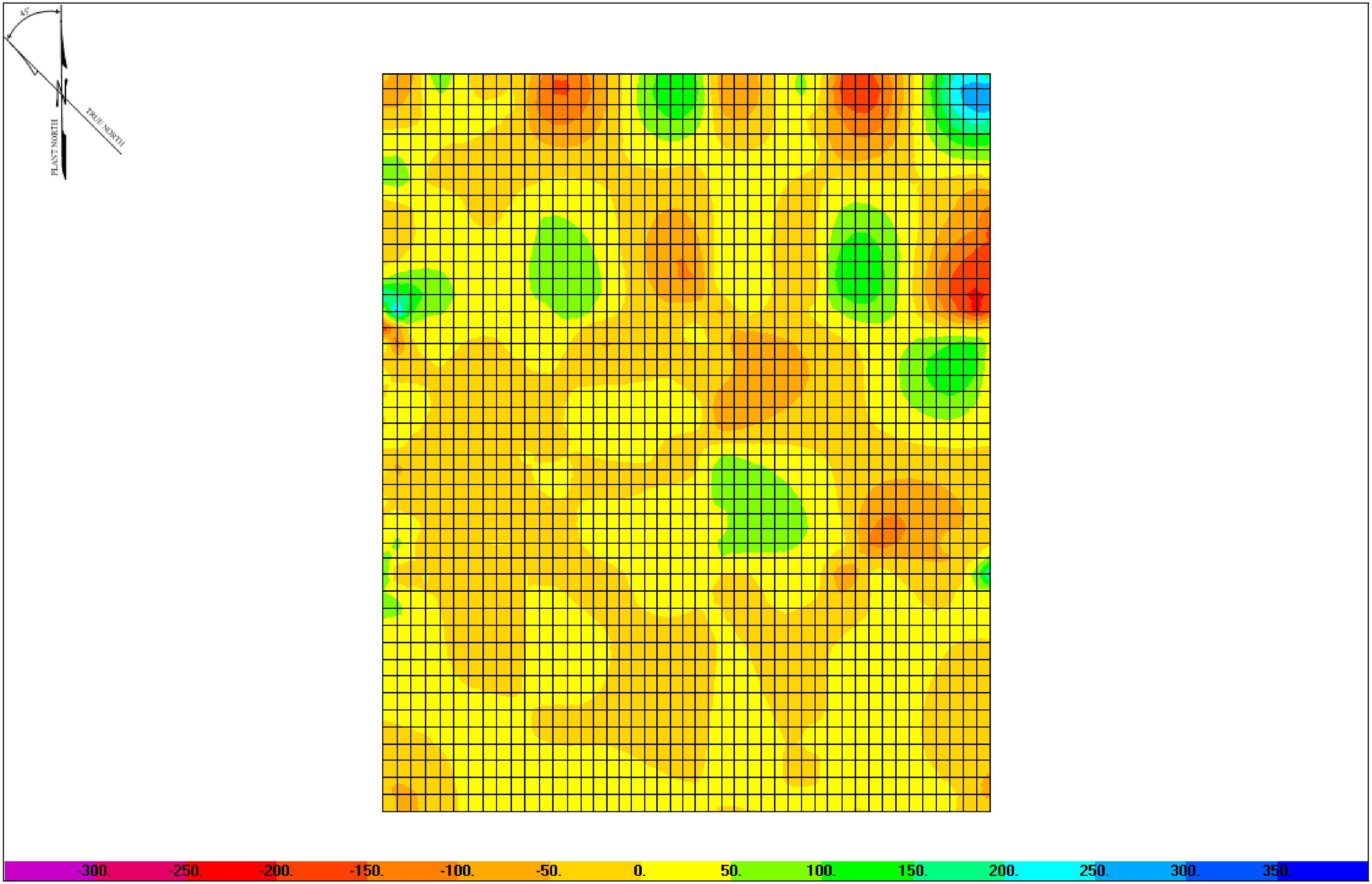
7 ft. Thick Resultant V23 Diagram – Combination 4 (DL+HX+0.4HY-0.4VZ) – kip



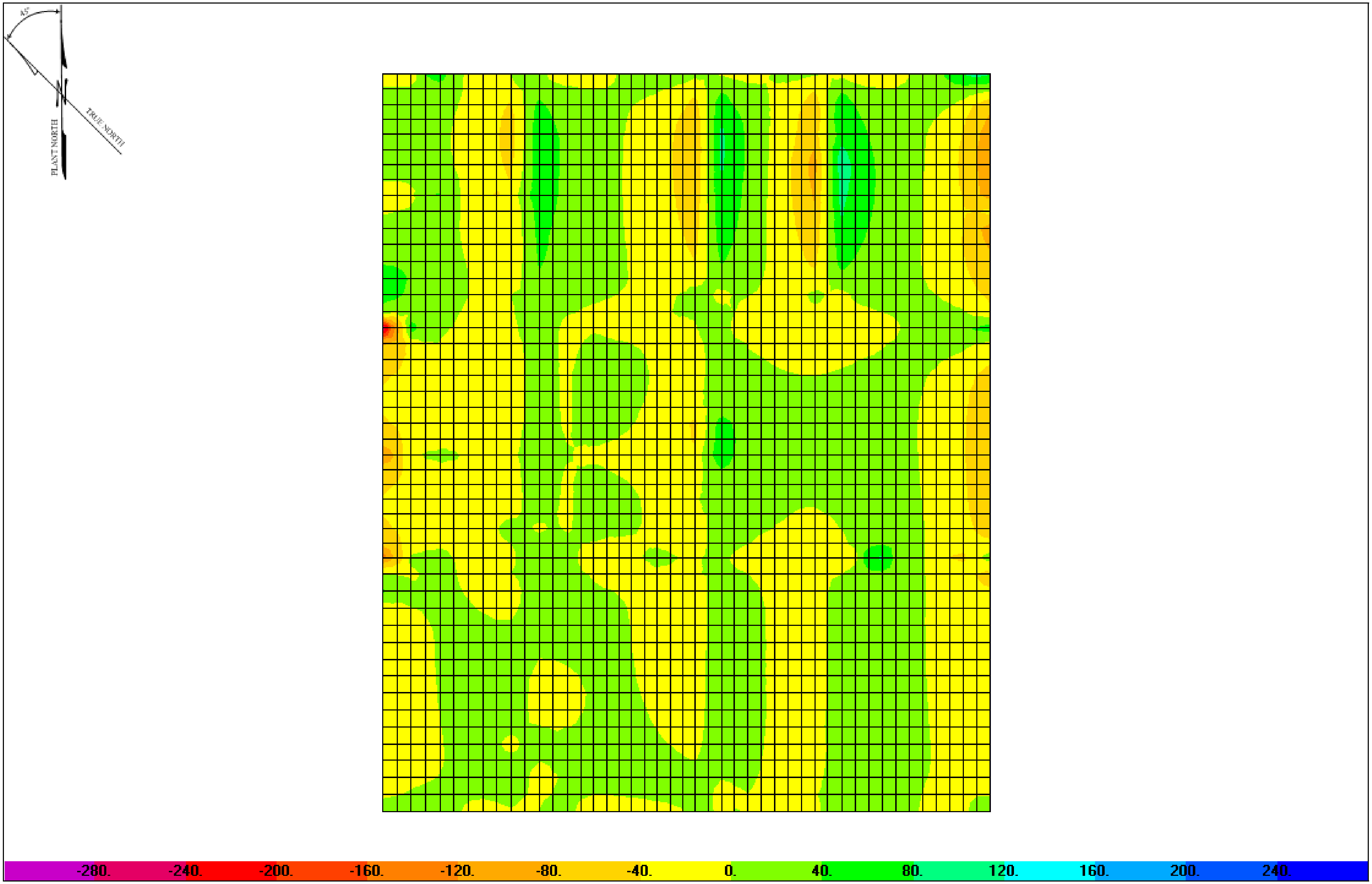
7 ft. Thick Resultant M11 Diagram – Combination 5 (DL+0.4HX+HY-0.4VZ) – kip-ft



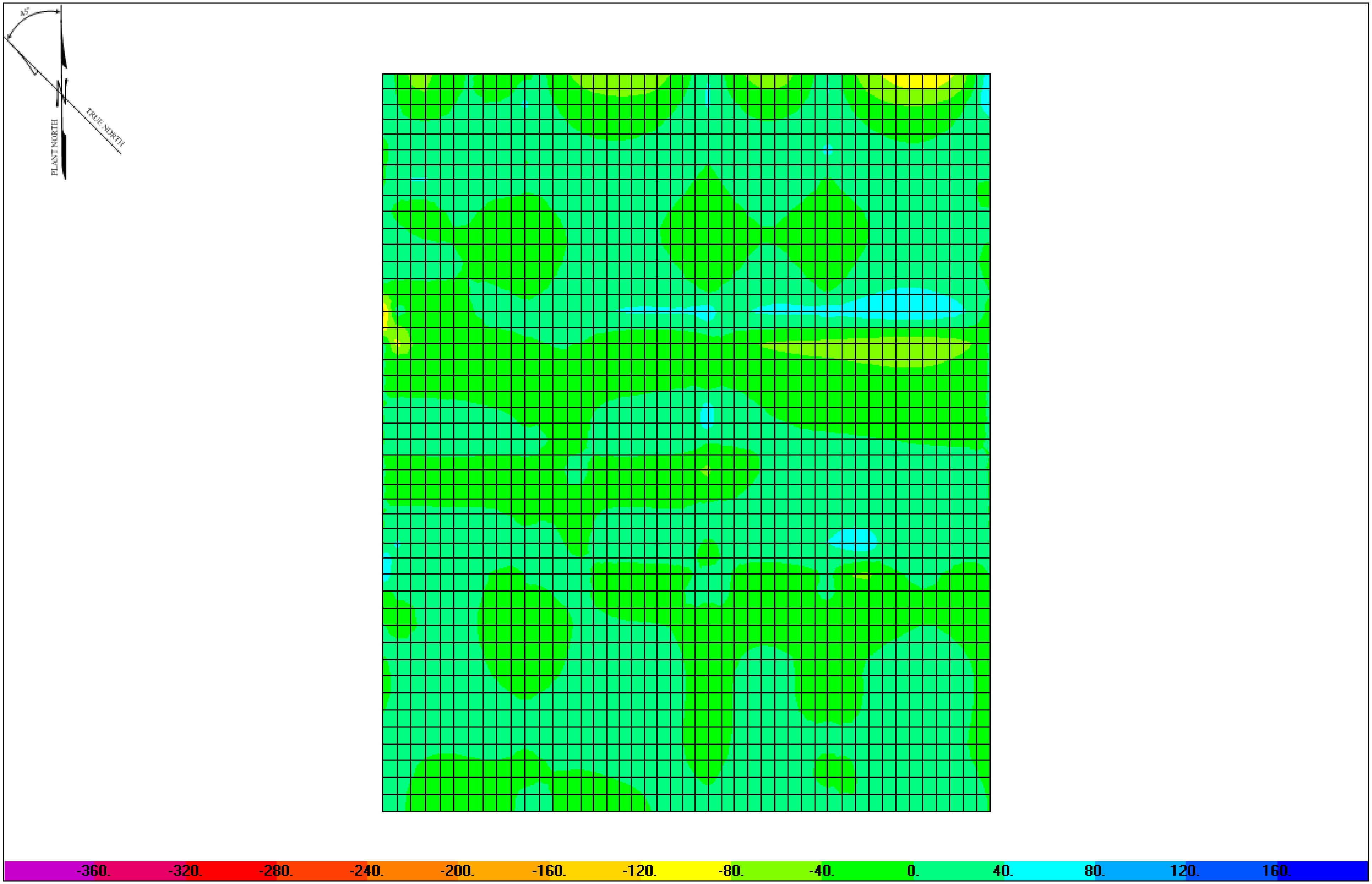
7 ft. Thick Resultant M22 Diagram – Combination 5 (DL+0.4HX+HY-0.4VZ) – kip-ft



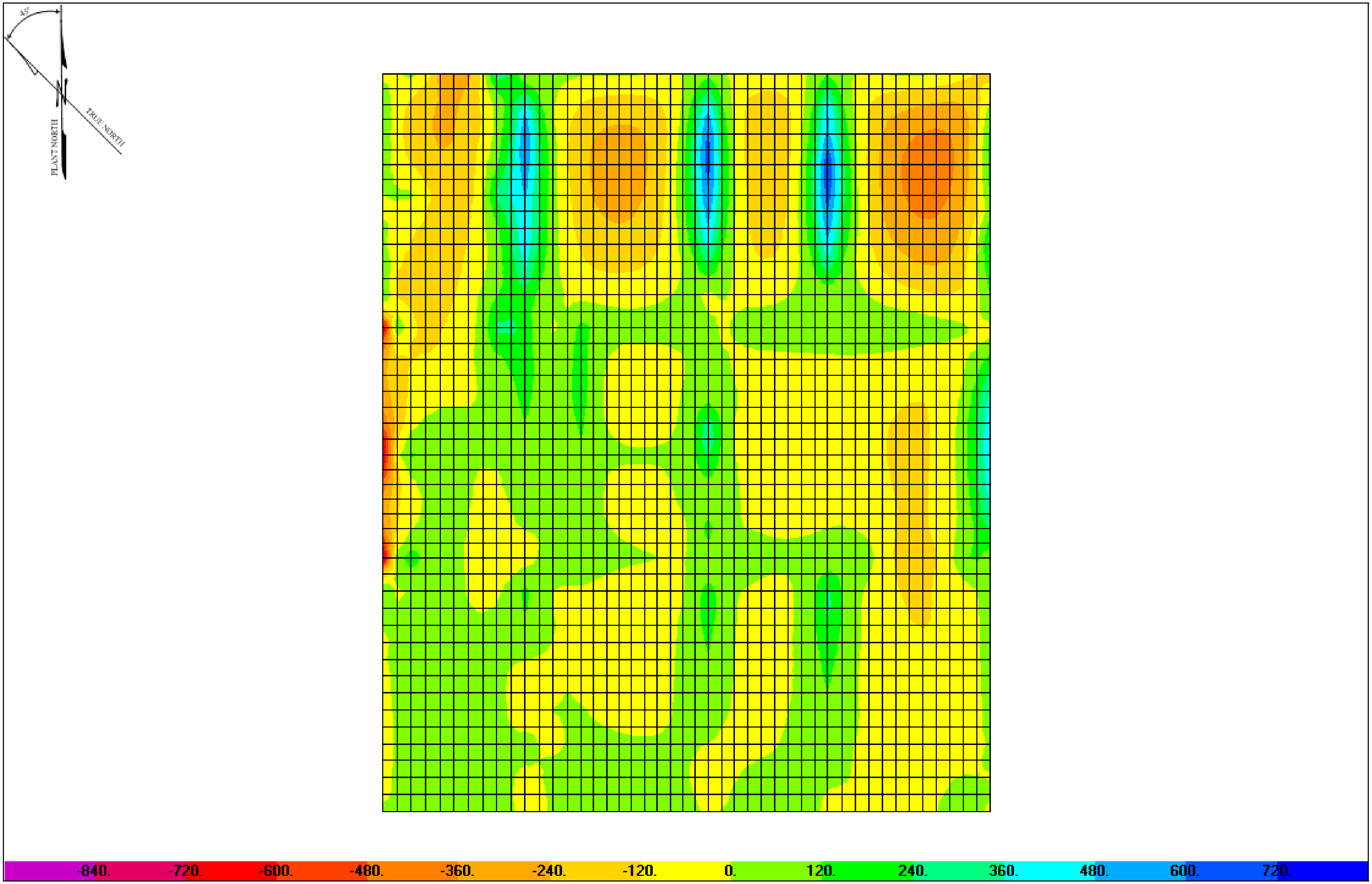
7 ft. Thick Resultant M12 Diagram – Combination 5 (DL+0.4HX+HY-0.4VZ) – kip-ft



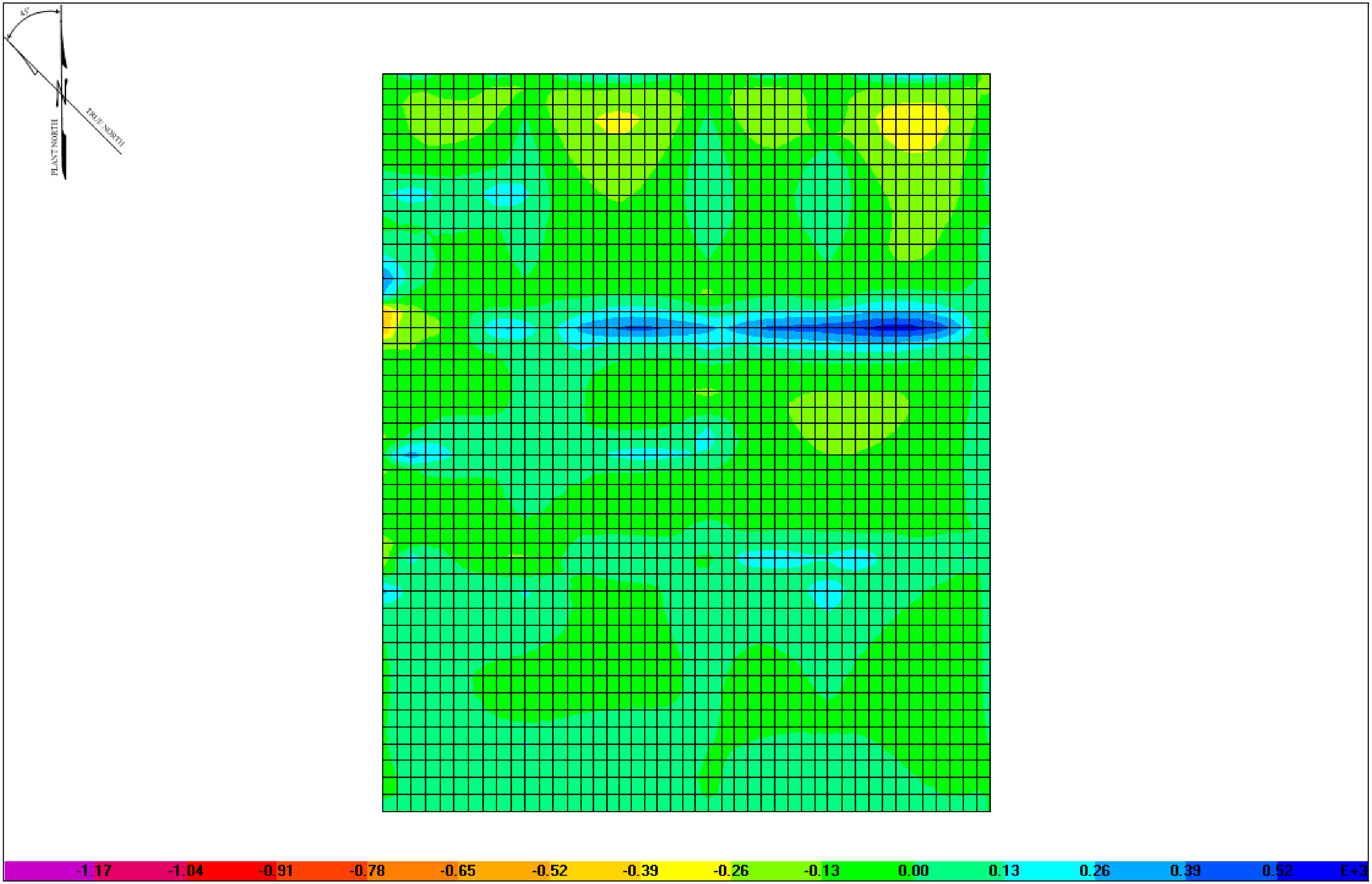
7 ft. Thick Resultant V13 Diagram – Combination 5 (DL+0.4HX+HY-0.4VZ) – kip



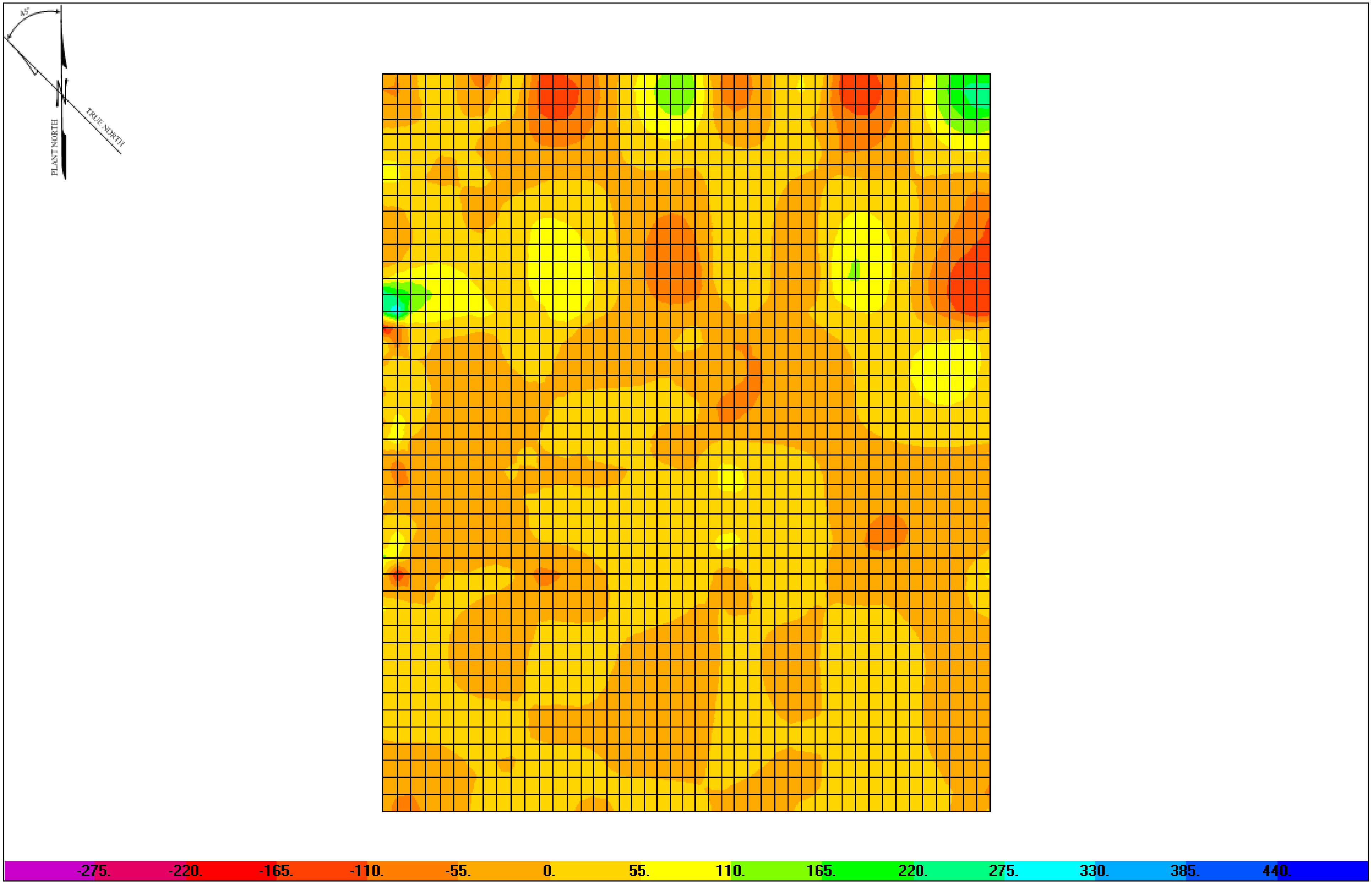
7 ft. Thick Resultant V23 Diagram – Combination 5 (DL+0.4HX+HY-0.4VZ) – kip



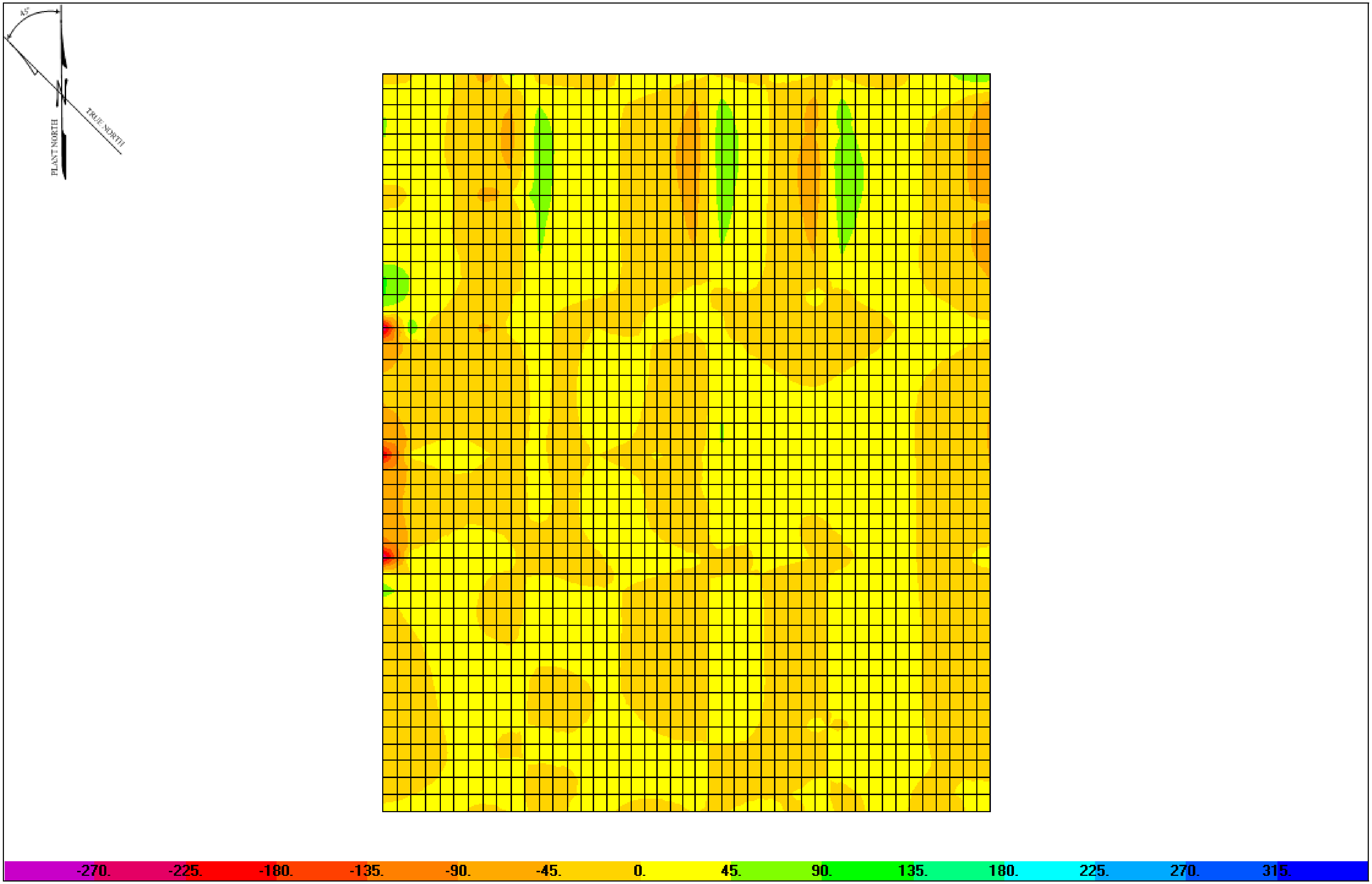
7 ft. Thick Resultant M11 Diagram – Combination 6 (DL-0.4HX+HY-0.4VZ) – kip-ft



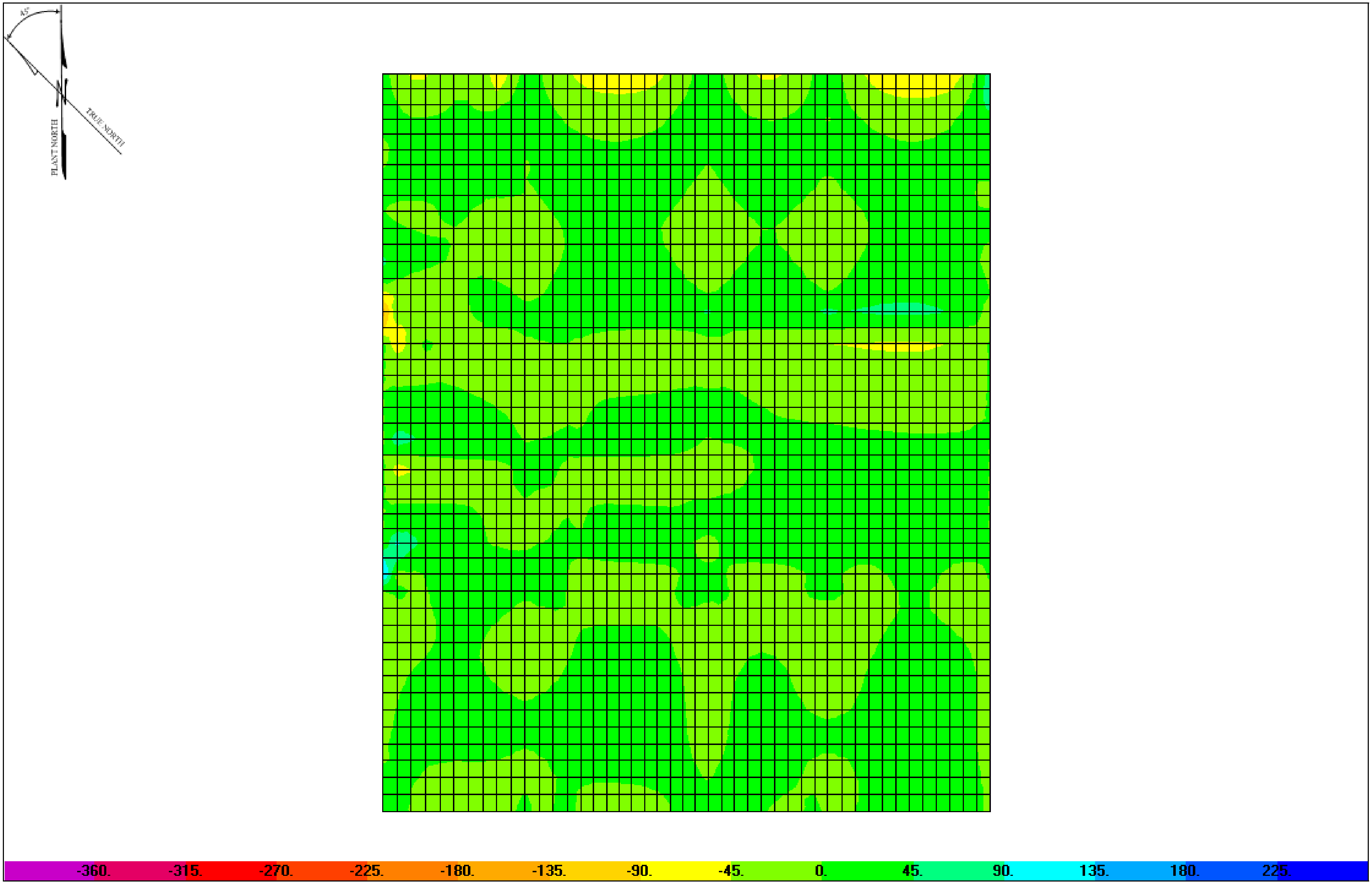
7 ft. Thick Resultant M22 Diagram – Combination 6 (DL-0.4HX+HY-0.4VZ) – kip-ft



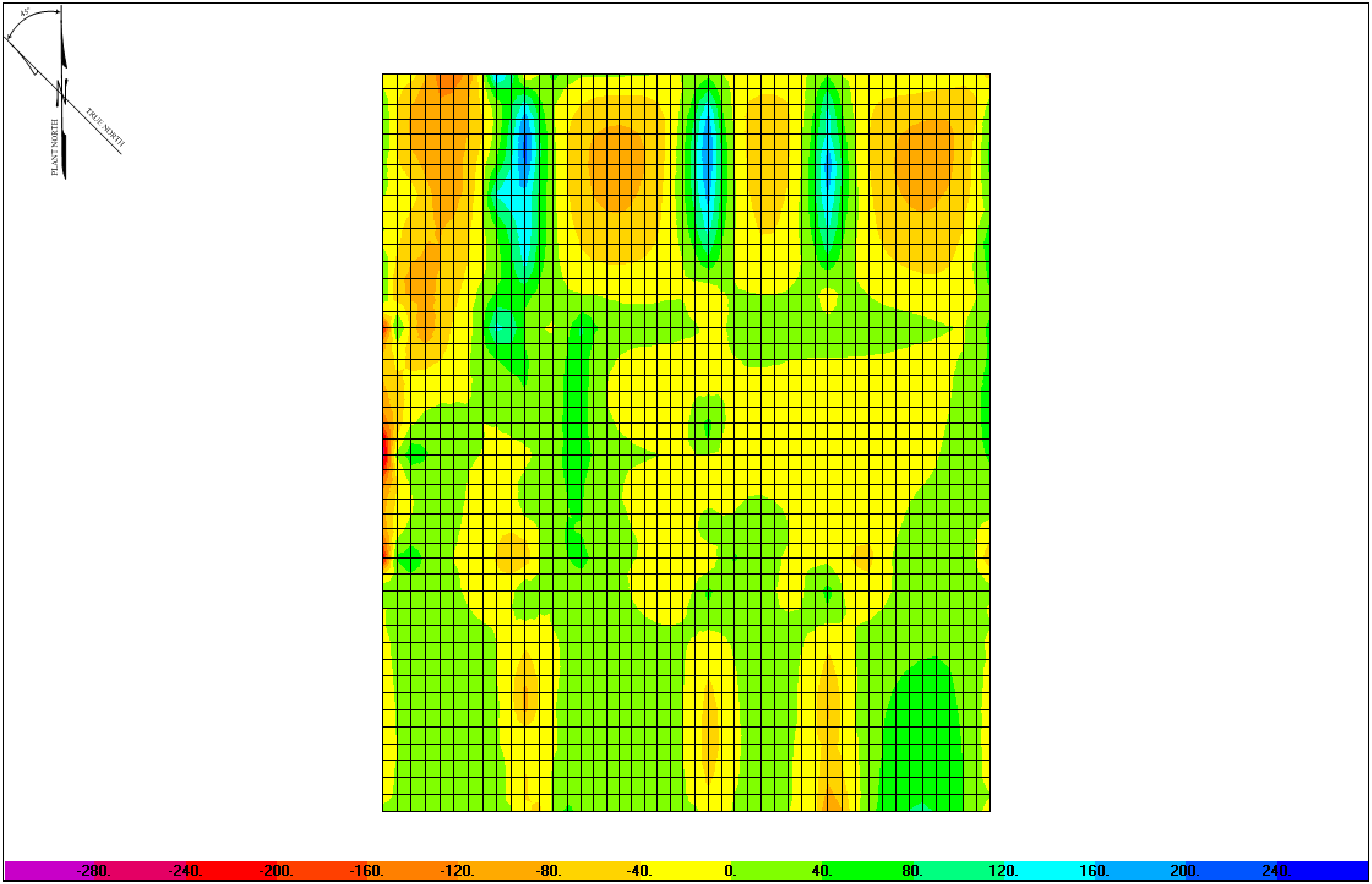
7 ft. Thick Resultant M12 Diagram – Combination 6 (DL-0.4HX+HY-0.4VZ) – kip-ft



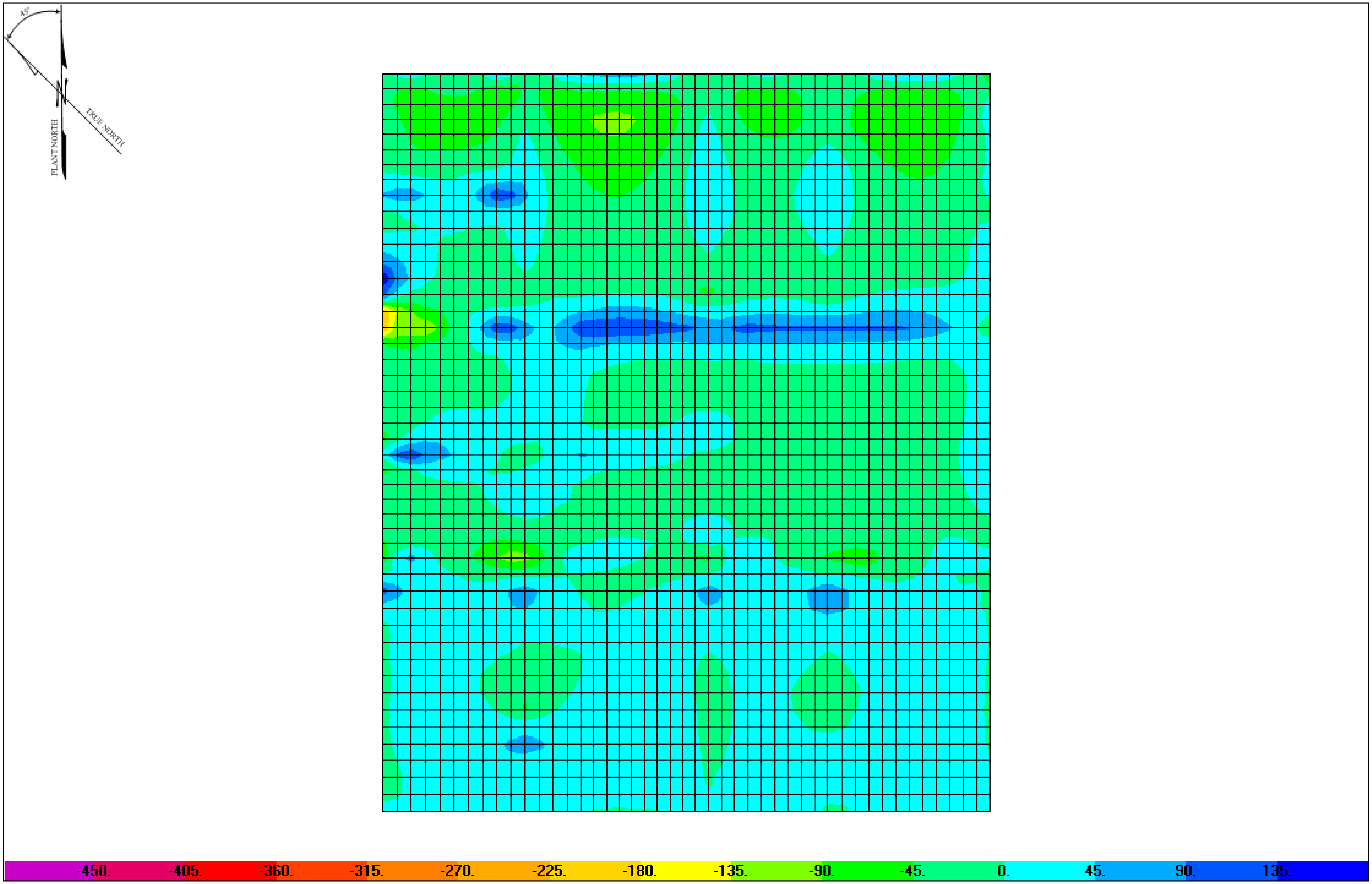
7 ft. Thick Resultant V13 Diagram – Combination 6 (DL-0.4HX+HY-0.4VZ) – kip



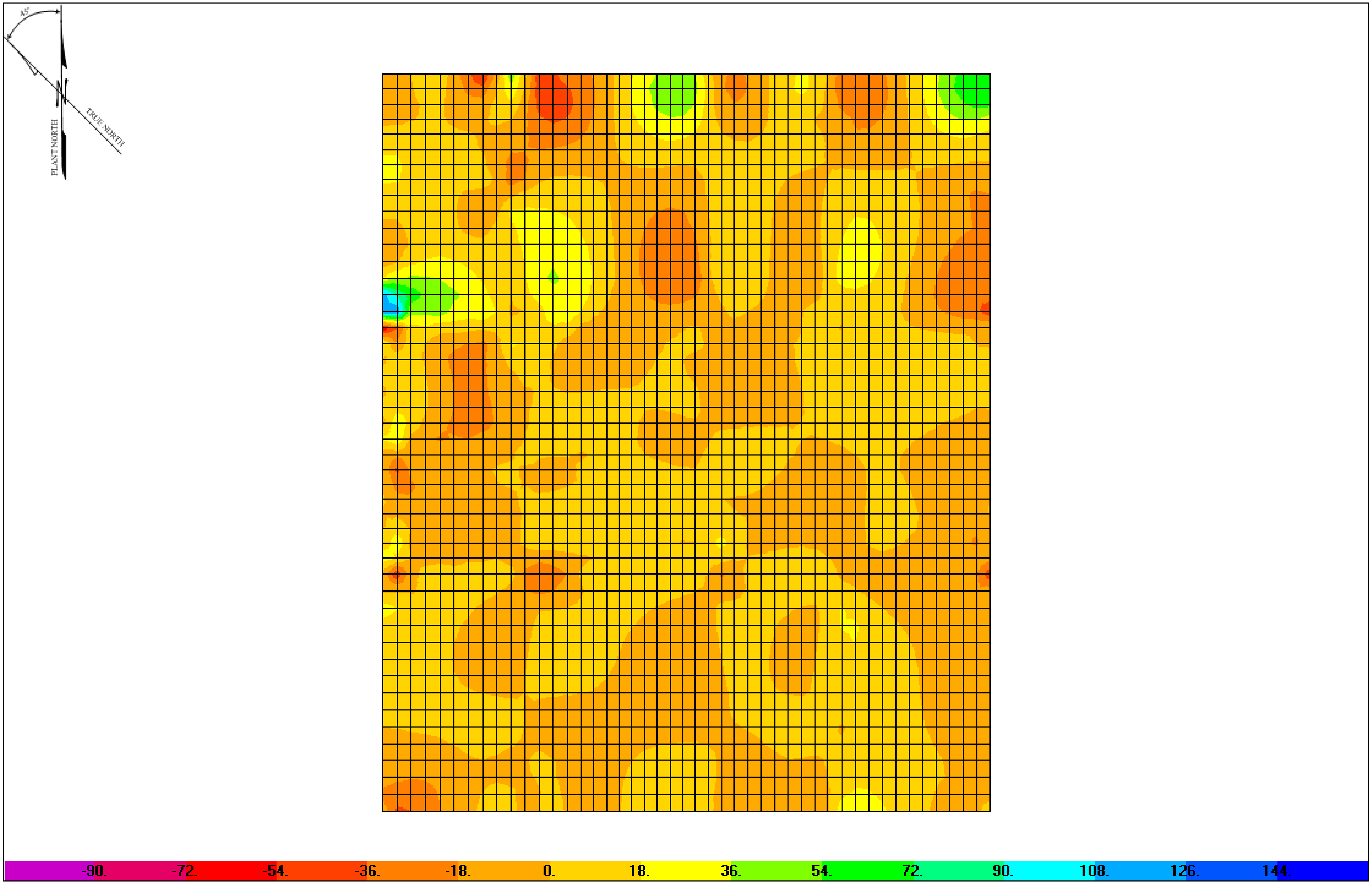
7 ft. Thick Resultant V23 Diagram – Combination 6 (DL-0.4HX+HY-0.4VZ) – kip



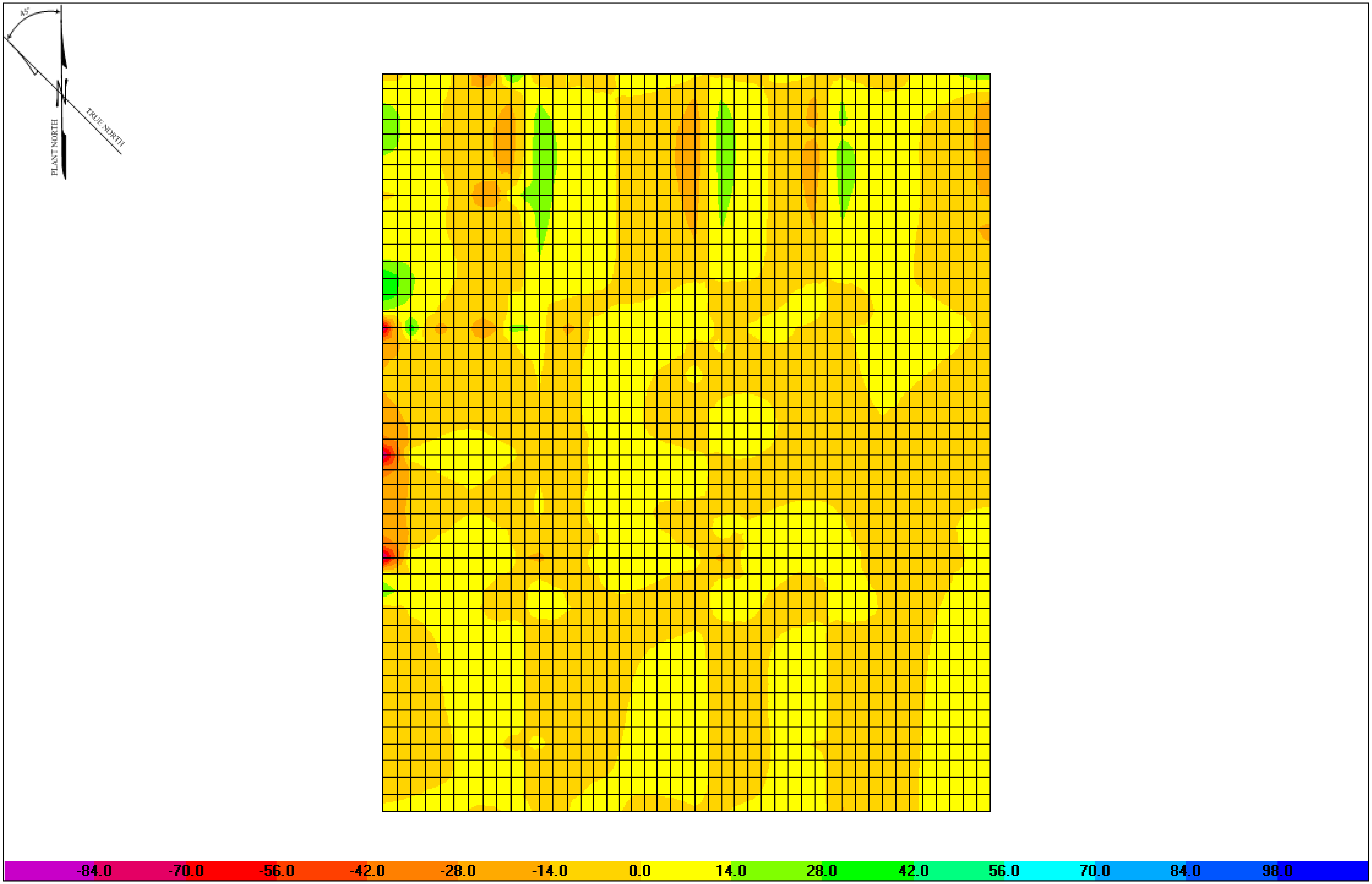
7 ft. Thick Resultant M11 Diagram – Combination 7 (DL-0.4HX+0.4HY+VZ) – kip-ft



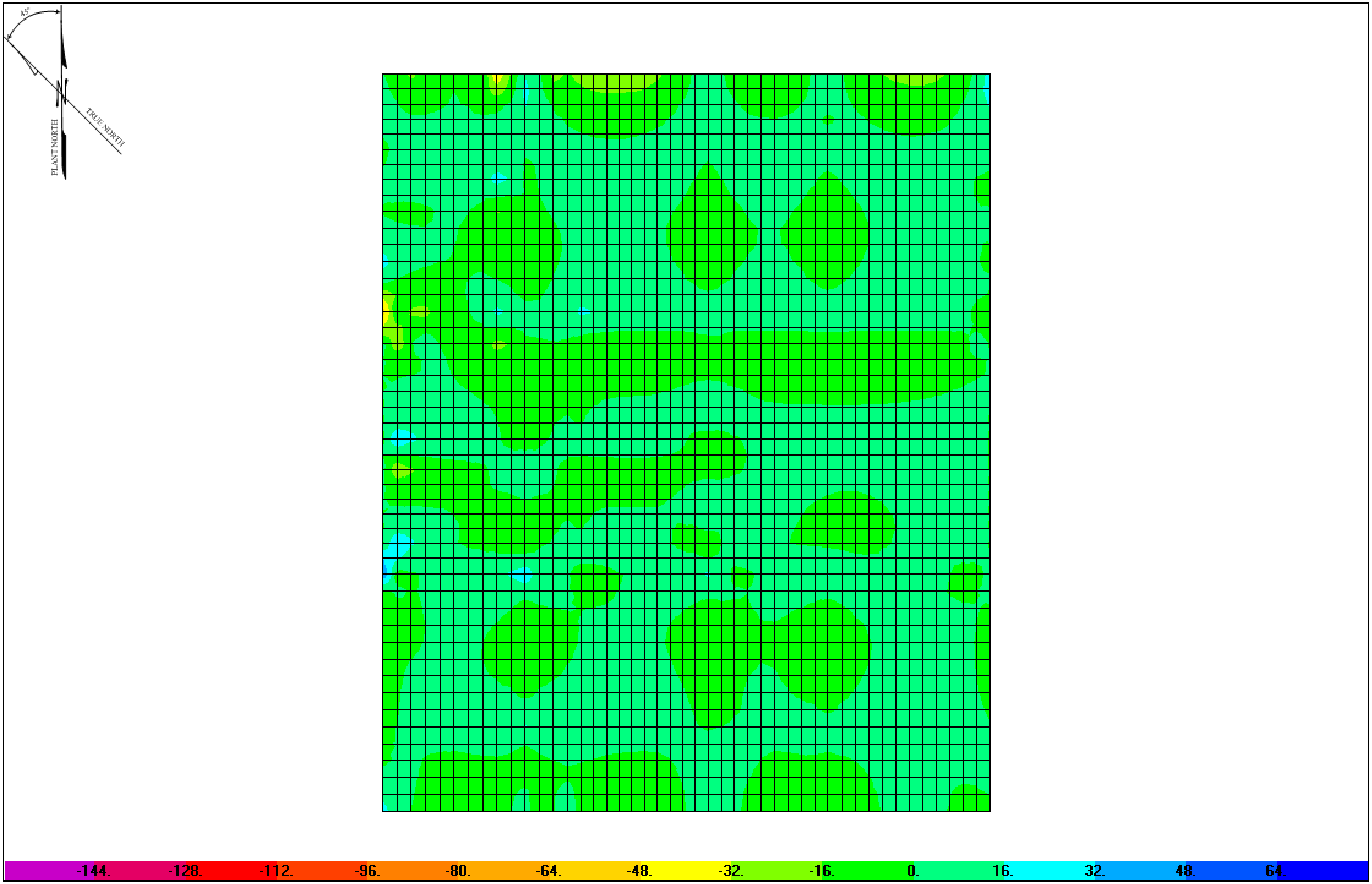
7 ft. Thick Resultant M22 Diagram – Combination 7 (DL-0.4HX+0.4HY+VZ) – kip-ft



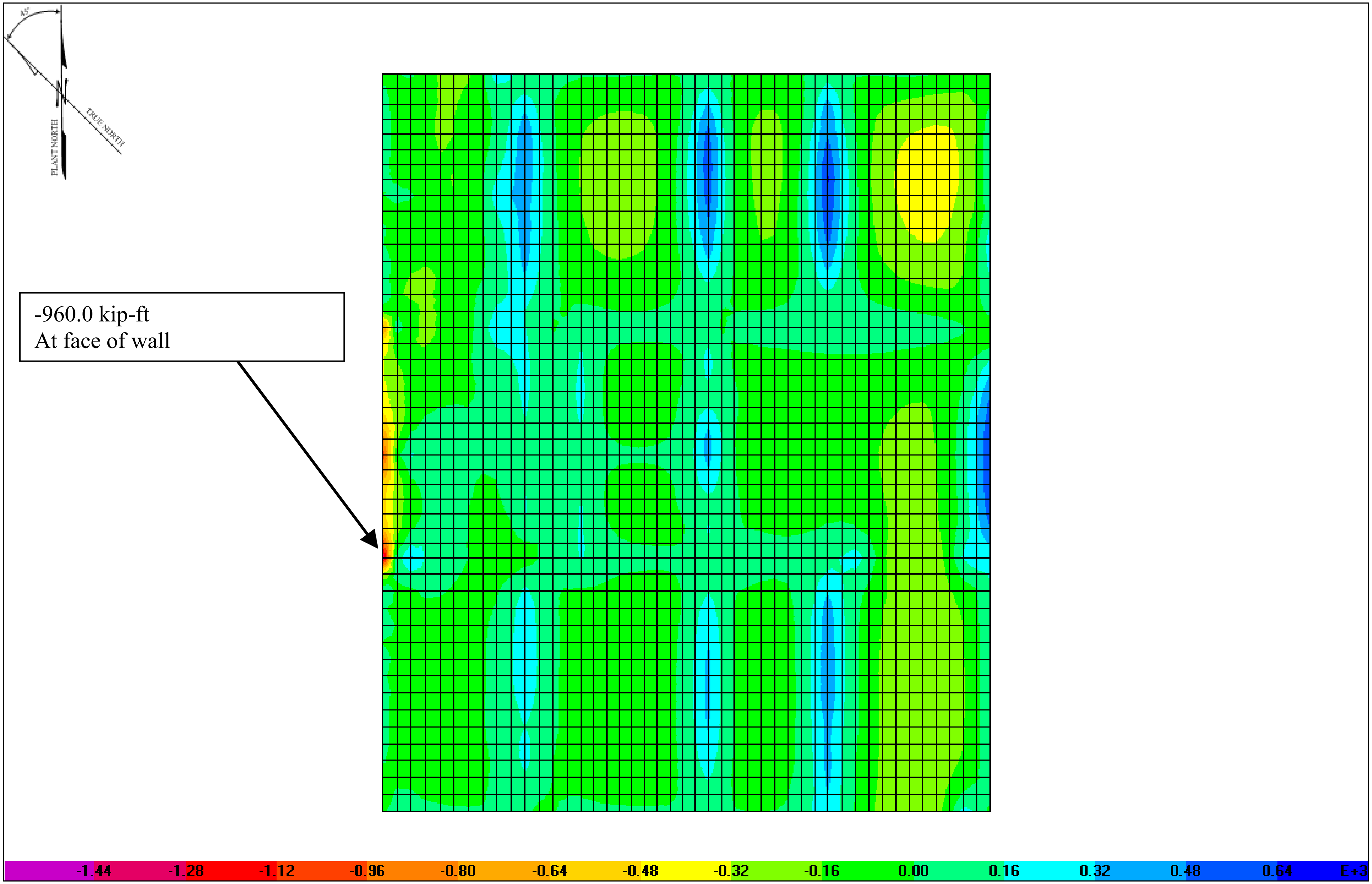
7 ft. Thick Resultant M12 Diagram – Combination 7 (DL-0.4HX+0.4HY+VZ) – kip-ft



7 ft. Thick Resultant V13 Diagram – Combination 7 (DL-0.4HX+0.4HY+VZ) – kip

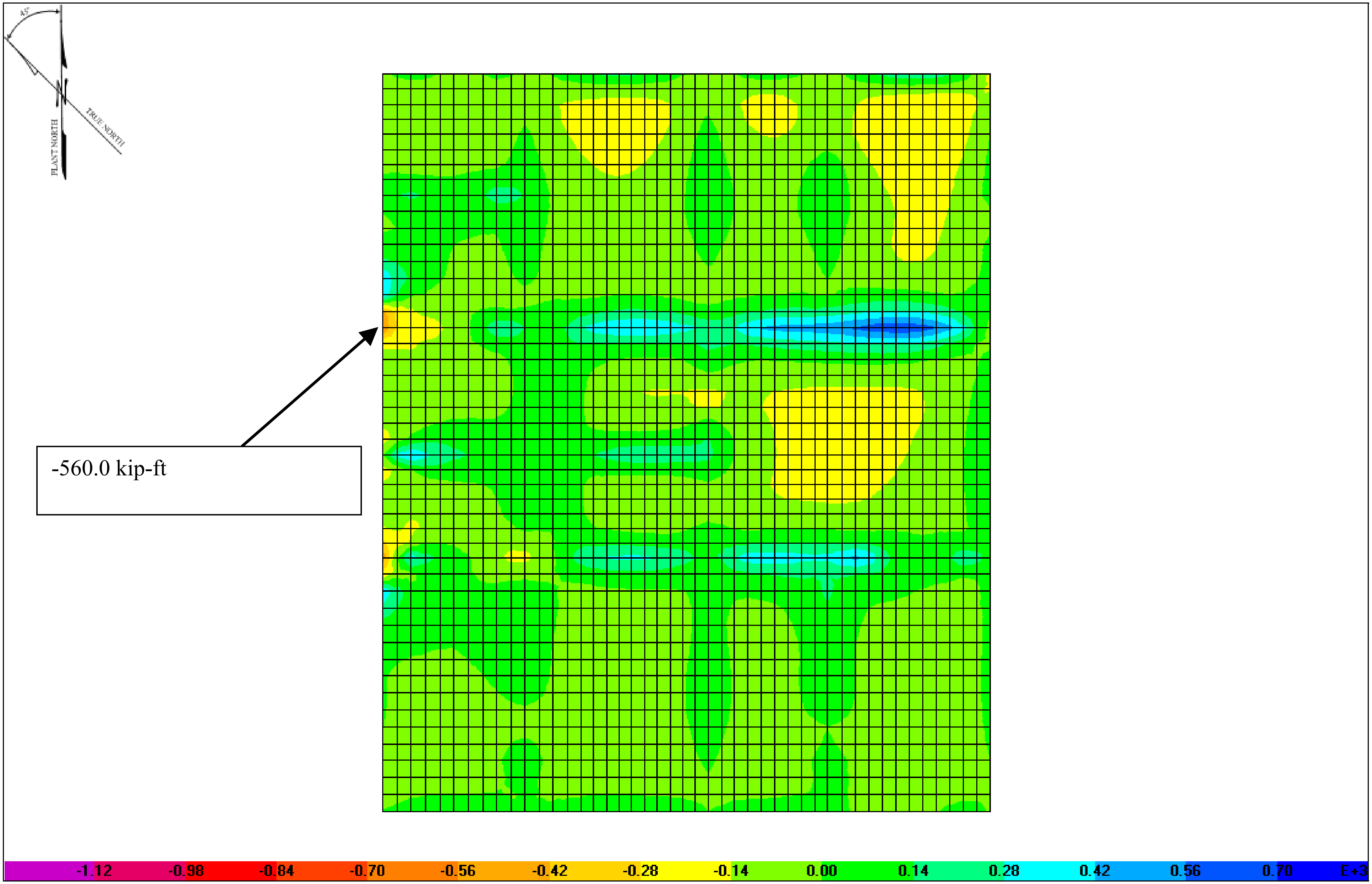


7 ft. Thick Resultant V23 Diagram – Combination 7 (DL-0.4HX+0.4HY+VZ) – kip

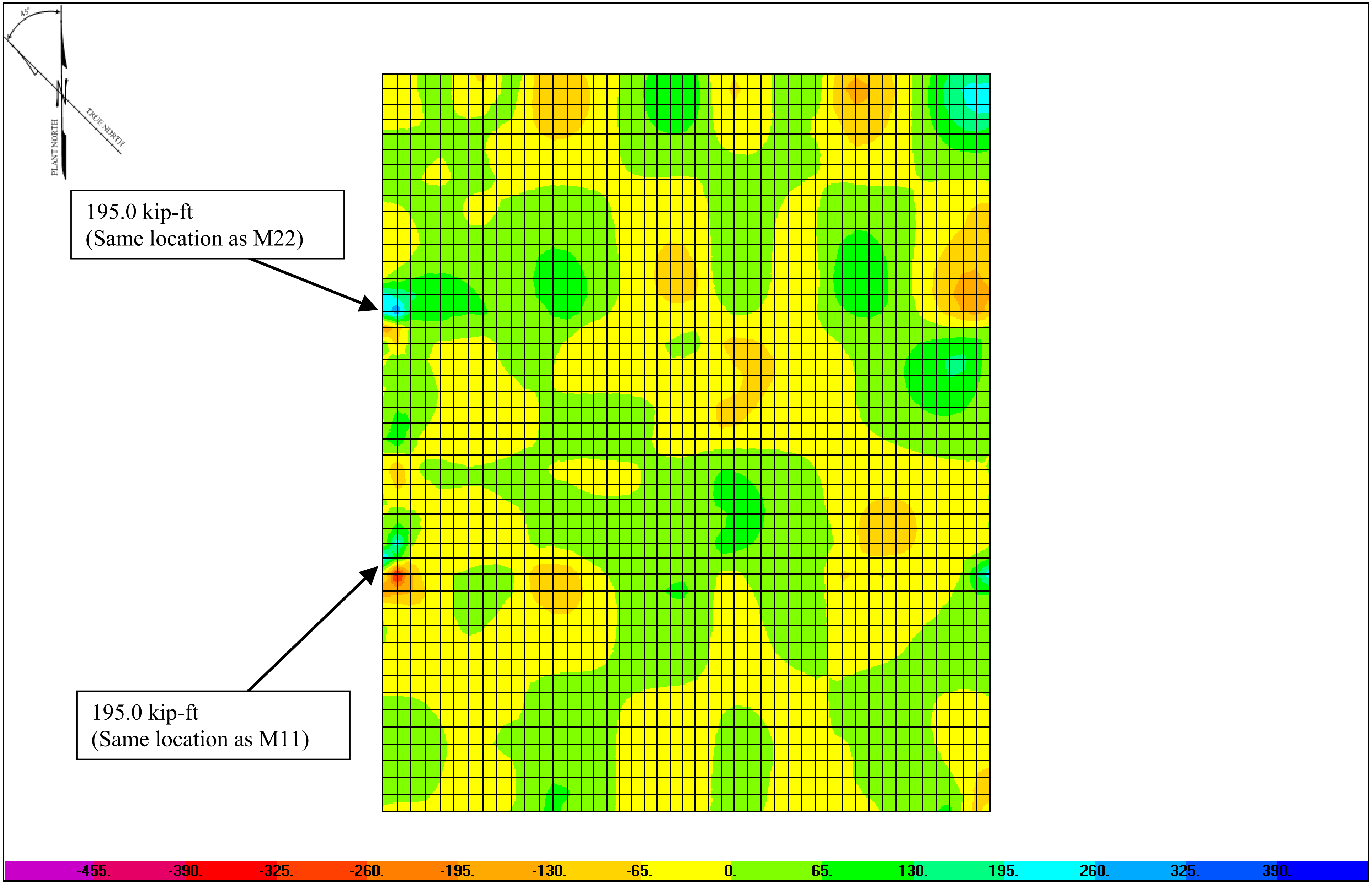


-960.0 kip-ft
At face of wall

7 ft. Thick Resultant M11 Diagram – Combination 8 (DL-0.4HX+0.4HY-VZ) – kip-ft



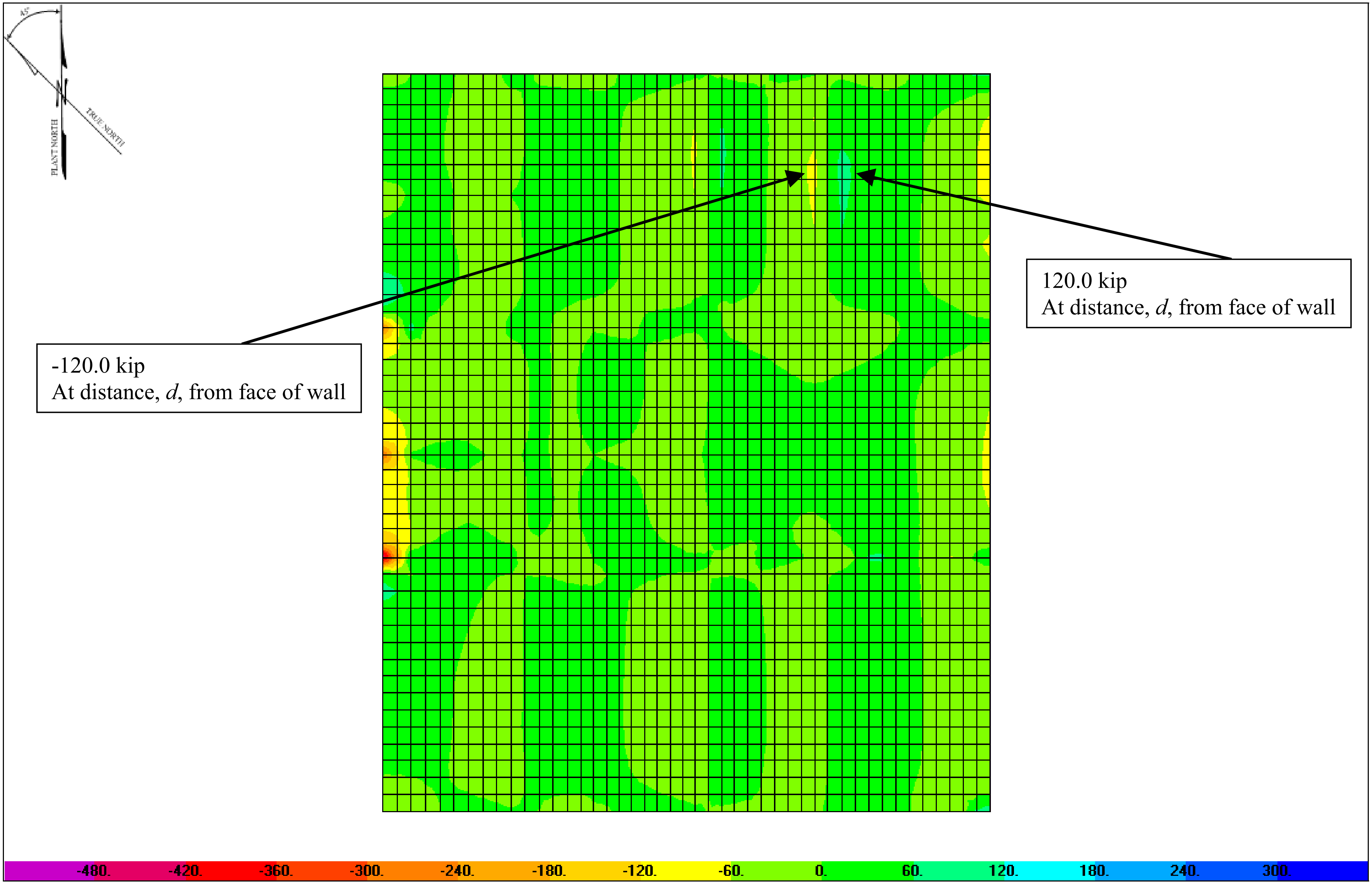
7 ft. Thick Resultant M22 Diagram – Combination 8 (DL-0.4HX+0.4HY-VZ) – kip-ft



195.0 kip-ft
(Same location as M22)

195.0 kip-ft
(Same location as M11)

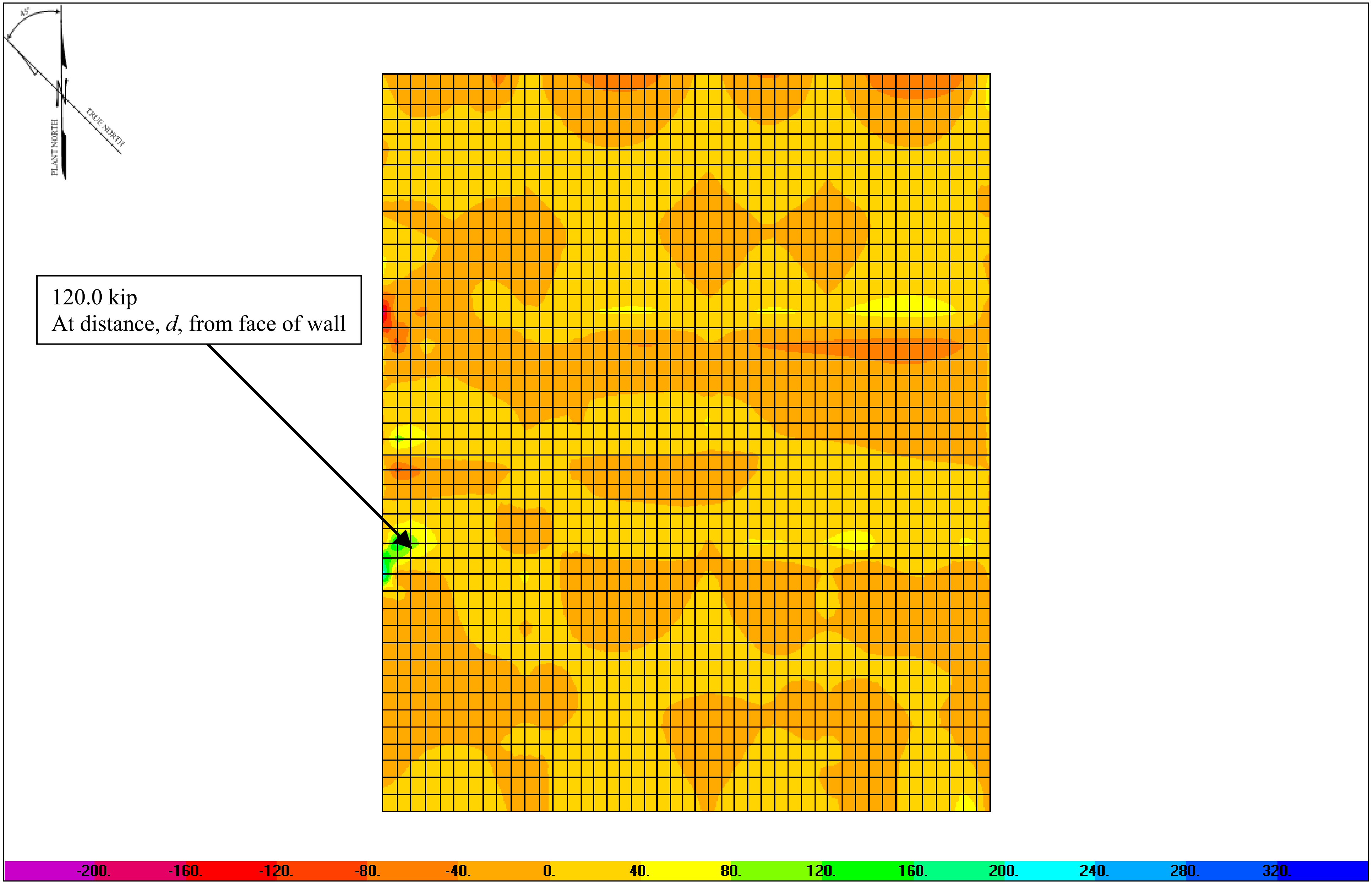
7 ft. Thick Resultant M12 Diagram – Combination 8 (DL-0.4HX+0.4HY-VZ) – kip-ft



-120.0 kip
At distance, *d*, from face of wall

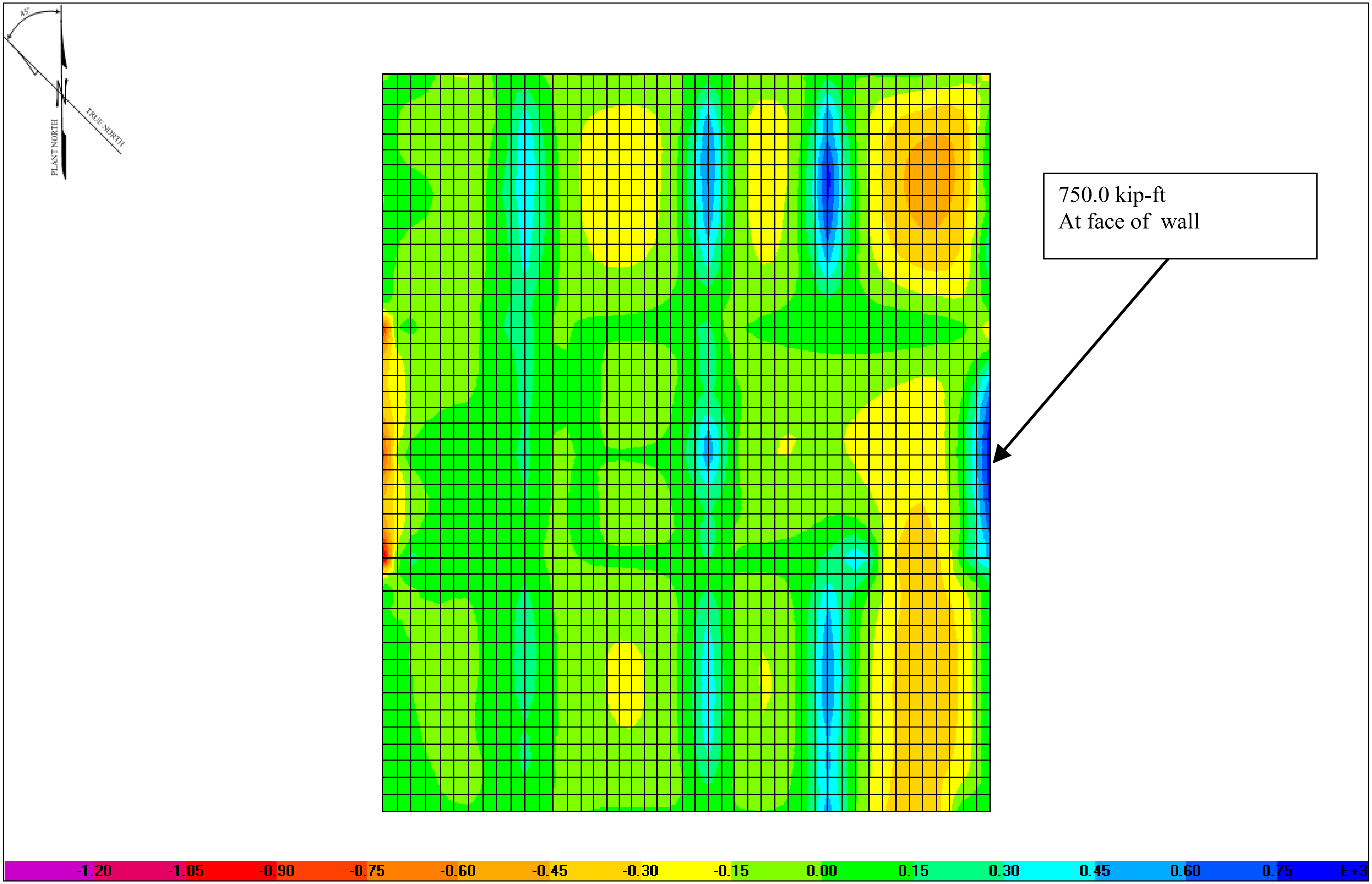
120.0 kip
At distance, *d*, from face of wall

7 ft. Thick Resultant V13 Diagram – Combination 8 (DL-0.4HX+0.4HY-VZ) – kip

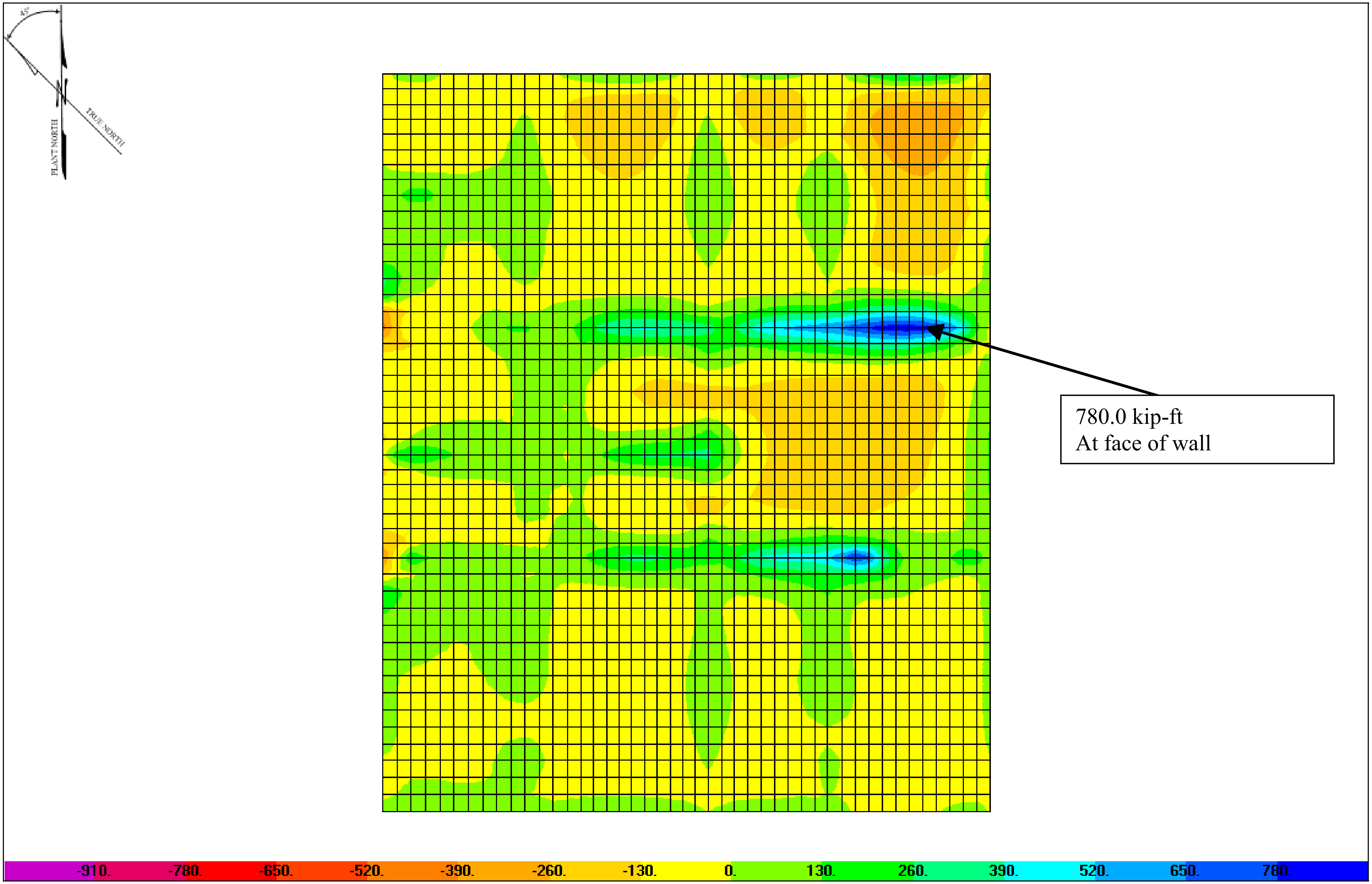


120.0 kip
At distance, *d*, from face of wall

7 ft. Thick Resultant V23 Diagram – Combination 8 (DL-0.4HX+0.4HY-VZ) – kip

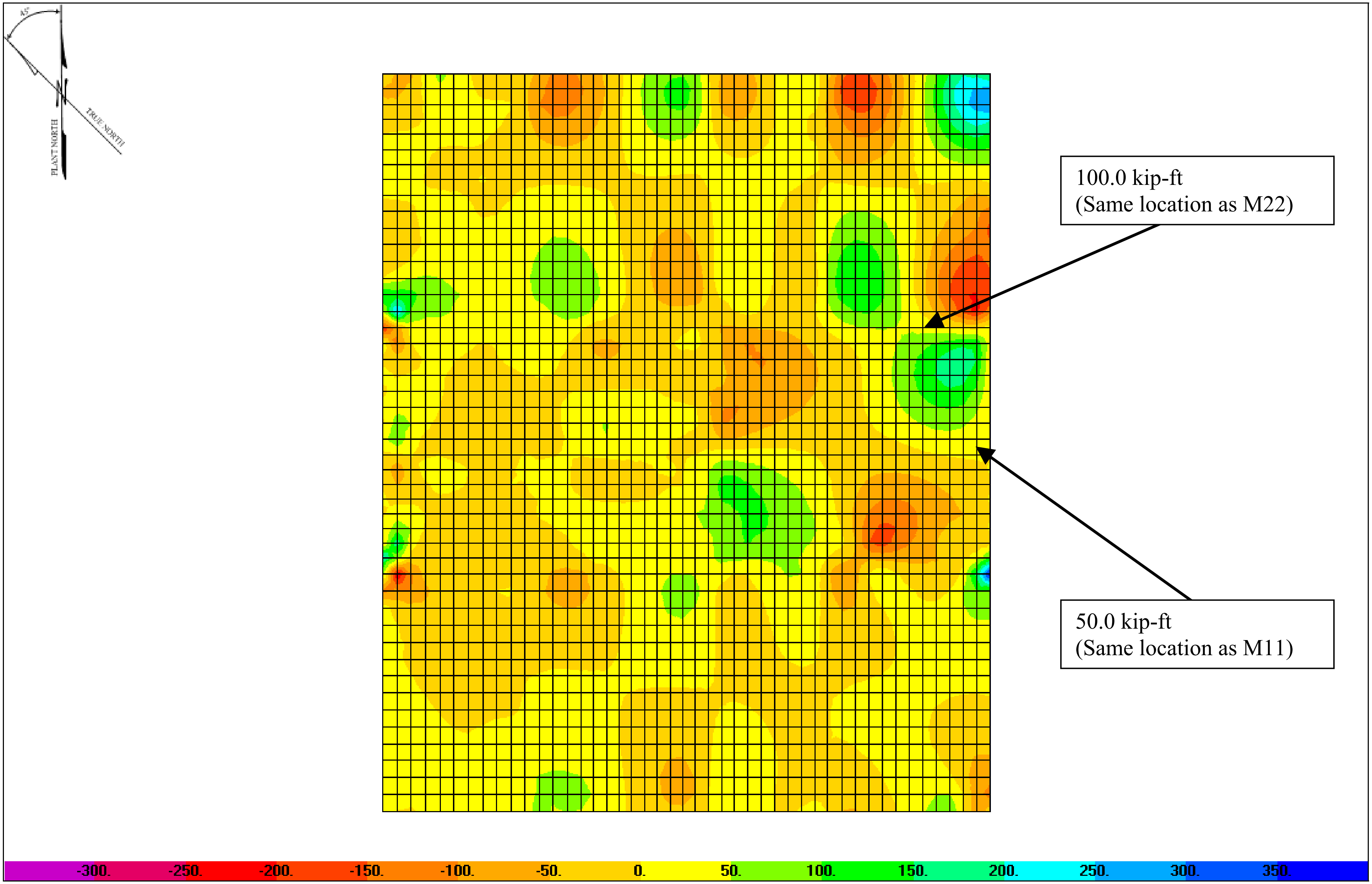


7 ft. Thick Resultant M11 Diagram – Combination 9 (DL+0.4HX+0.4HY-VZ) – kip-ft



780.0 kip-ft
At face of wall

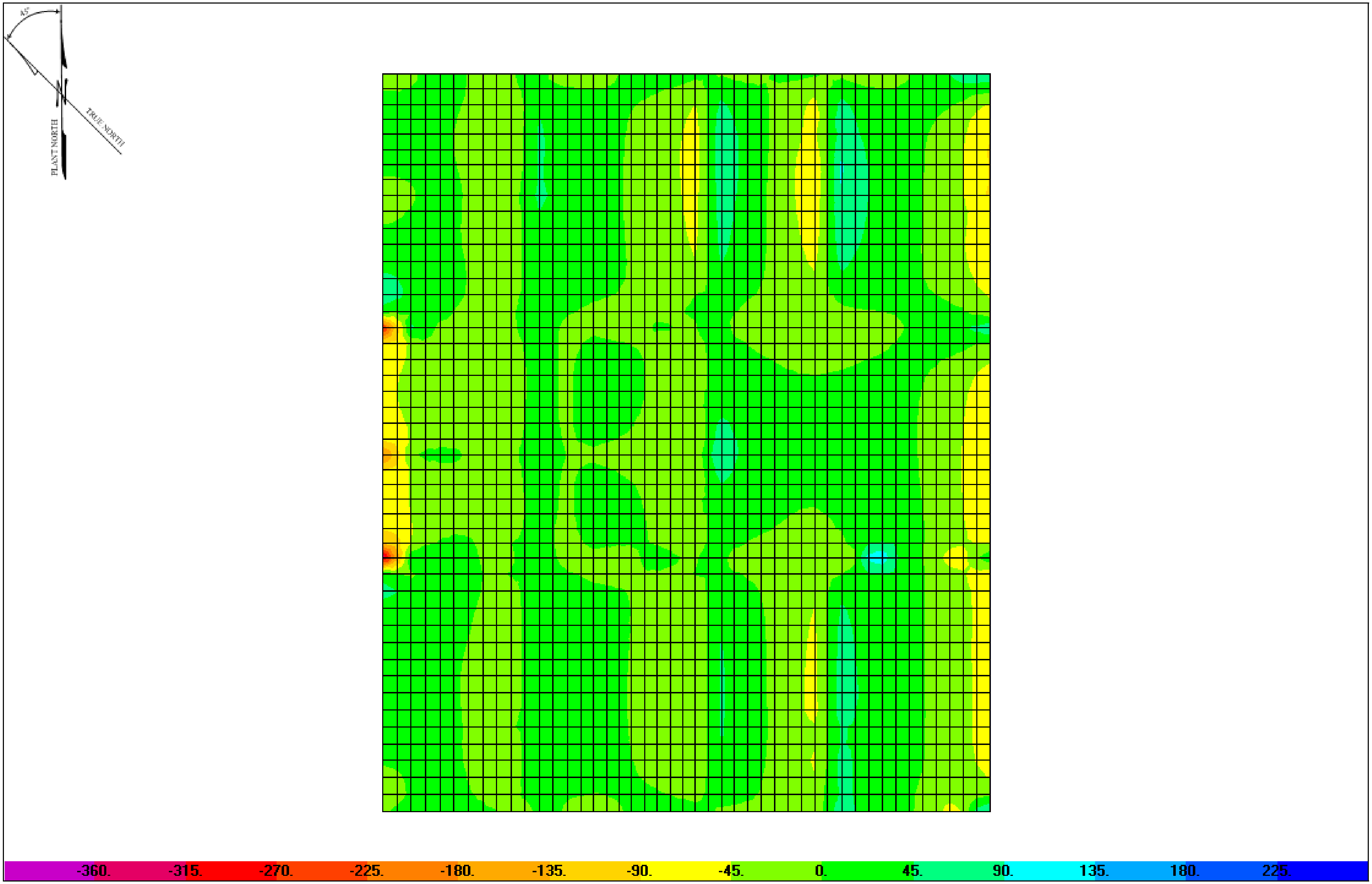
7 ft. Thick Resultant M22 Diagram – Combination 9 (DL+0.4HX+0.4HY-VZ) – kip-ft



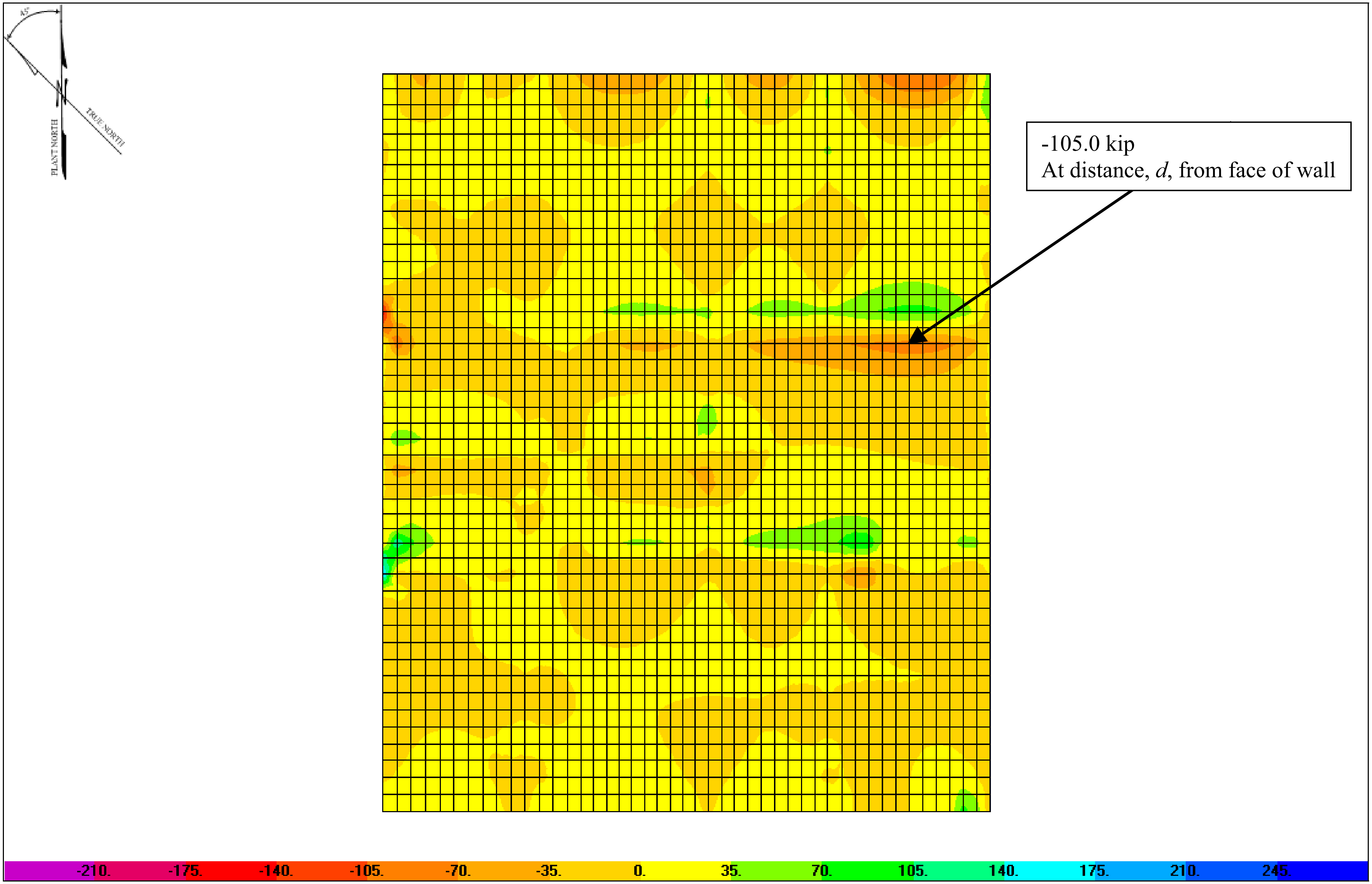
100.0 kip-ft
(Same location as M22)

50.0 kip-ft
(Same location as M11)

7 ft. Thick Resultant M12 Diagram – Combination 9 (DL+0.4HX+0.4HY-VZ) – kip-ft

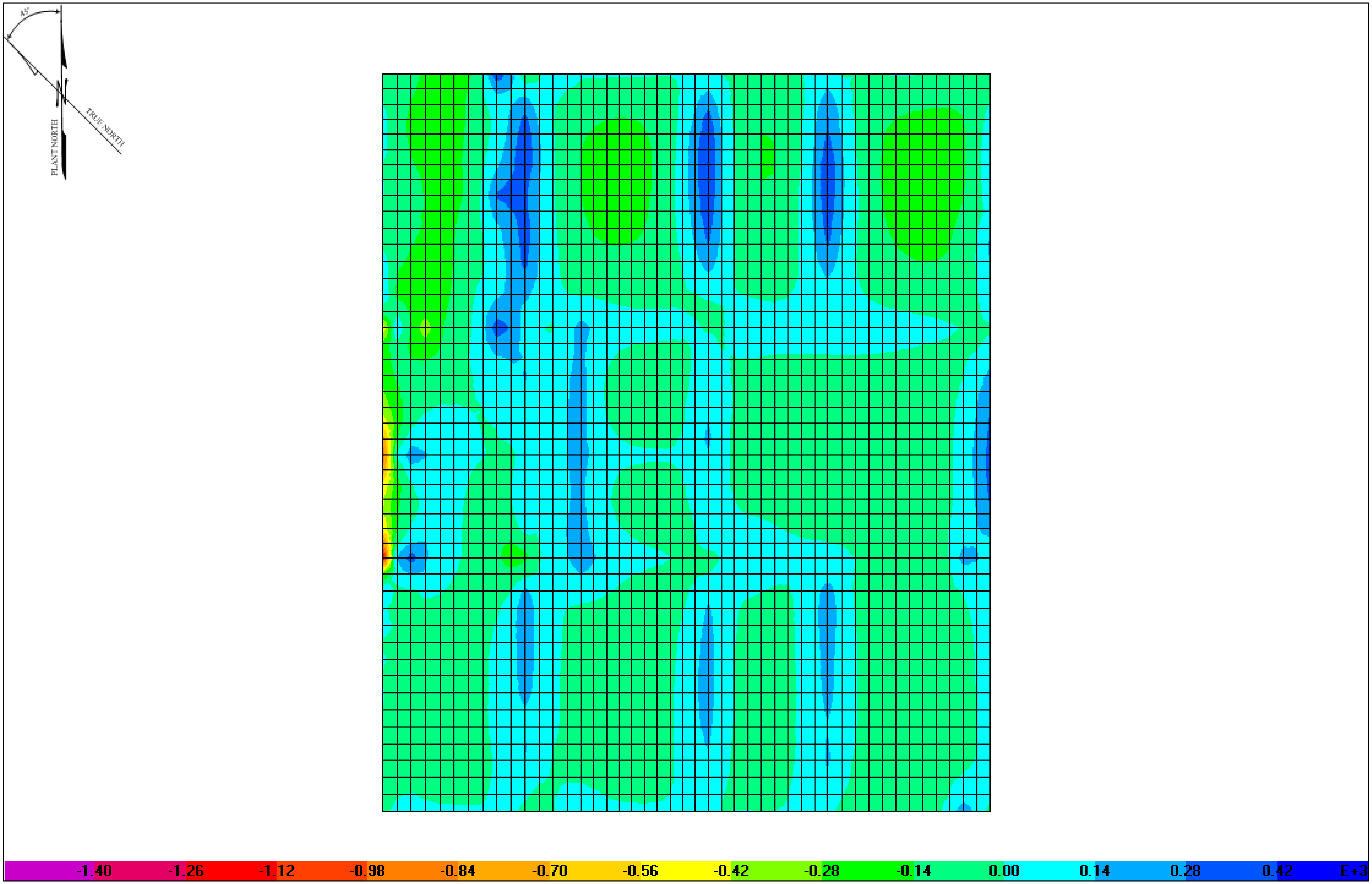


7 ft. Thick Resultant V13 Diagram – Combination 9 (DL+0.4HX+0.4HY-VZ) – kip

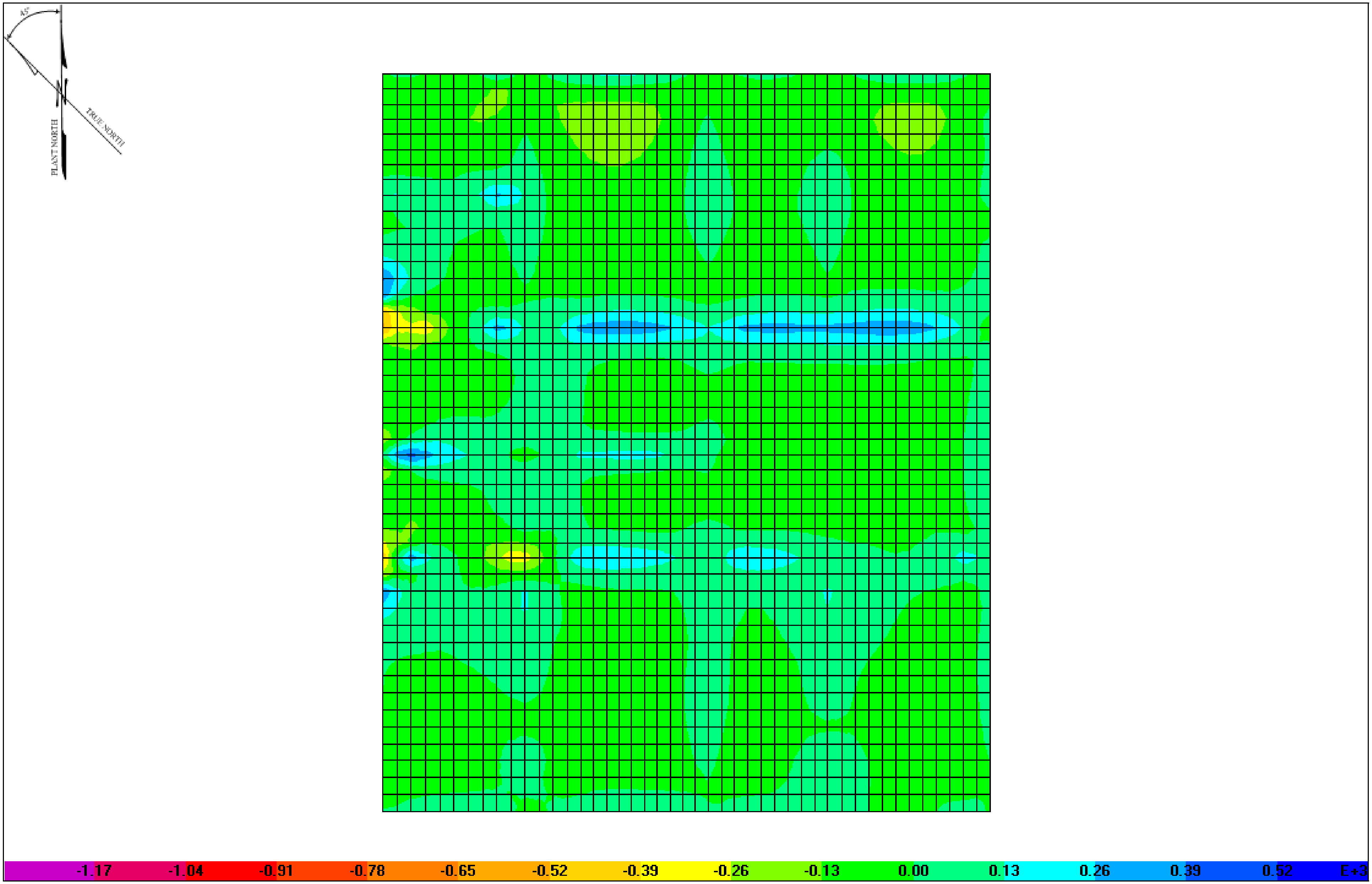


-105.0 kip
At distance, *d*, from face of wall

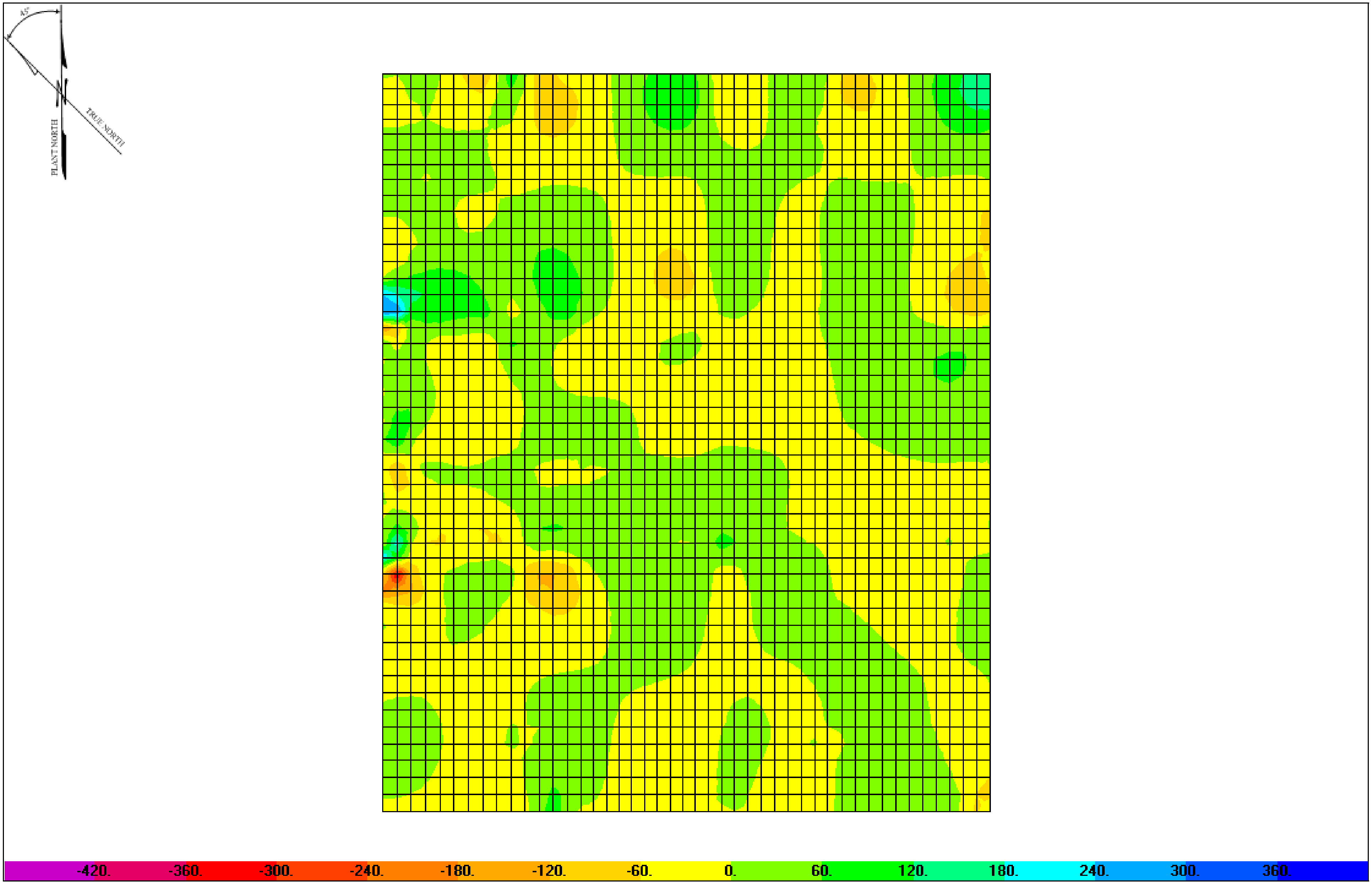
7 ft. Thick Resultant V23 Diagram – Combination 9 (DL+0.4HX+0.4HY-VZ) – kip



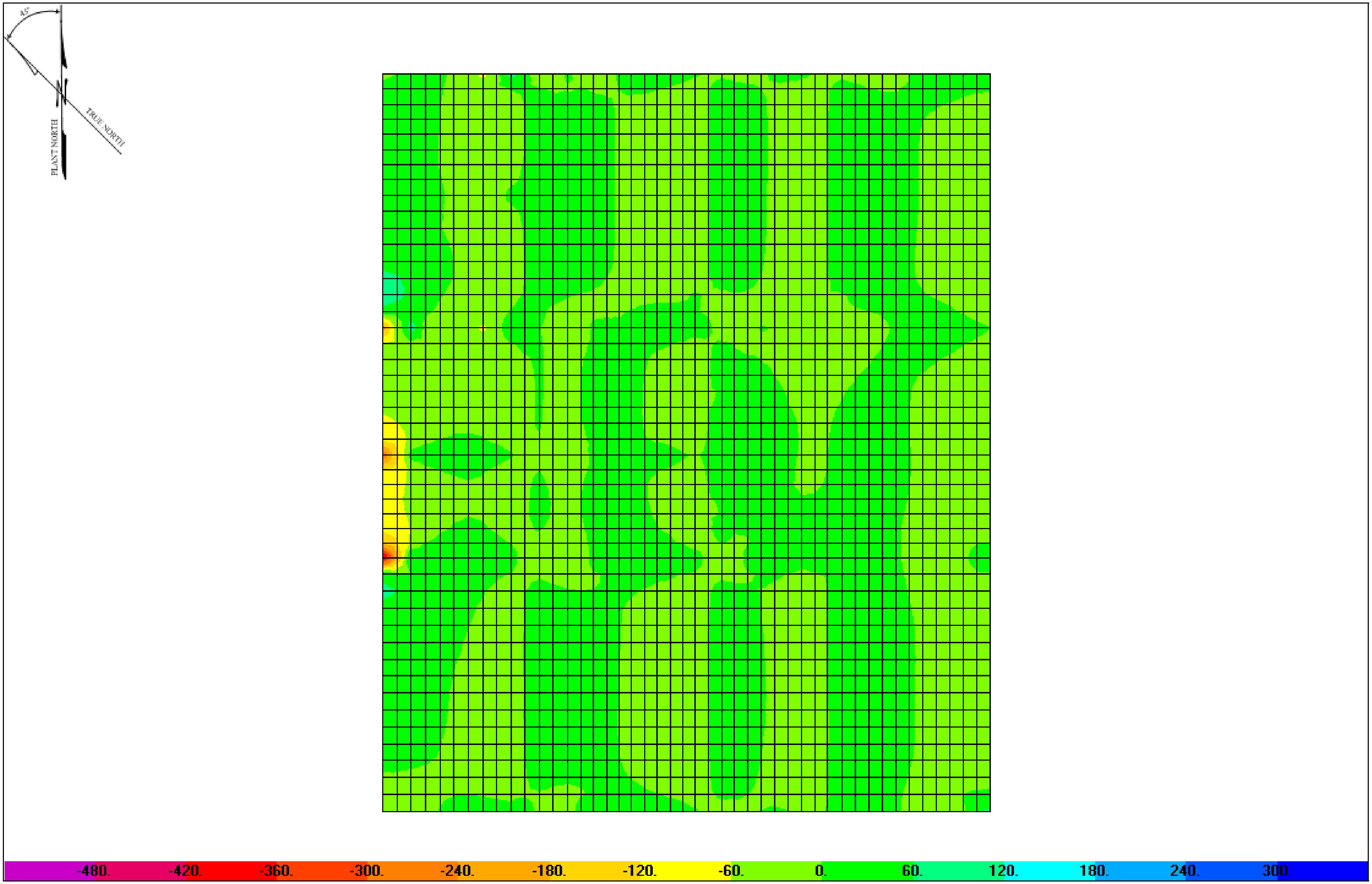
7 ft. Thick Resultant M11 Diagram – Combination 10 (DL-HX+0.4HY-0.4VZ) – kip-ft



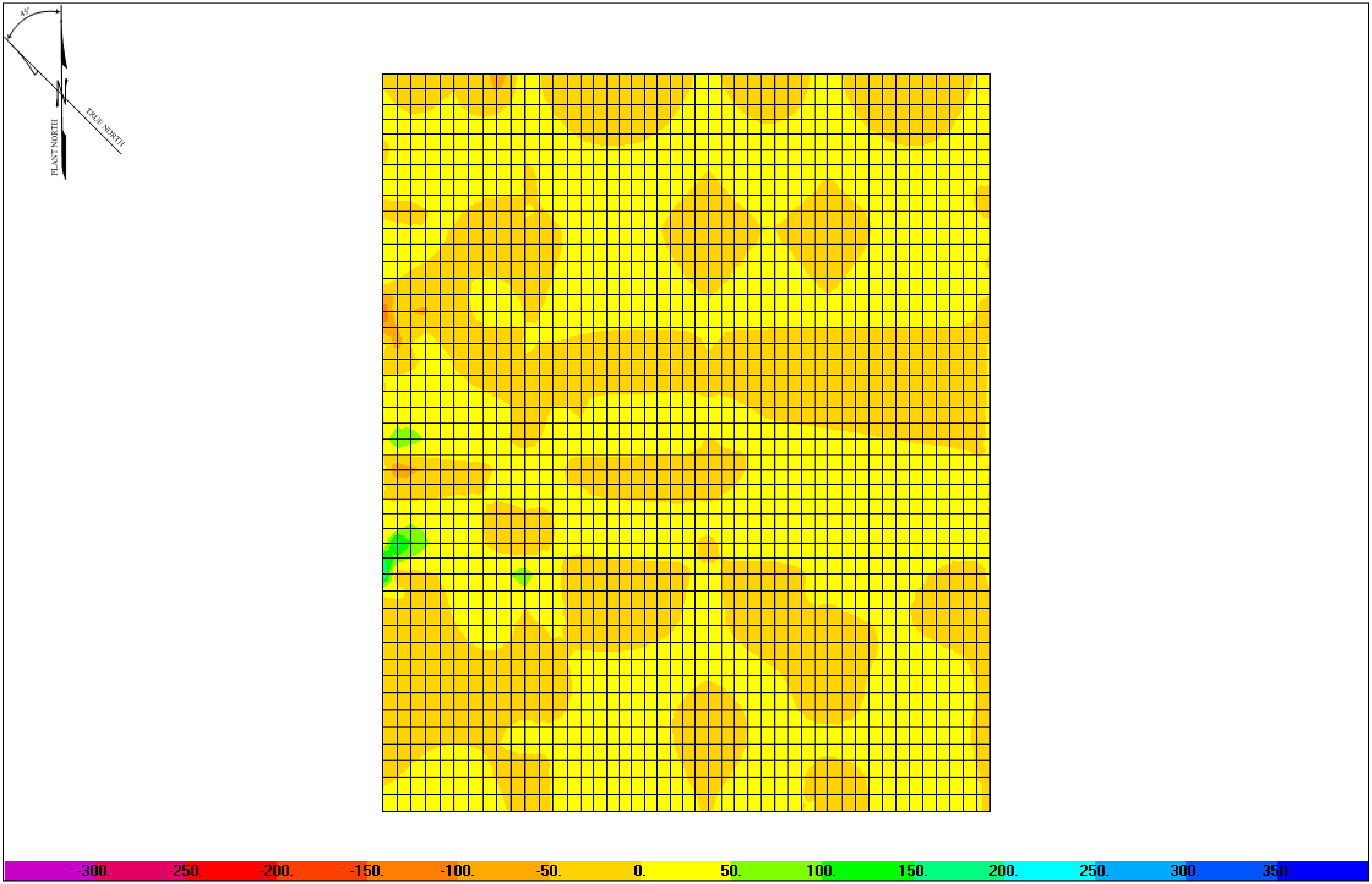
7 ft. Thick Resultant M22 Diagram – Combination 10 (DL-HX+0.4HY-0.4VZ) – kip-ft



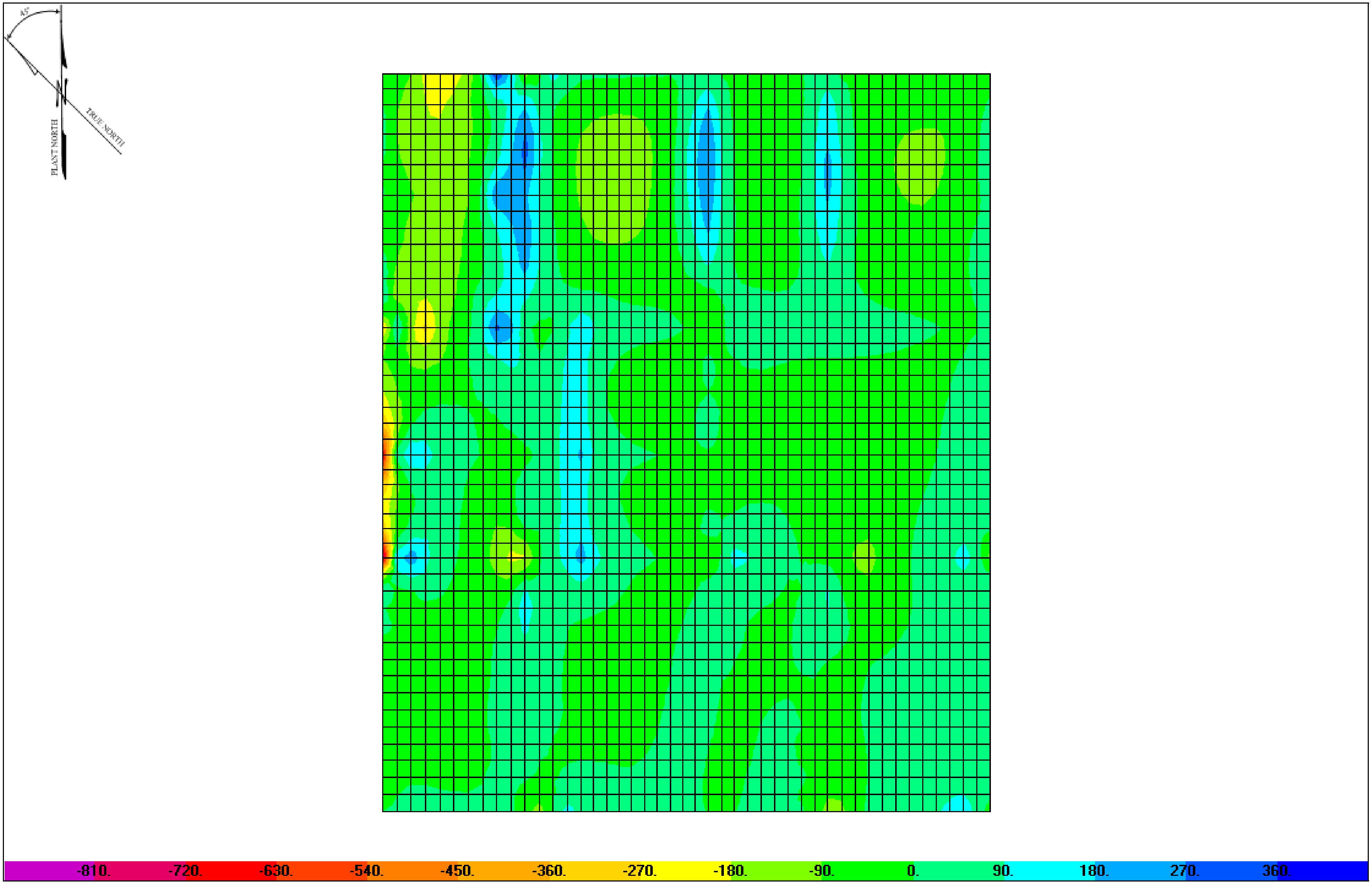
7 ft. Thick Resultant M12 Diagram – Combination 10 (DL-HX+0.4HY-0.4VZ) – kip-ft



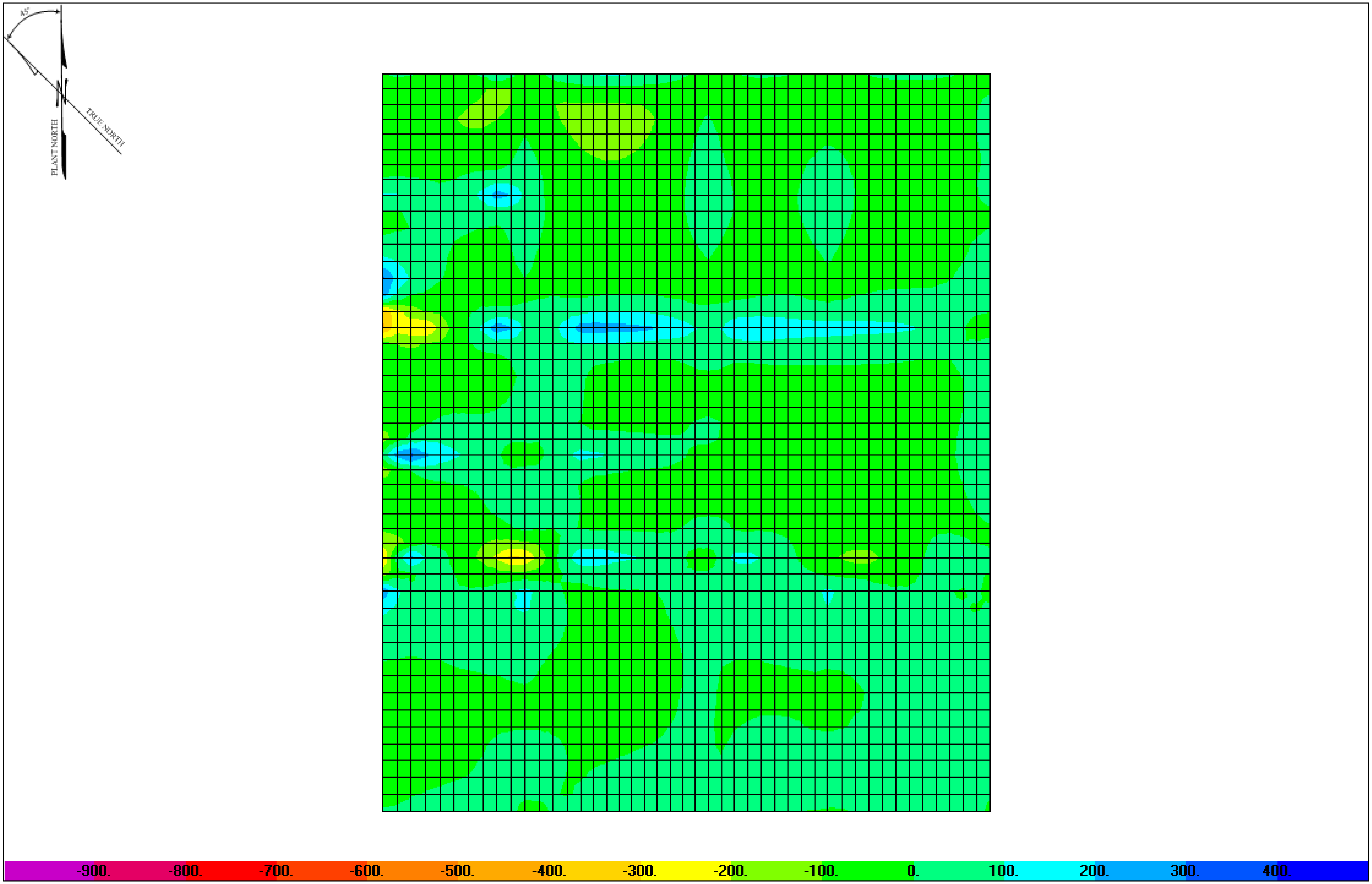
7 ft. Thick Resultant V13 Diagram – Combination 10 (DL-HX+0.4HY-0.4VZ) – kip



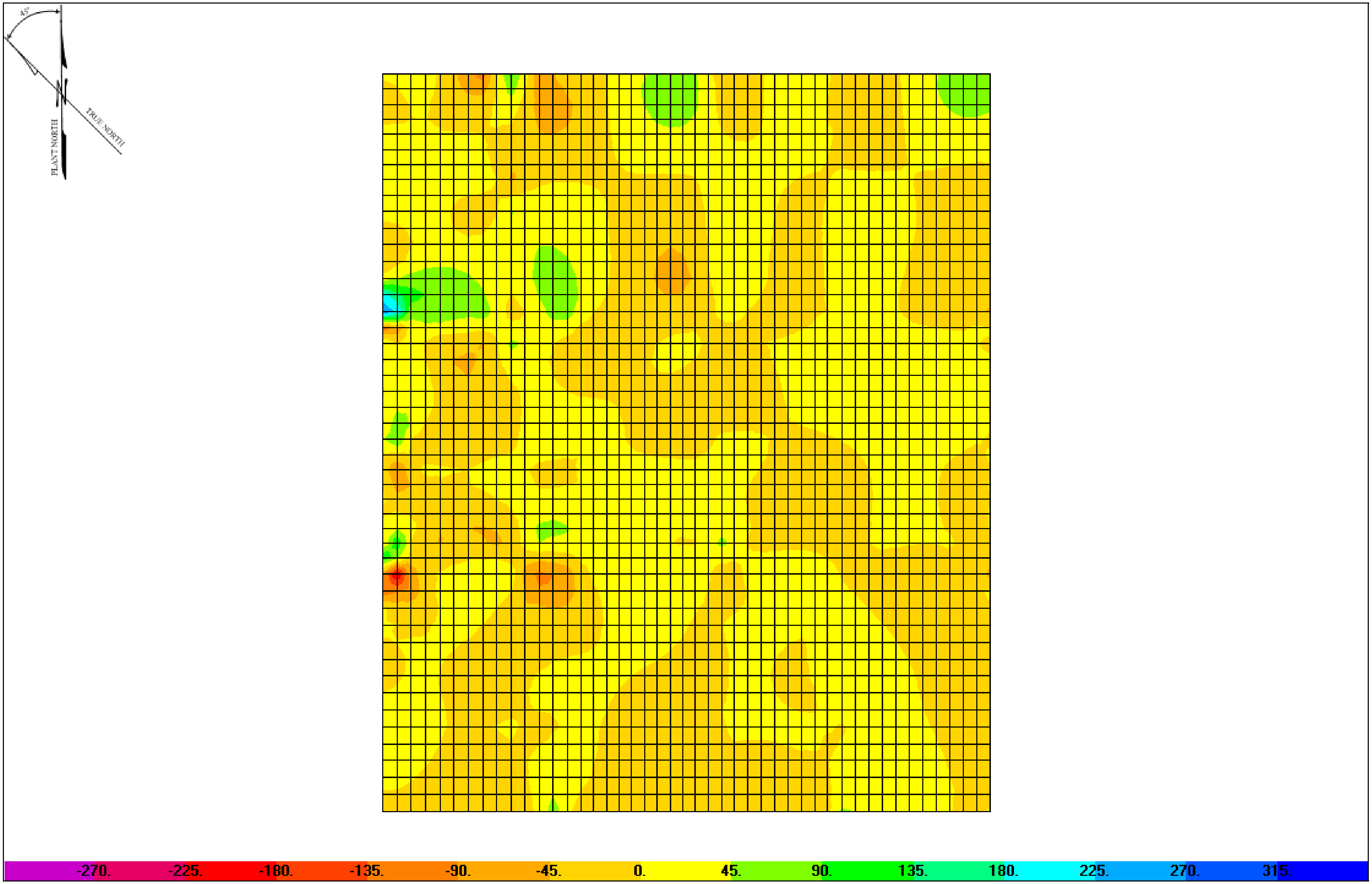
7 ft. Thick Resultant V23 Diagram – Combination 10 (DL-HX+0.4HY-0.4VZ) – kip



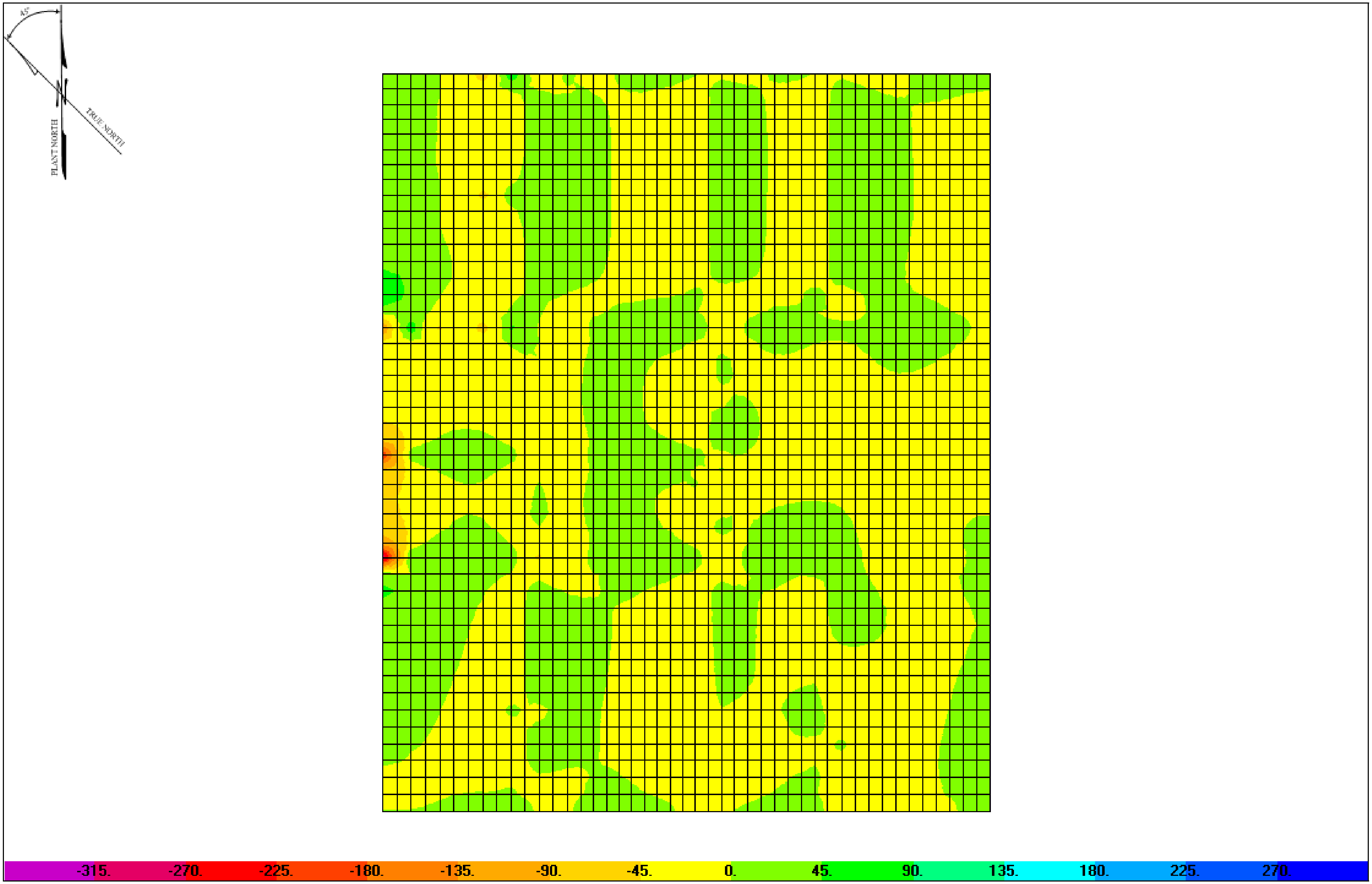
7 ft. Thick Resultant M11 Diagram – Combination 11 (DL-HX+0.4HY+0.4VZ) – kip-ft



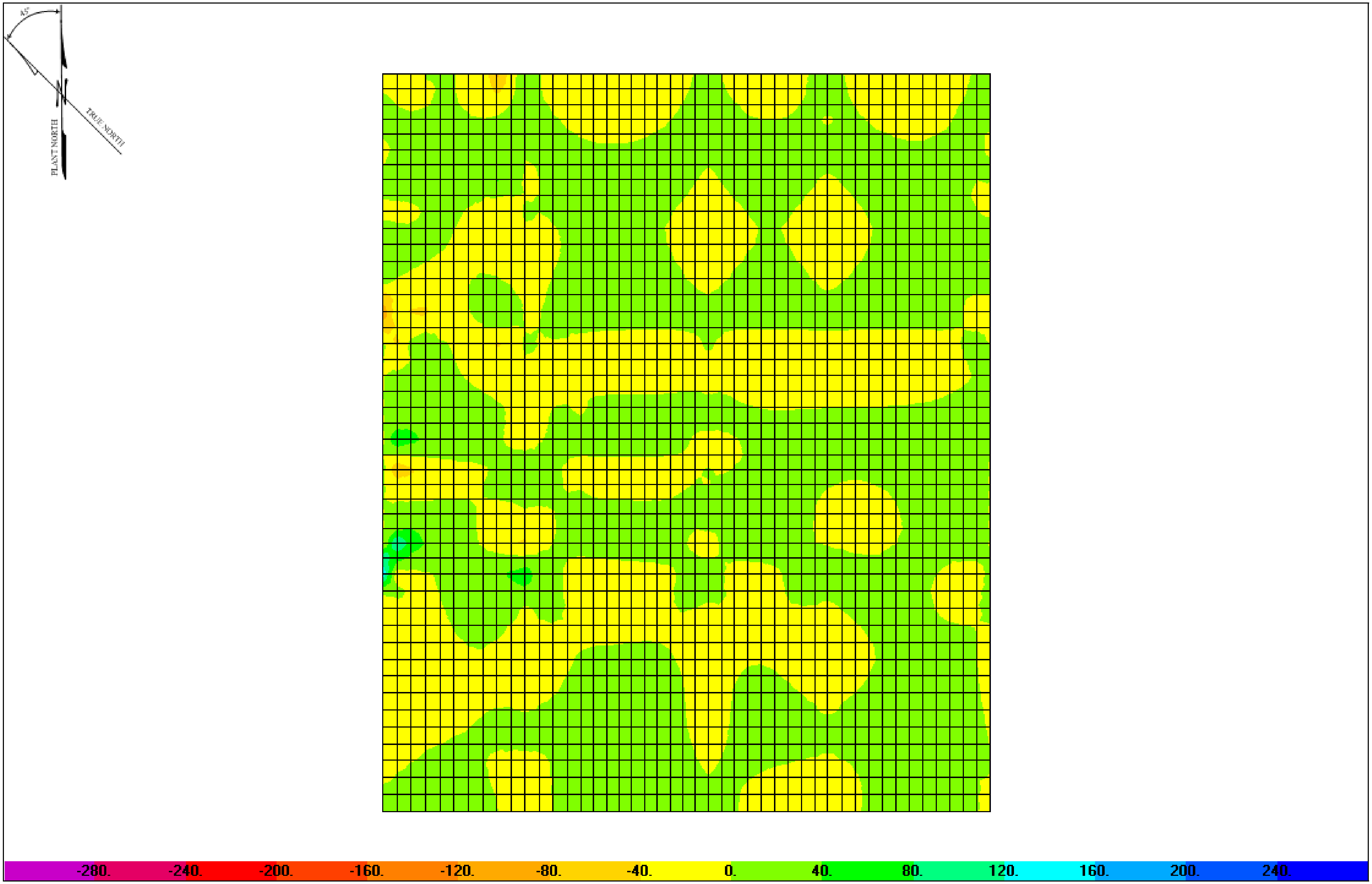
7 ft. Thick Resultant M22 Diagram – Combination 11 (DL-HX+0.4HY+0.4VZ) – kip-ft



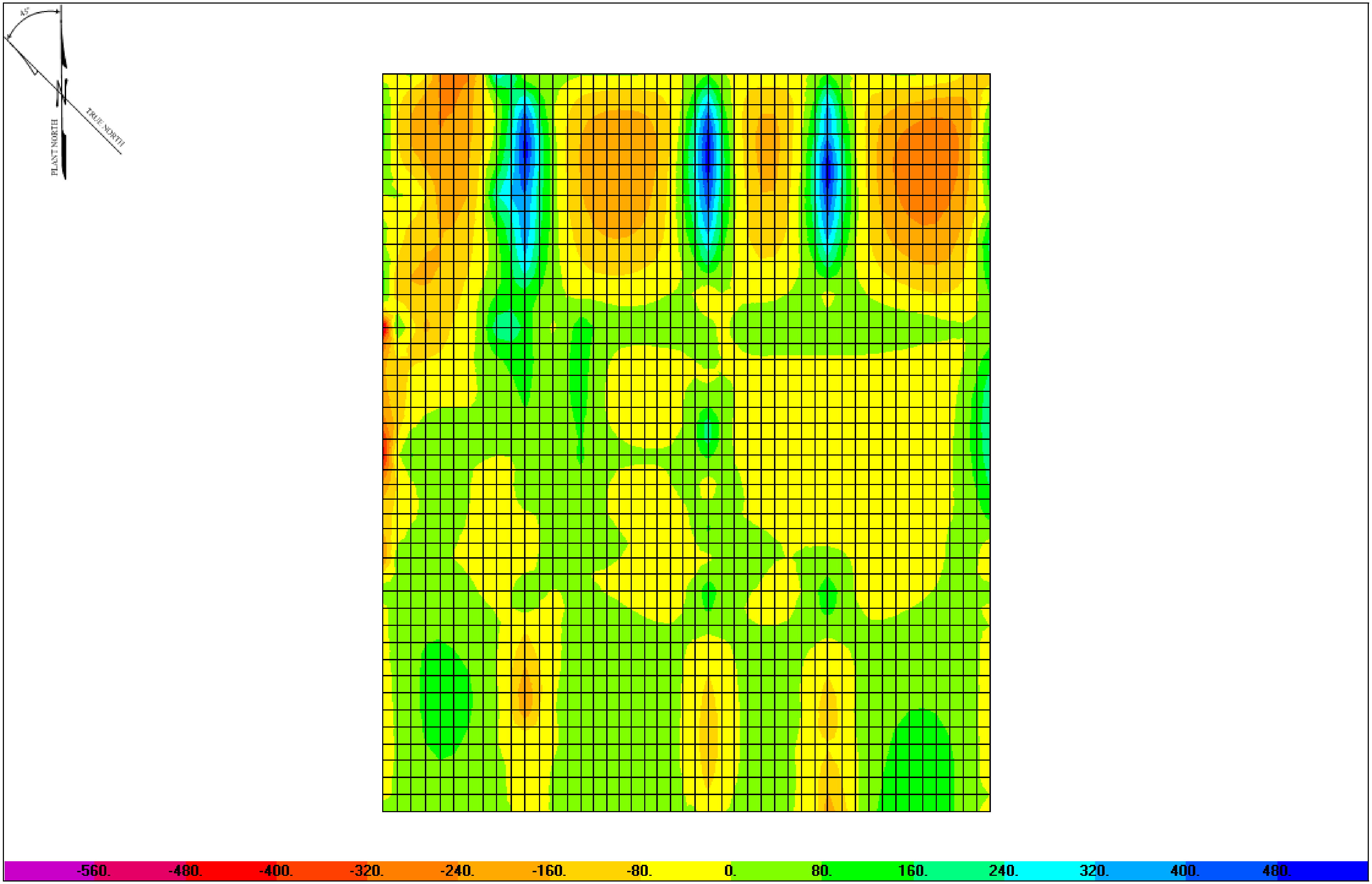
7 ft. Thick Resultant M12 Diagram – Combination 11 (DL-HX+0.4HY+0.4VZ) – kip-ft



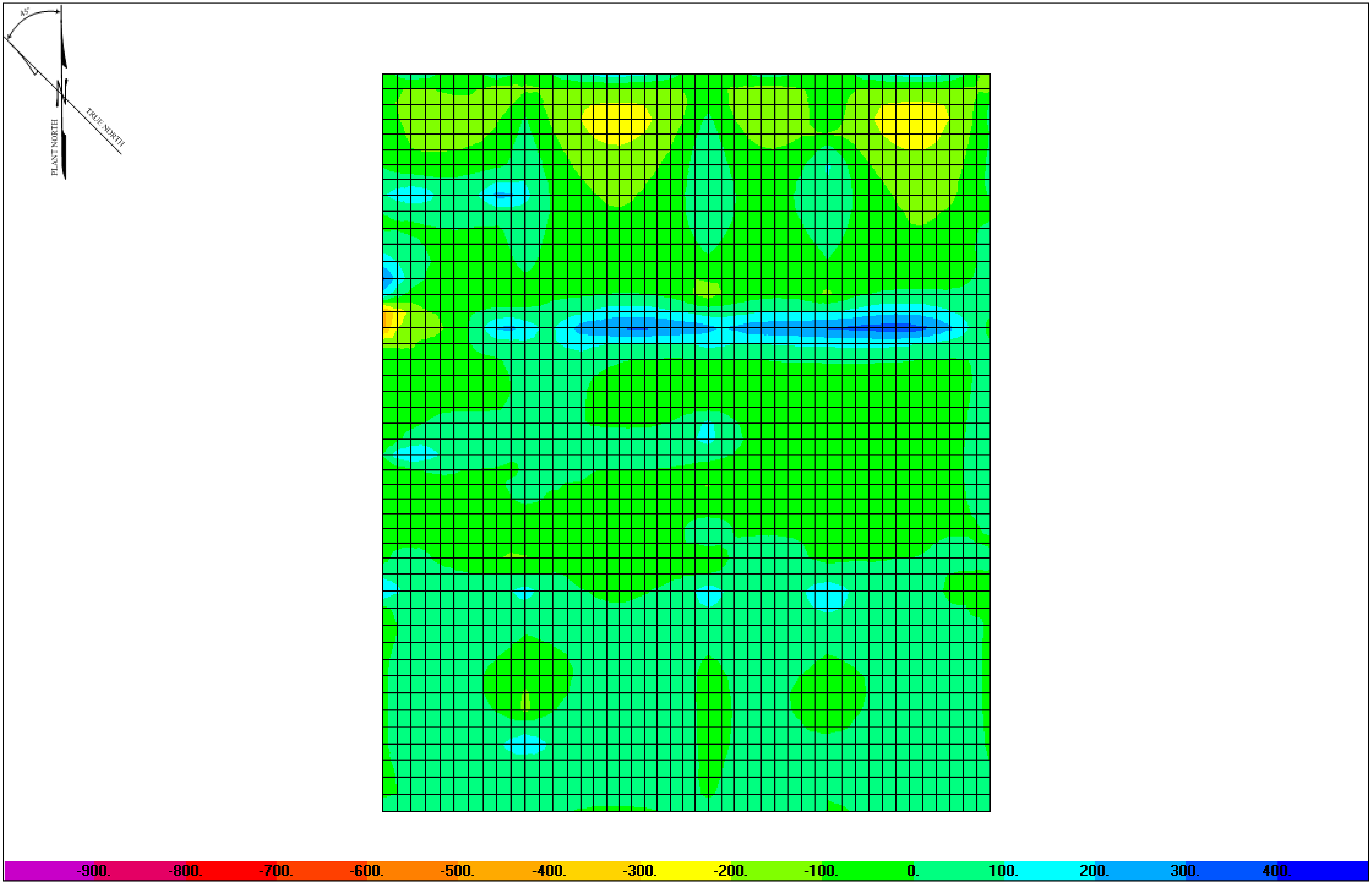
7 ft. Thick Resultant V13 Diagram – Combination 11 (DL-HX+0.4HY+0.4VZ) – kip



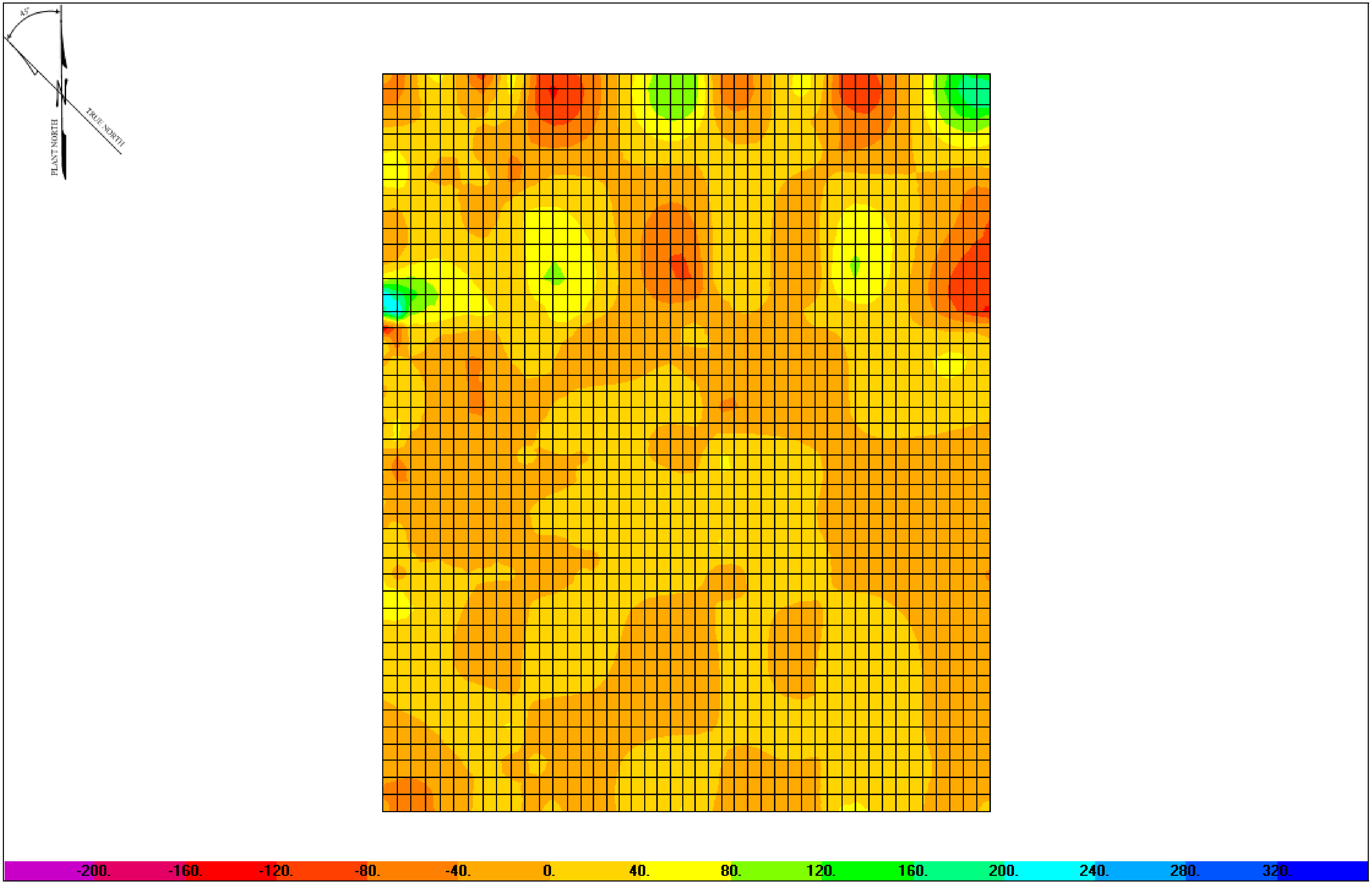
7 ft. Thick Resultant V23 Diagram – Combination 11 (DL-HX+0.4HY+0.4VZ) – kip



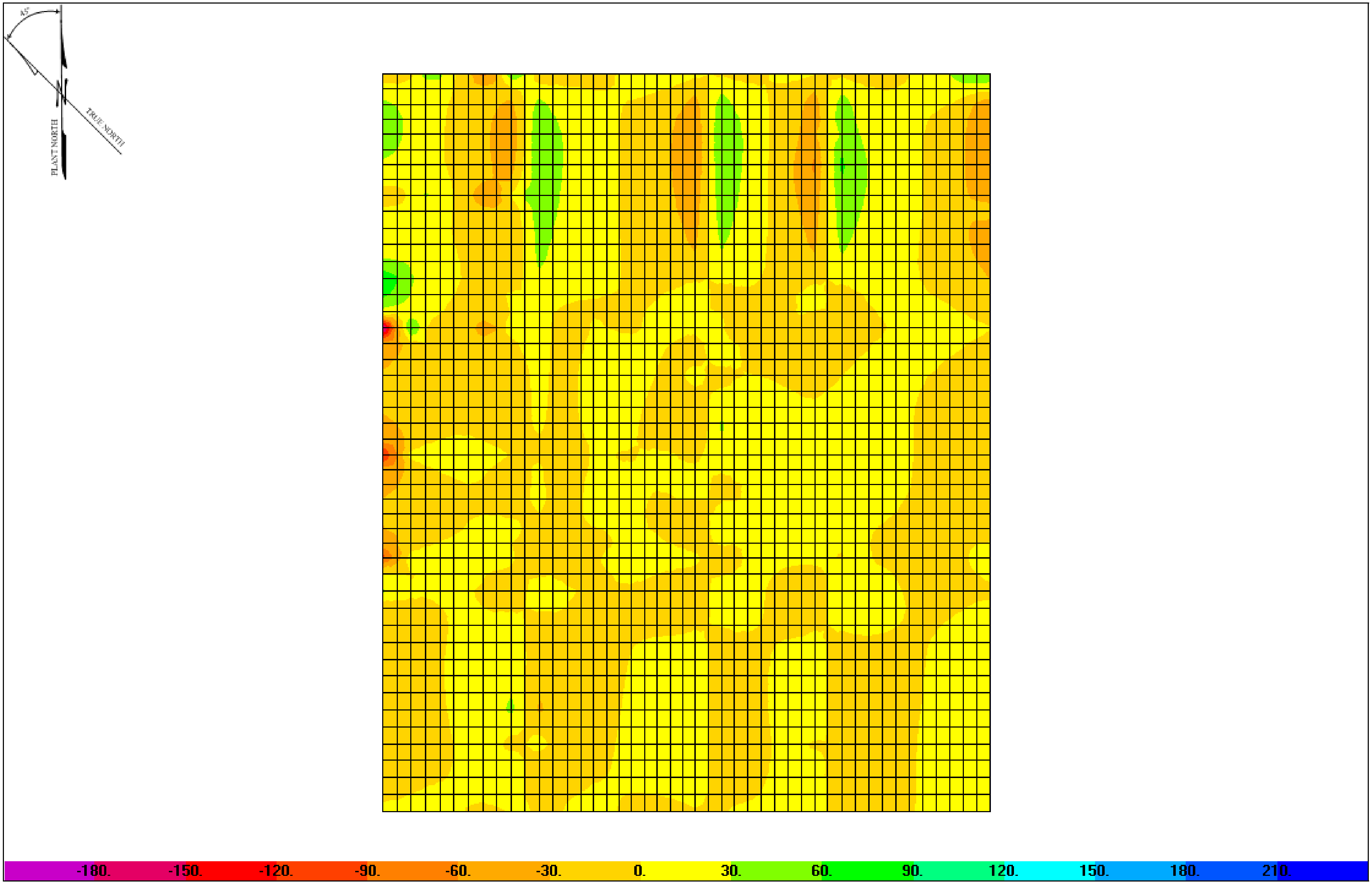
7 ft. Thick Resultant M11 Diagram – Combination 12 (DL-0.4HX+HY+0.4VZ) – kip-ft



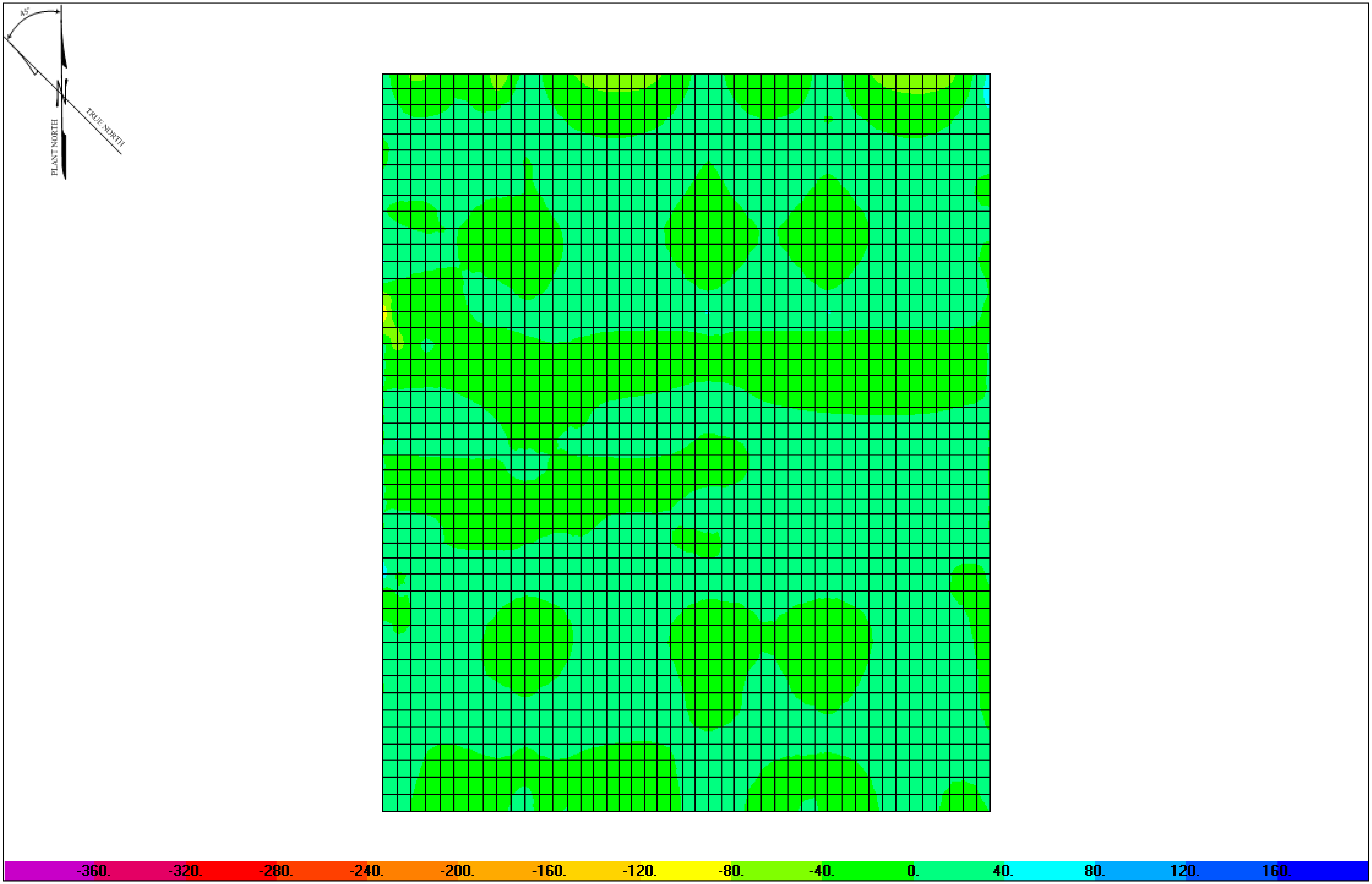
7 ft. Thick Resultant M22 Diagram – Combination 12 (DL-0.4HX+HY+0.4VZ) – kip-ft



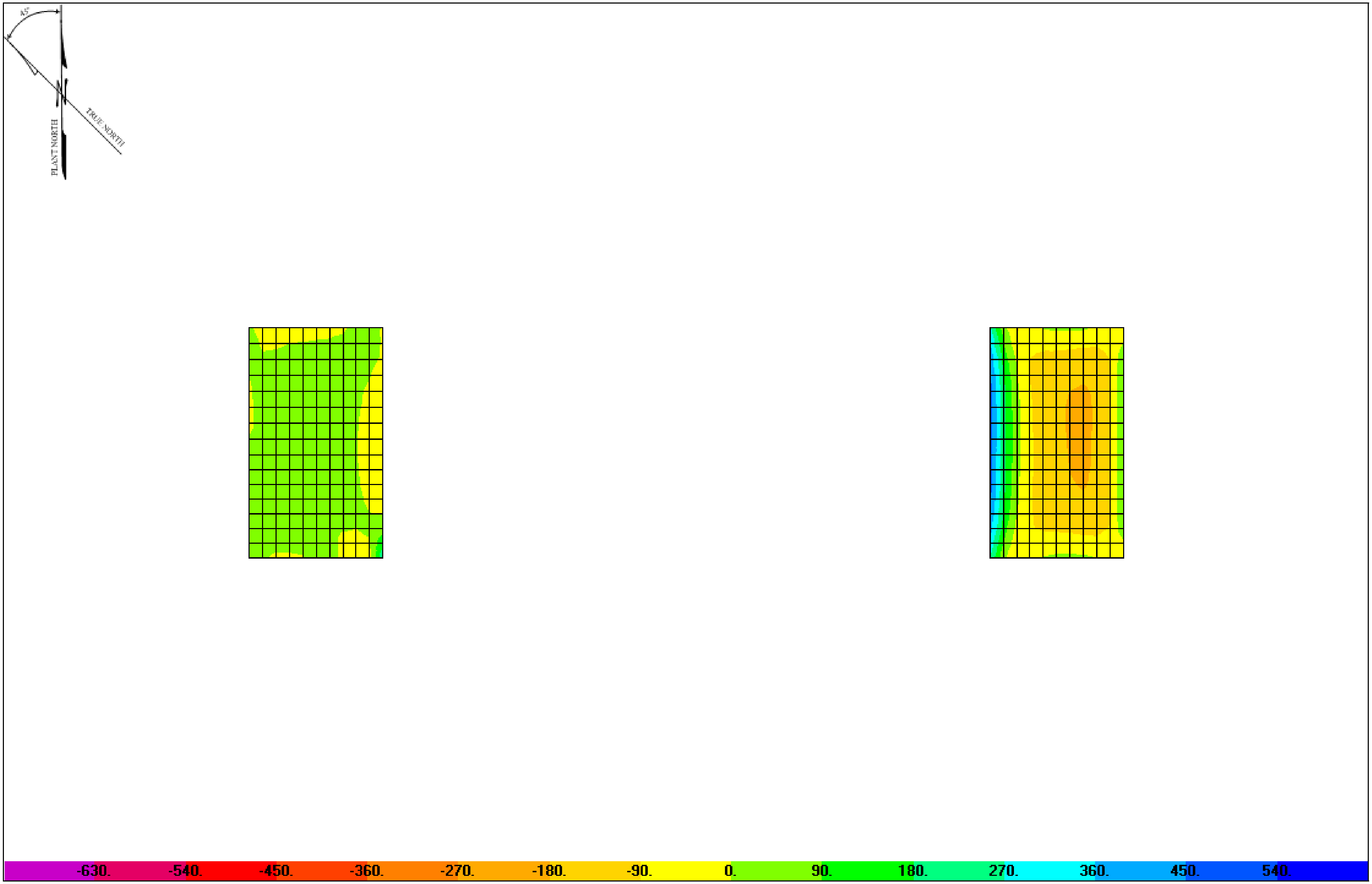
7 ft. Thick Resultant M12 Diagram – Combination 12 (DL-0.4HX+HY+0.4VZ) – kip-ft



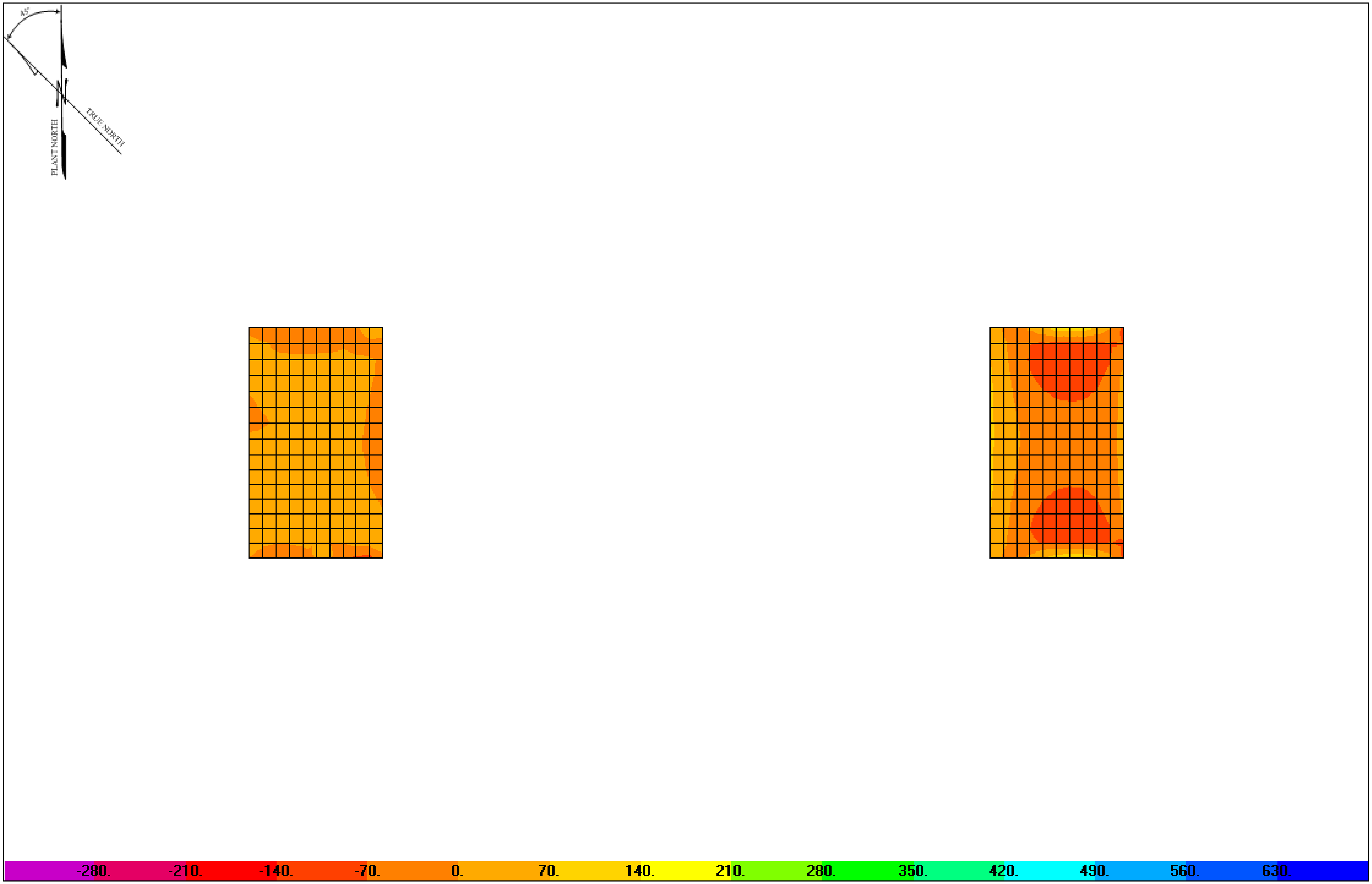
7 ft. Thick Resultant V13 Diagram – Combination 12 (DL-0.4HX+HY+0.4VZ) – kip



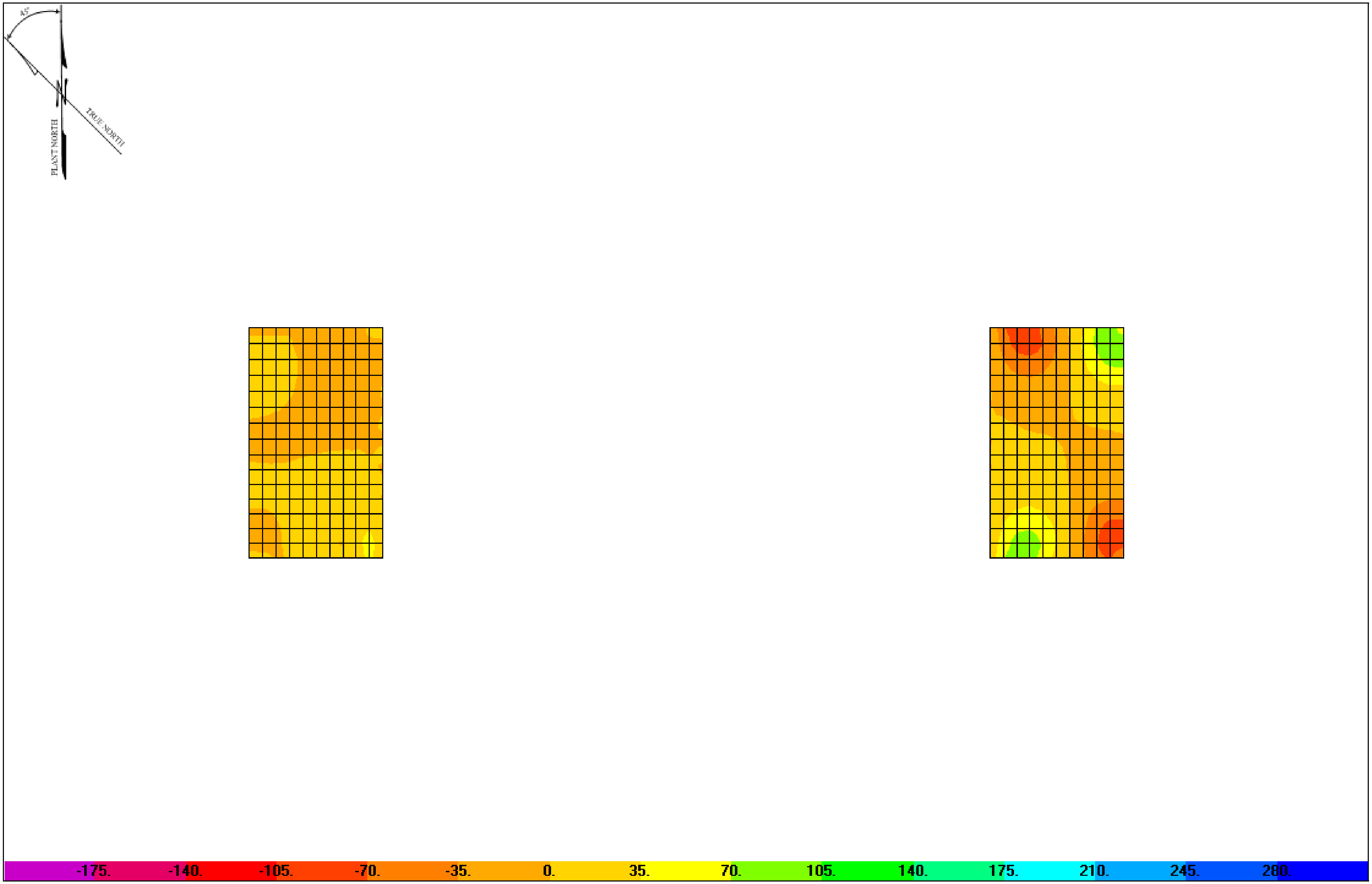
7 ft. Thick Resultant V23 Diagram – Combination 12 (DL-0.4HX+HY+0.4VZ) – kip



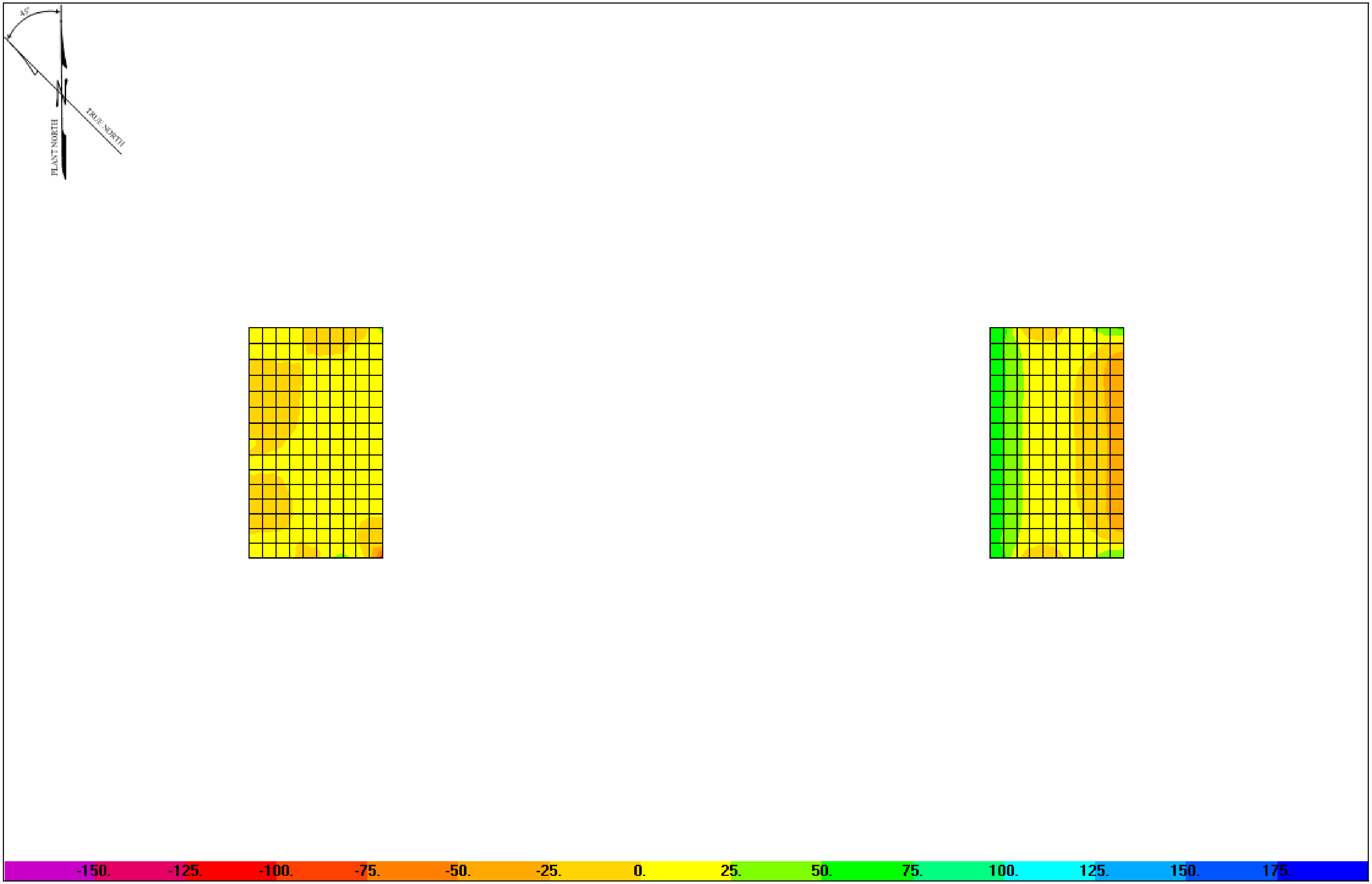
4 ft. Thick Resultant M11 Diagram – Combination 1 (DL+HX+0.4HY+0.4VZ) – kip-ft



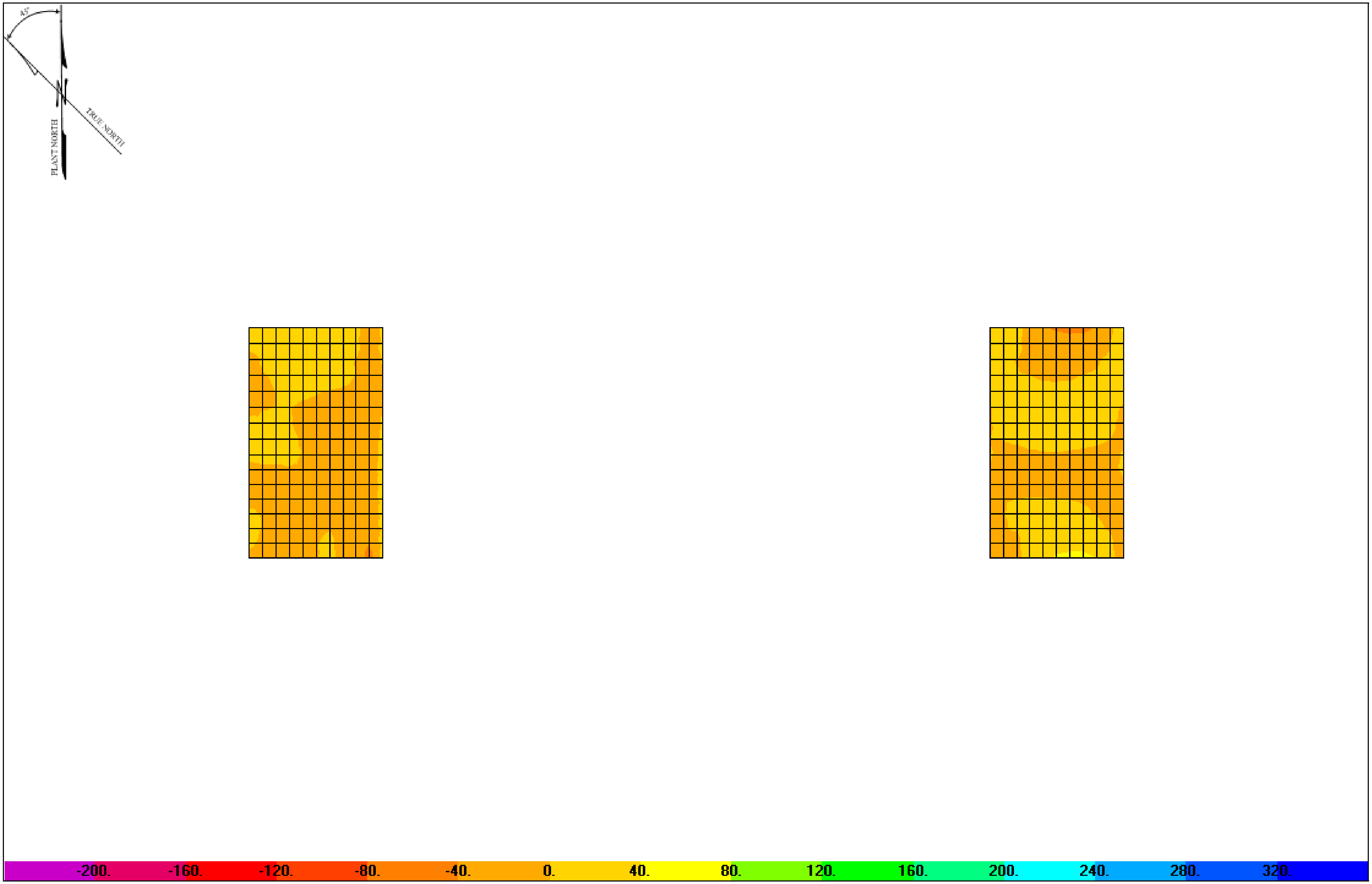
4 ft. Thick Resultant M22 Diagram – Combination 1 (DL+HX+0.4HY+0.4VZ) – kip-ft



4 ft. Thick Resultant M12 Diagram – Combination 1 (DL+HX+0.4HY+0.4VZ) – kip-ft



4 ft. Thick Resultant V13 Diagram – Combination 1 (DL+HX+0.4HY+0.4VZ) – kip



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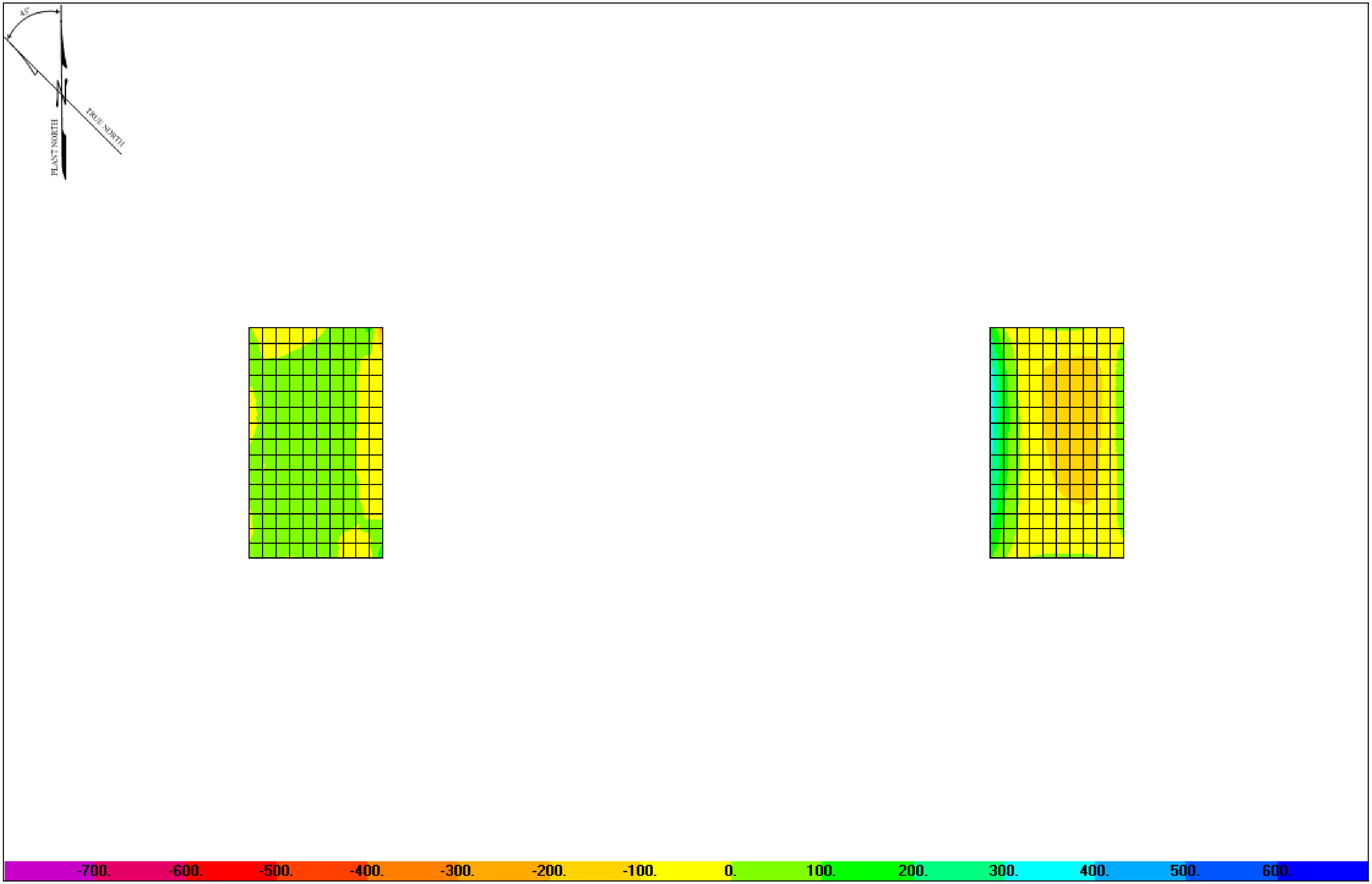
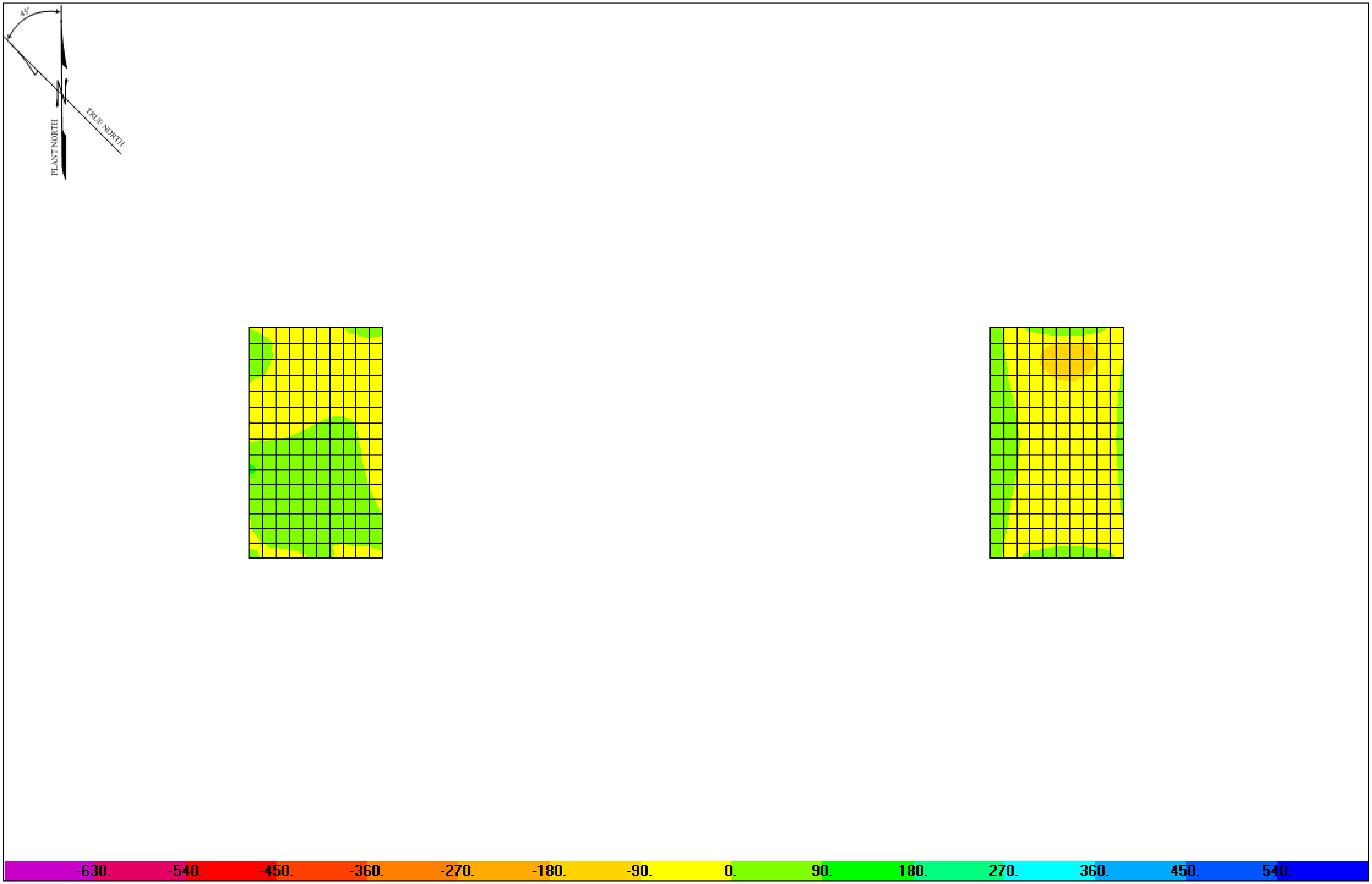
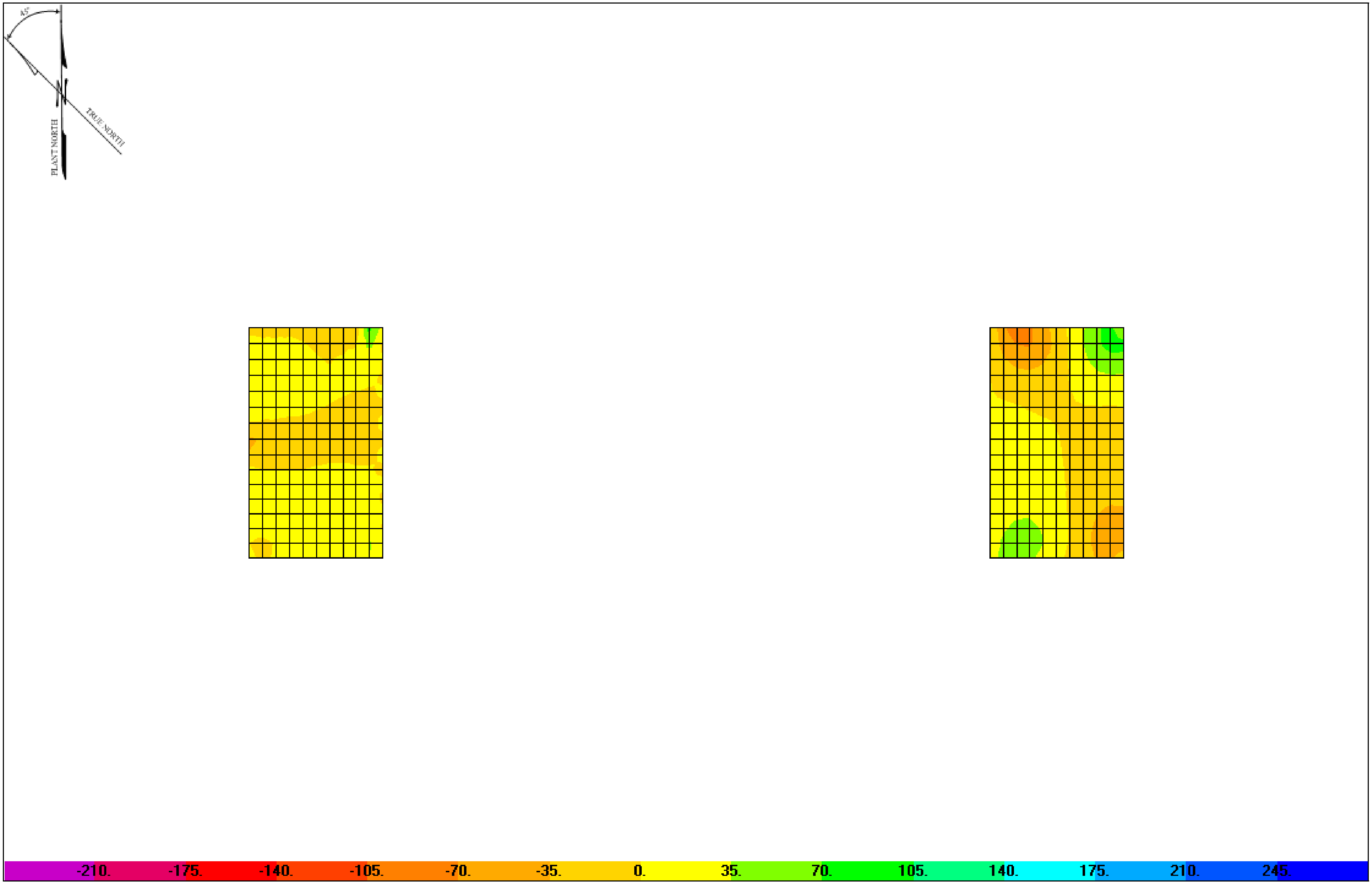


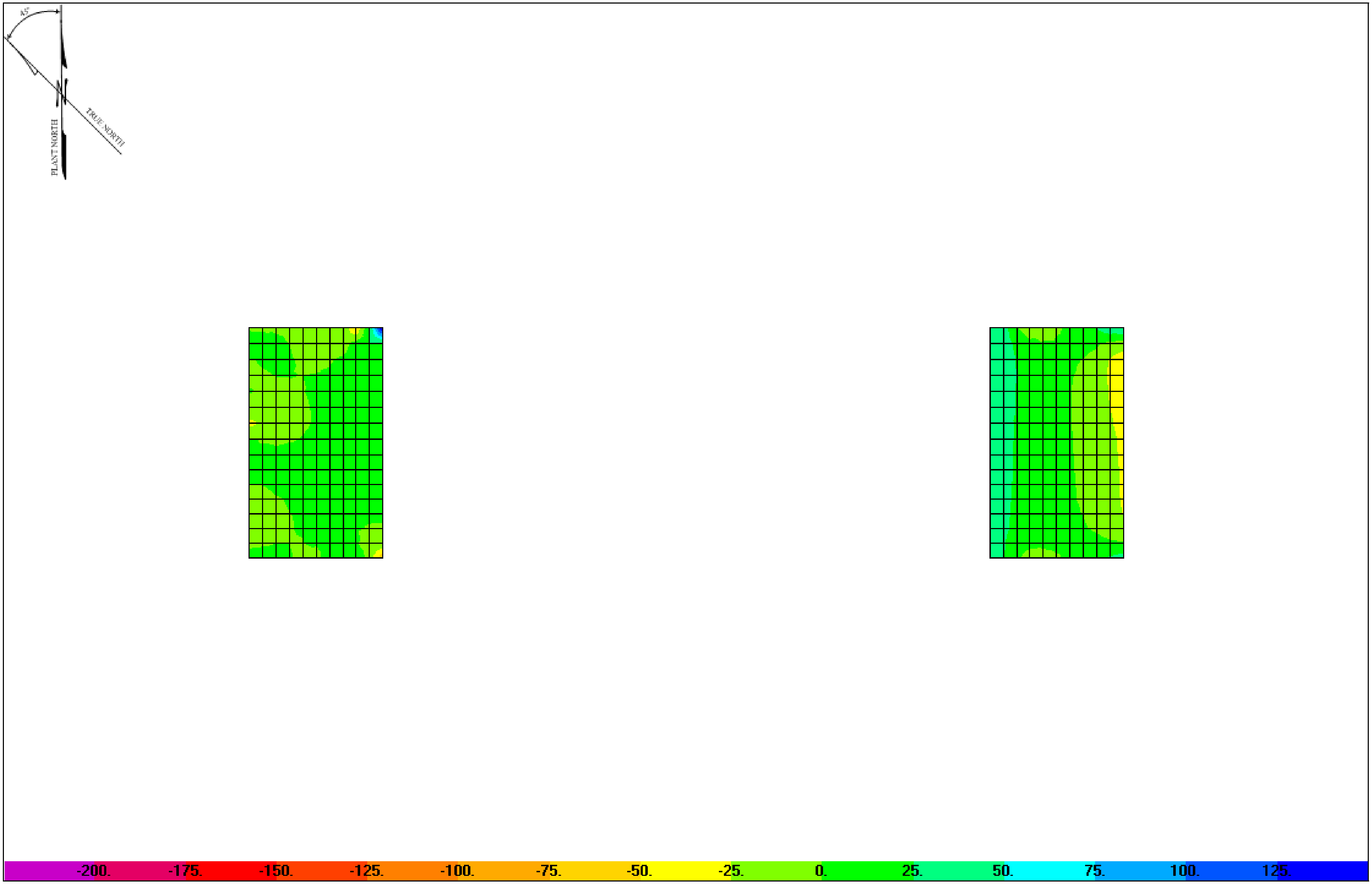
4 ft. Thick Resultant M11 Diagram – Combination 2 (DL+0.4HX+HY+0.4VZ) – kip-ft



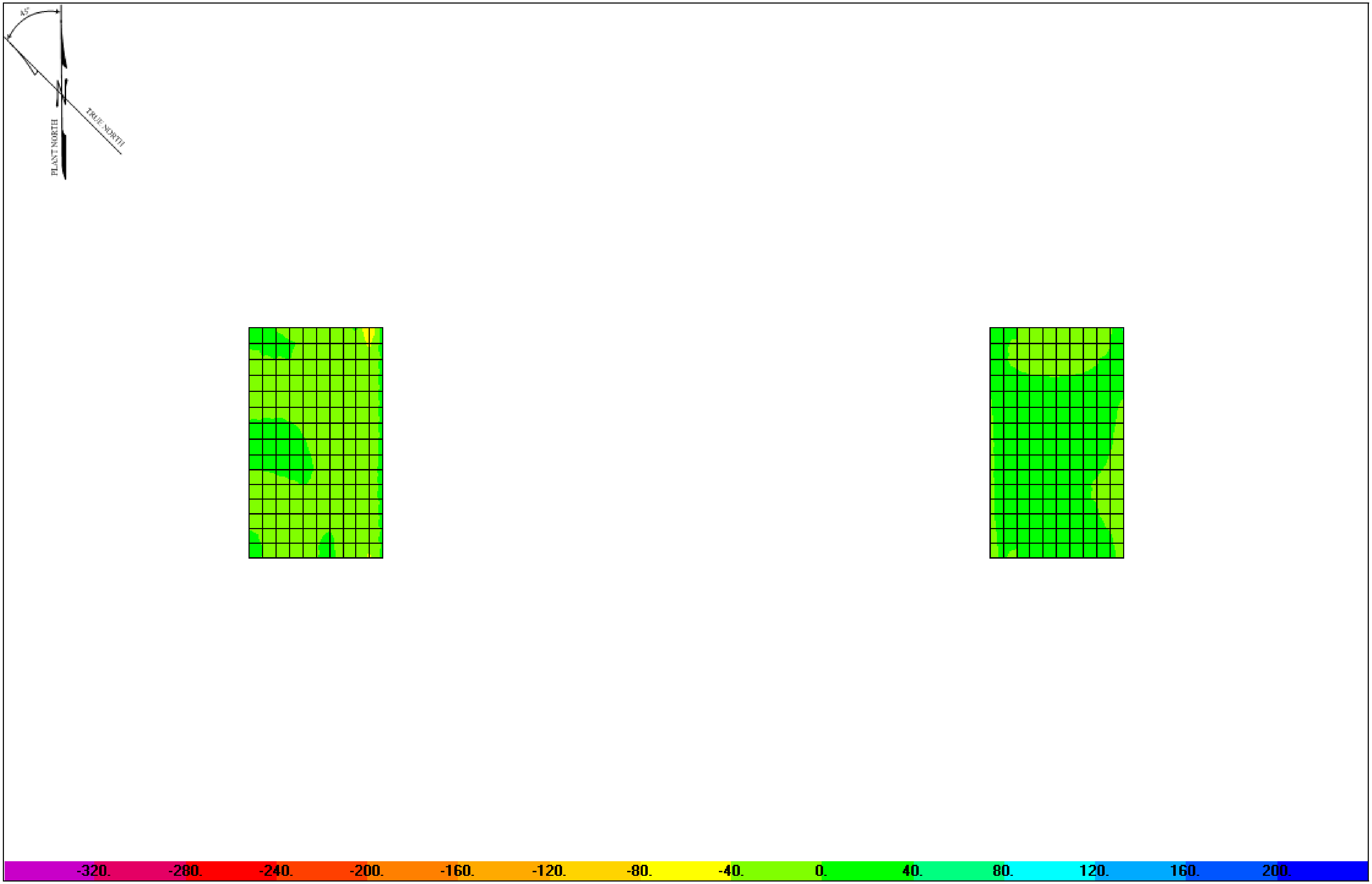
4 ft. Thick Resultant M22 Diagram – Combination 2 (DL+0.4HX+HY+0.4VZ) – kip-ft



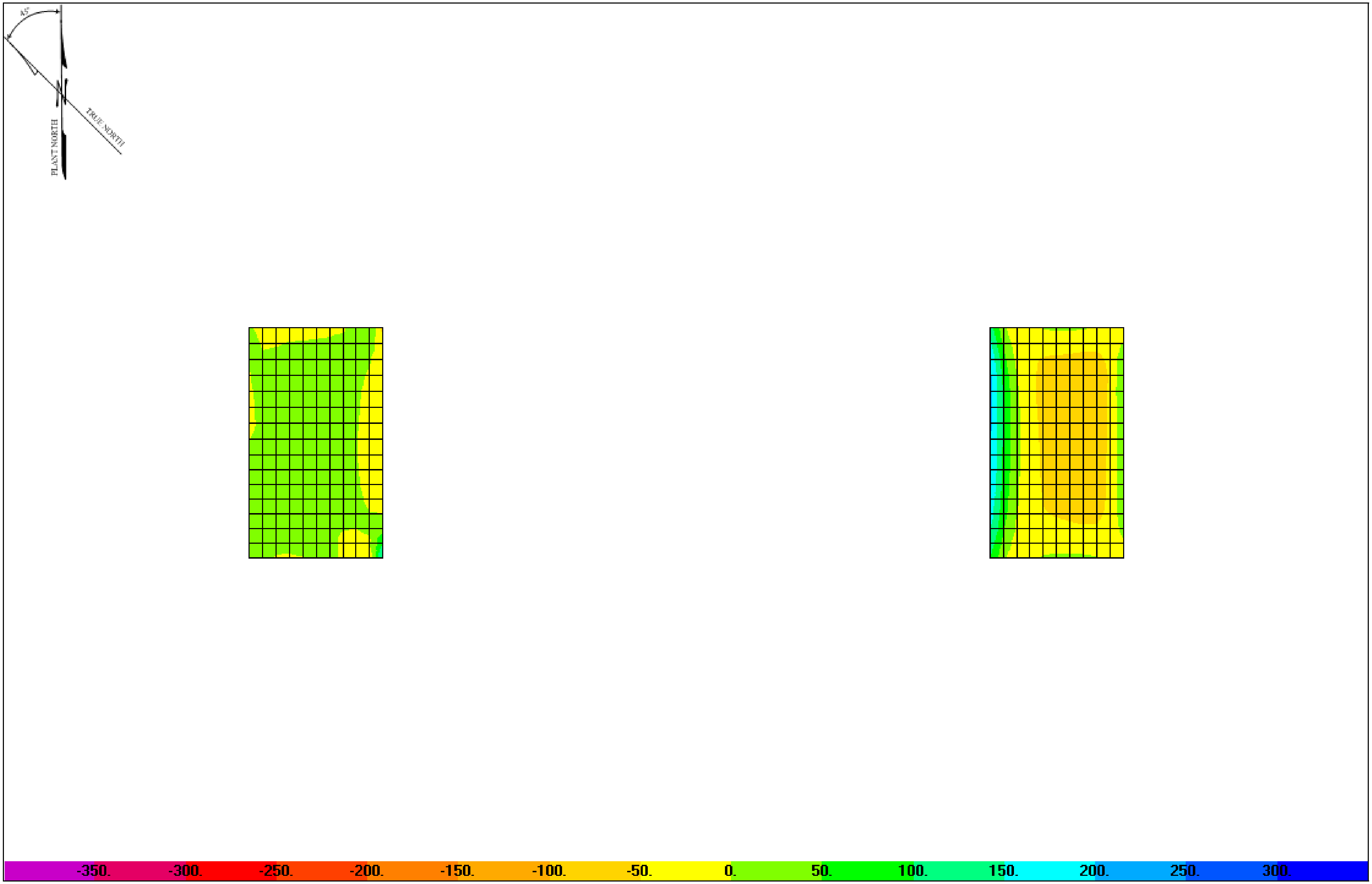
4 ft. Thick Resultant M12 Diagram – Combination 2 (DL+0.4HX+HY+0.4VZ) – kip-ft



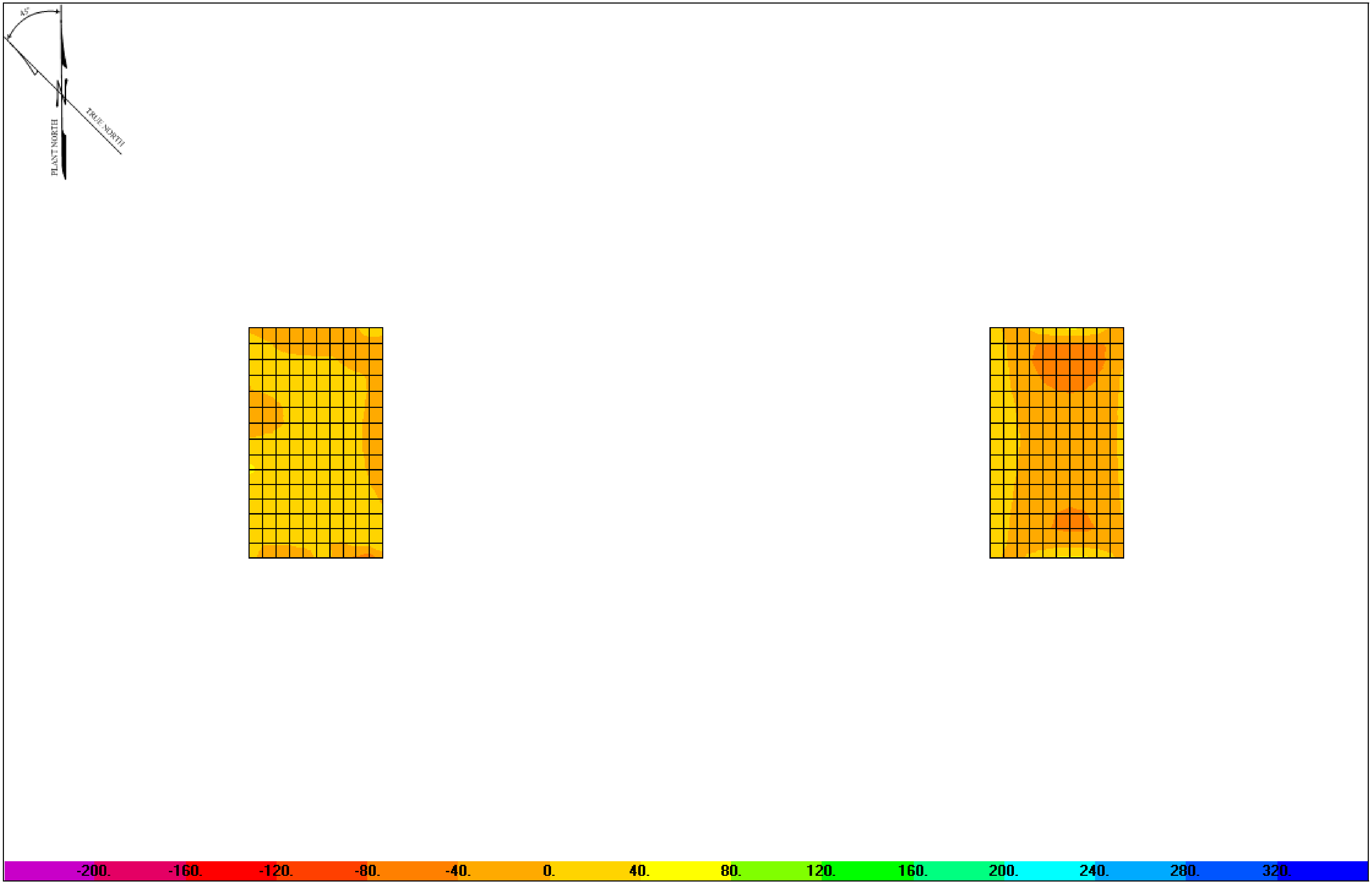
4 ft. Thick Resultant V13 Diagram – Combination 2 (DL+0.4HX+HY+0.4VZ) – kip



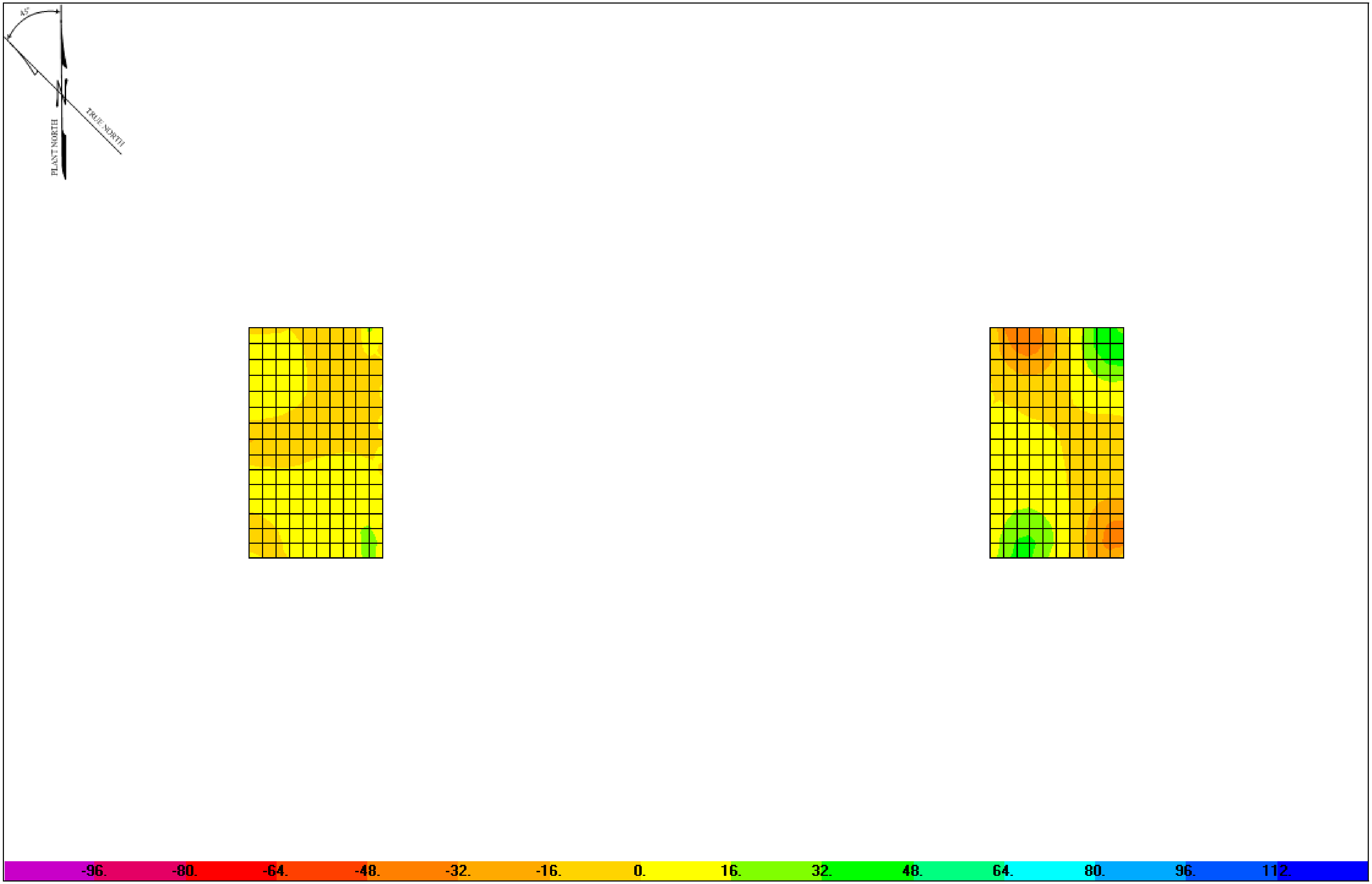
4 ft. Thick Resultant V23 Diagram – Combination 2 (DL+0.4HX+HY+0.4VZ) – kip



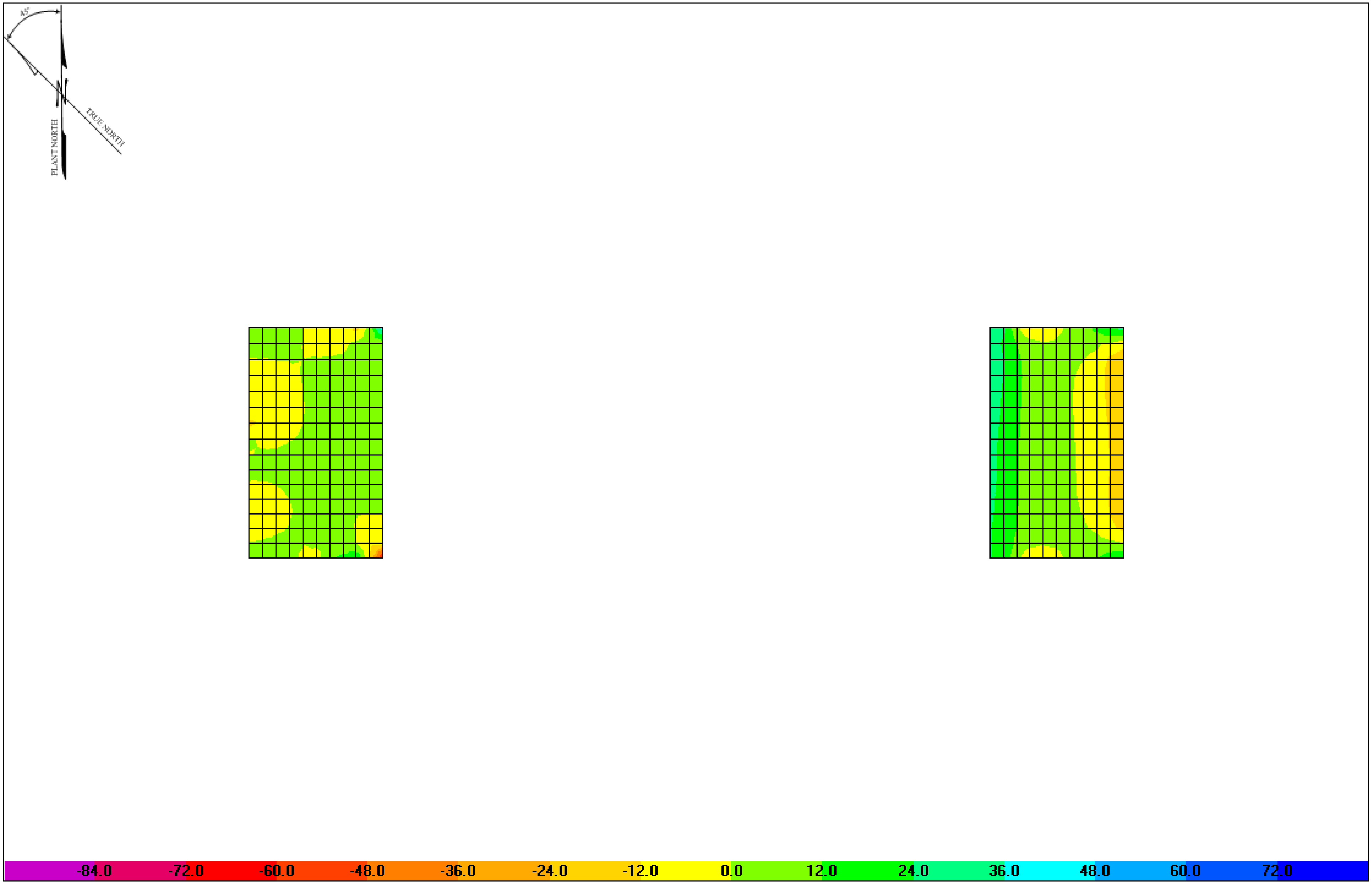
4 ft. Thick Resultant M11 Diagram – Combination 3 (DL+0.4HX+0.4HY+VZ) – kip-ft



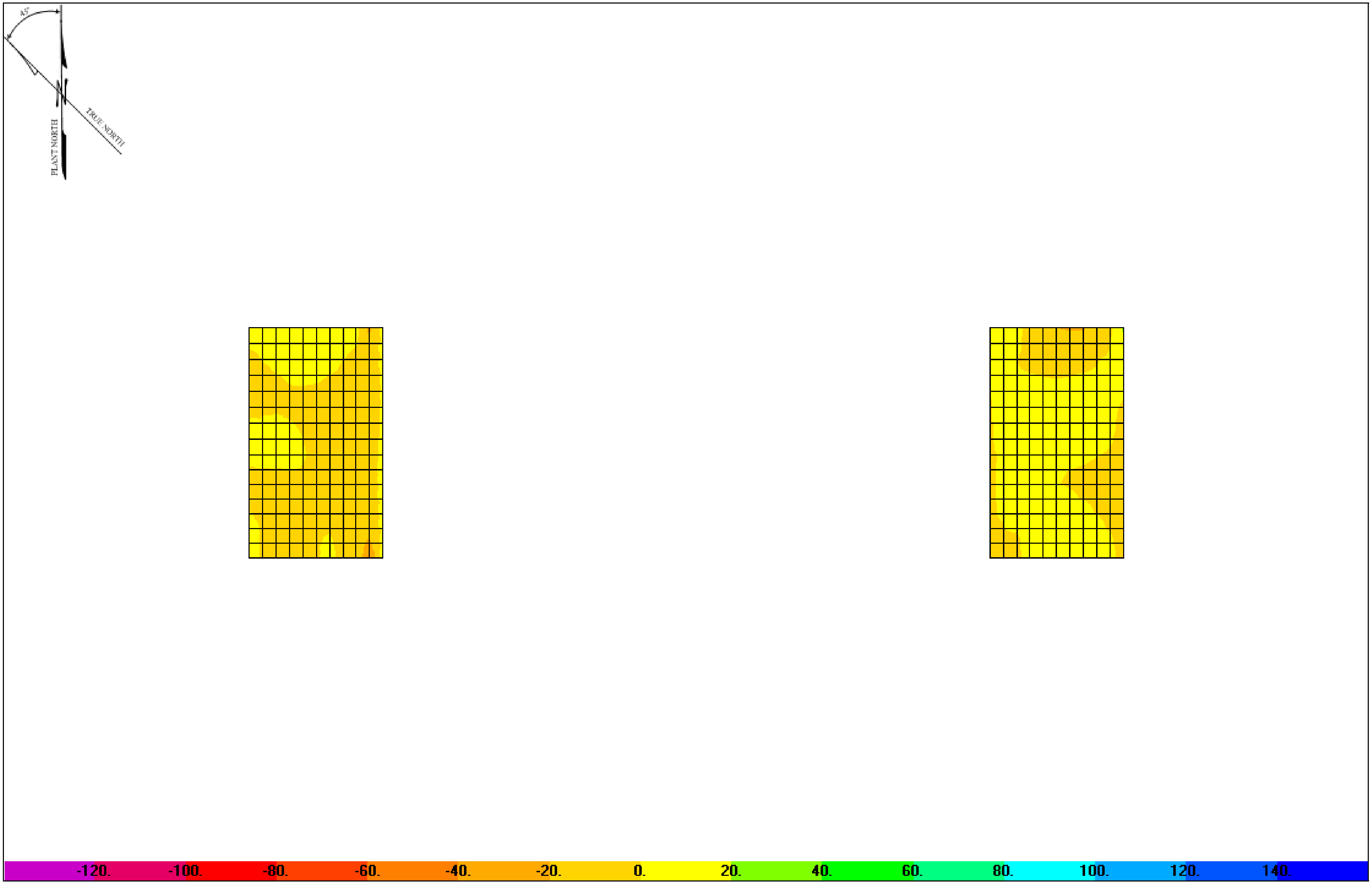
4 ft. Thick Resultant M22 Diagram – Combination 3 (DL+0.4HX+0.4HY+VZ) – kip-ft



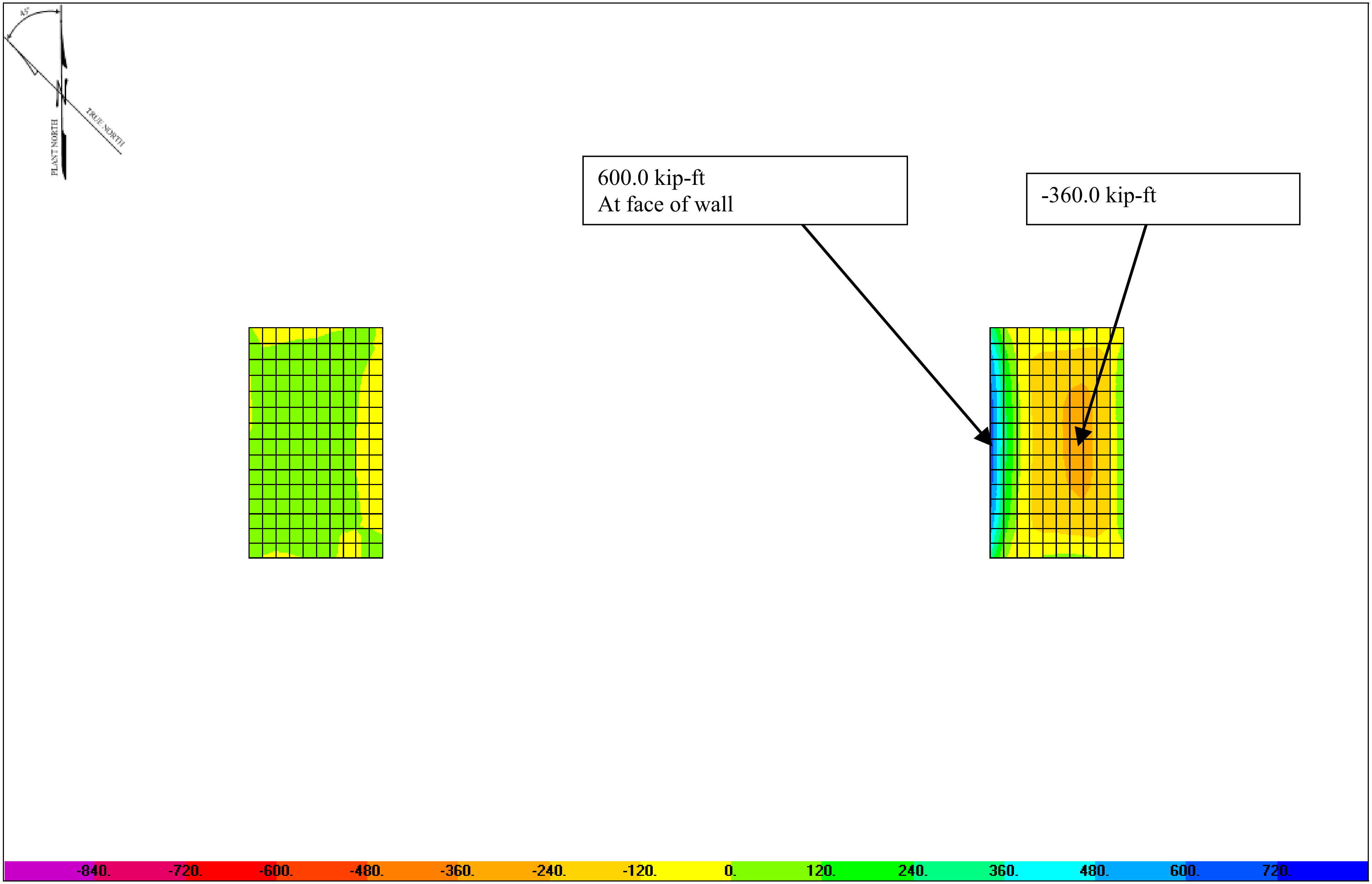
4 ft. Thick Resultant M12 Diagram – Combination 3 (DL+0.4HX+0.4HY+VZ) – kip-ft



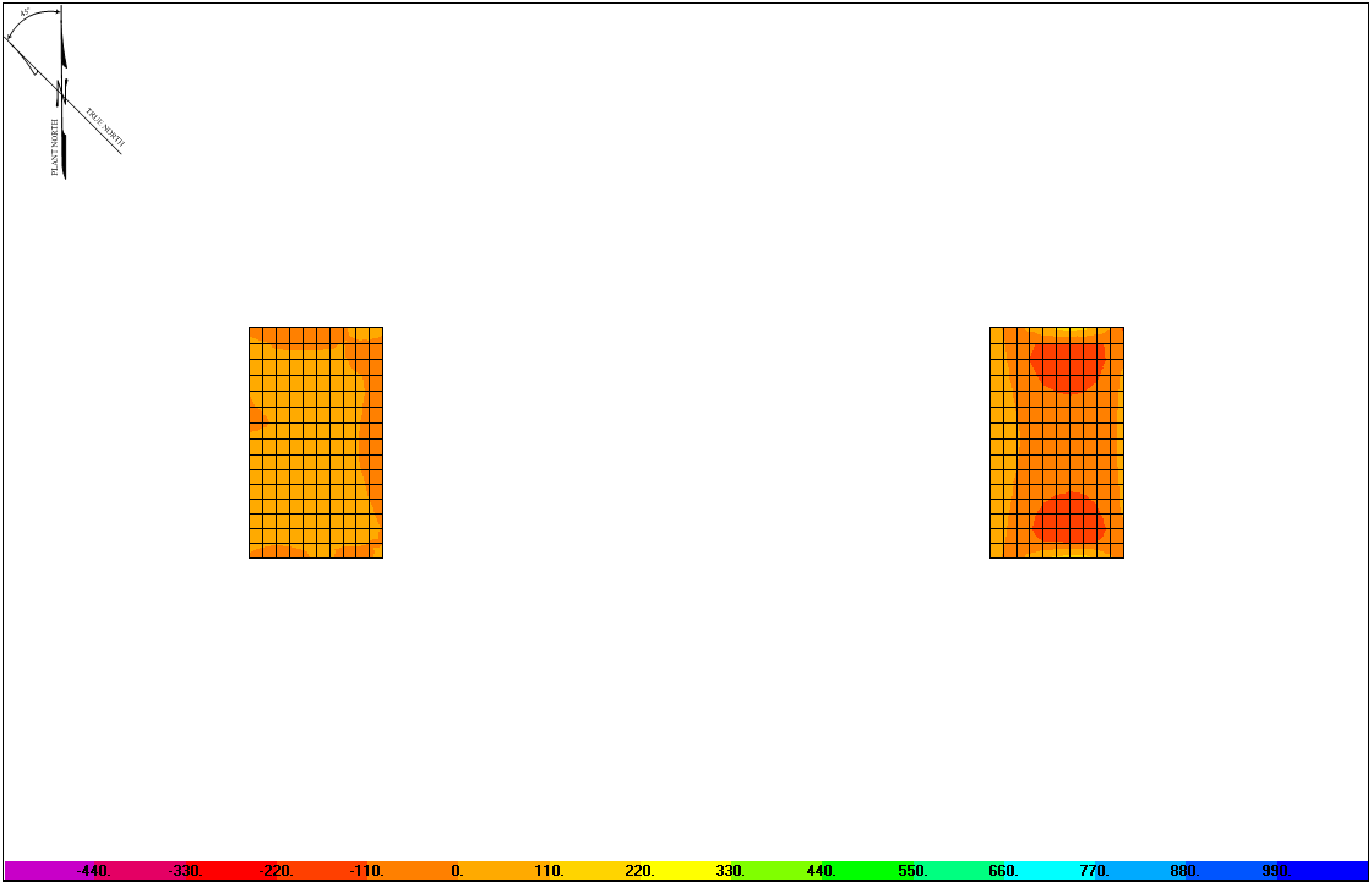
4 ft. Thick Resultant V13 Diagram – Combination 3 (DL+0.4HX+0.4HY+VZ) – kip



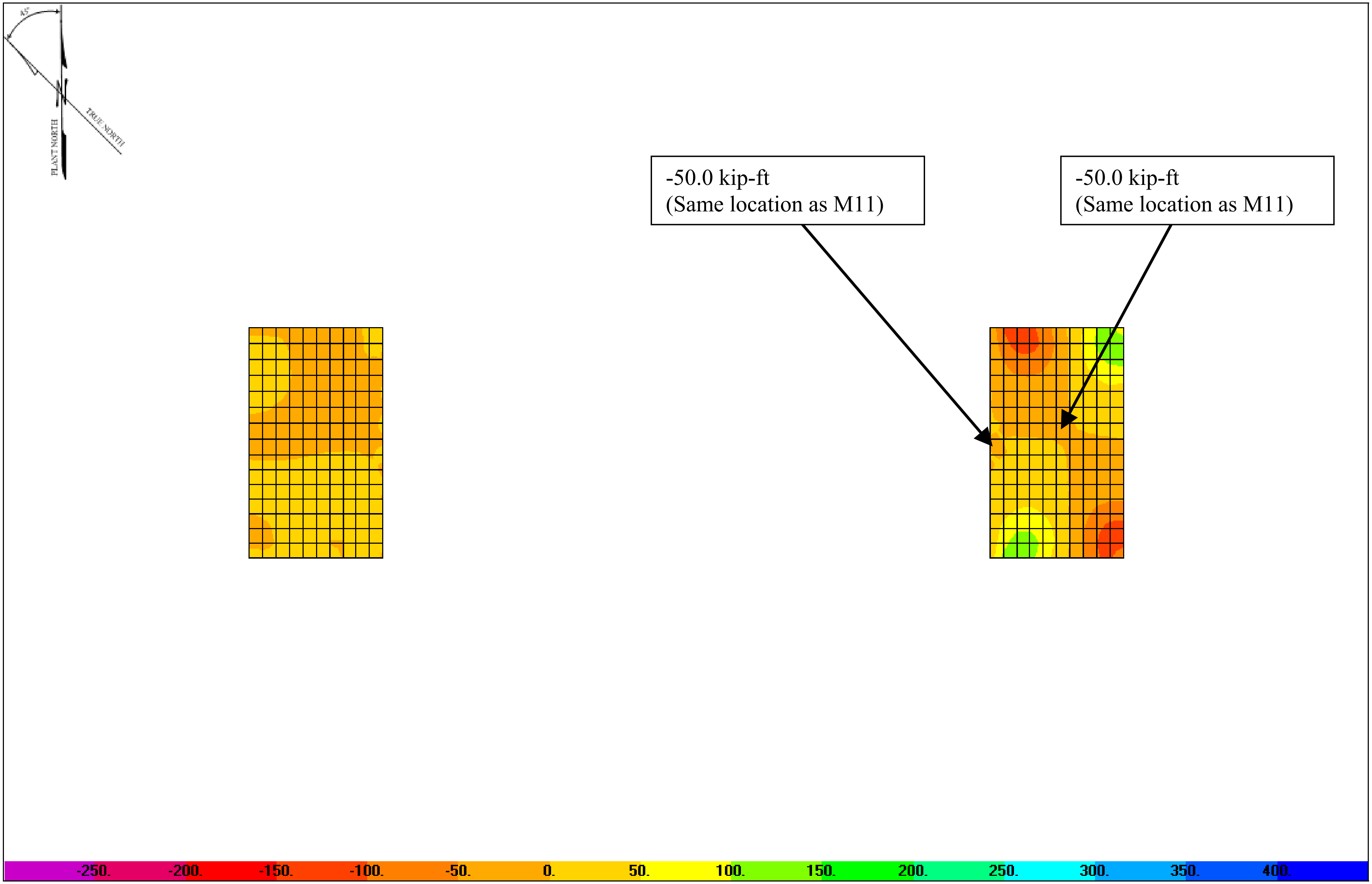
4 ft. Thick Resultant V23 Diagram – Combination 3 (DL+0.4HX+0.4HY+VZ) – kip



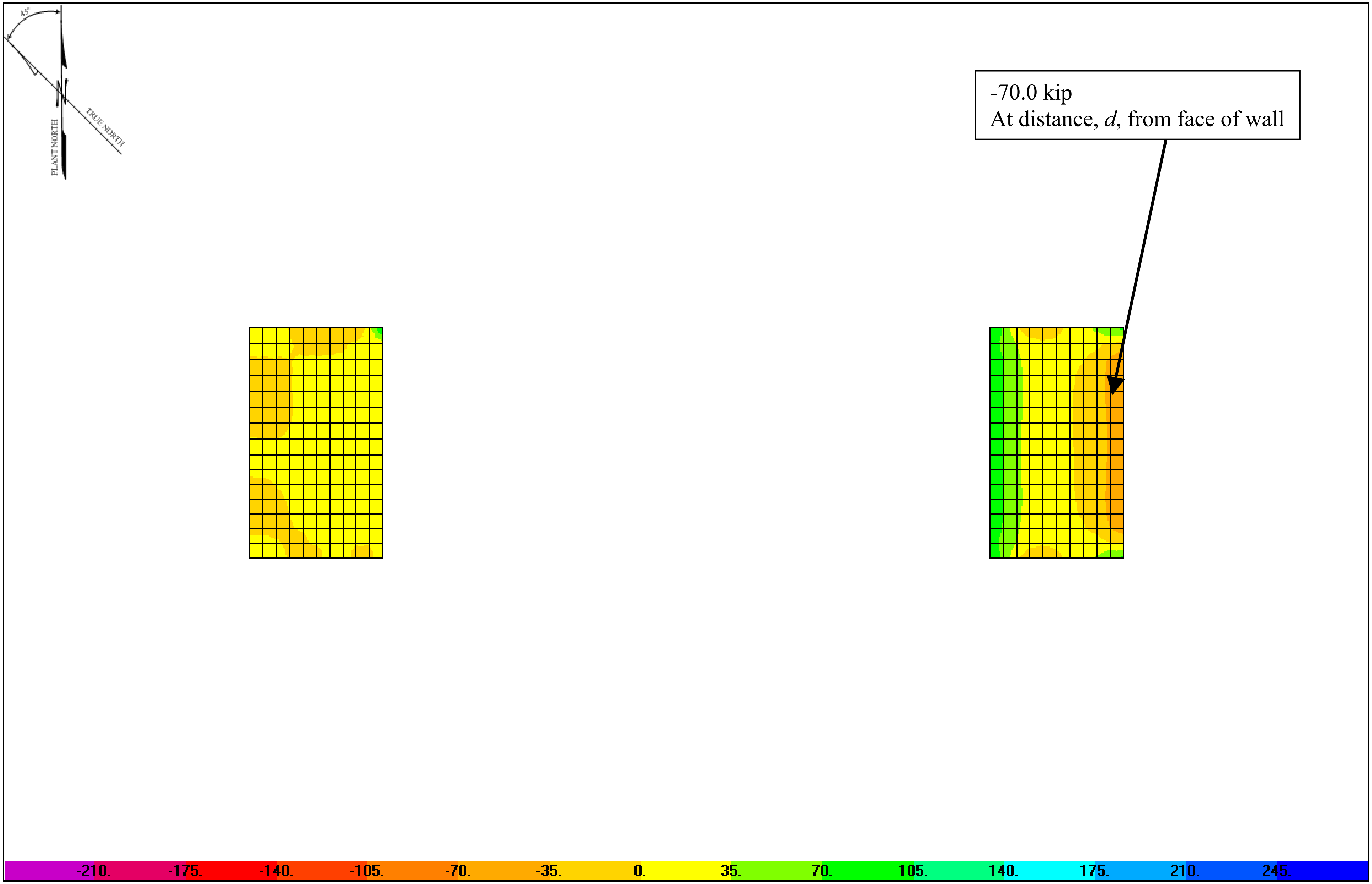
4 ft. Thick Resultant M11 Diagram – Combination 4 (DL+HX+0.4HY-0.4VZ) – kip-ft



4 ft. Thick Resultant M22 Diagram – Combination 4 (DL+HX+0.4HY-0.4VZ) – kip-ft

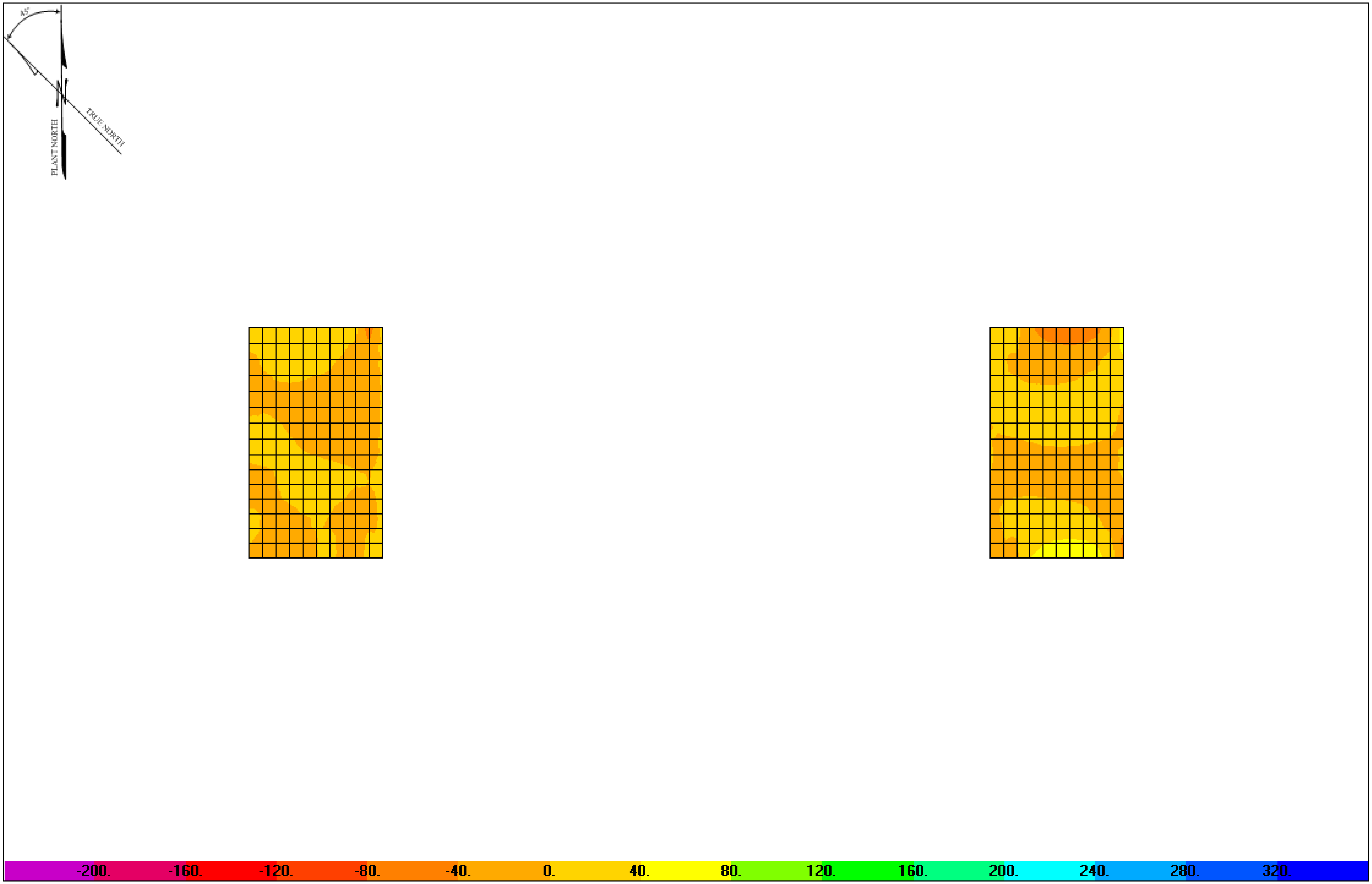


4 ft. Thick Resultant M12 Diagram – Combination 4 (DL+HX+0.4HY-0.4VZ) – kip-ft

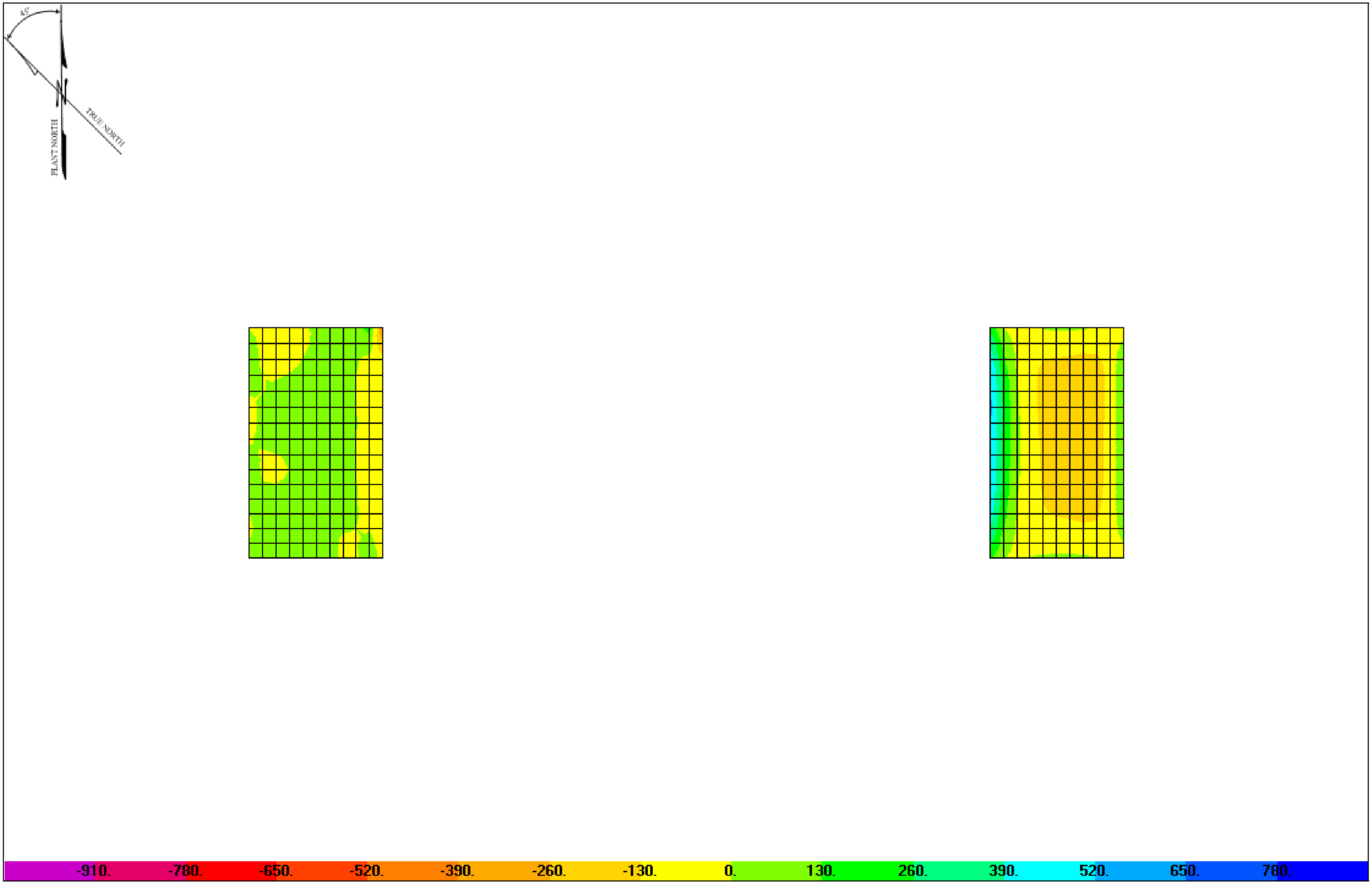


-70.0 kip
At distance, *d*, from face of wall

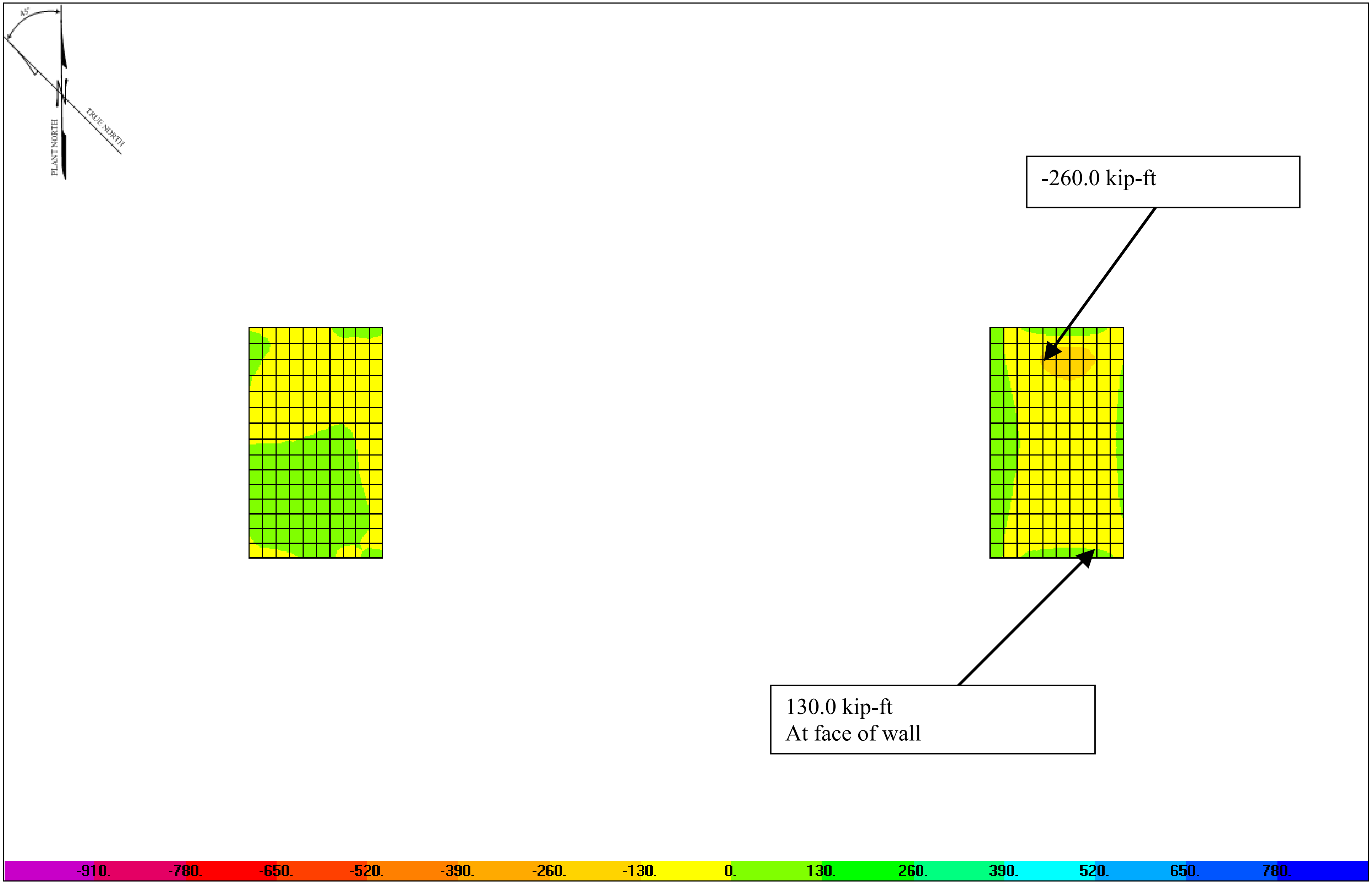
4 ft. Thick Resultant V13 Diagram – Combination 4 (DL+HX+0.4HY-0.4VZ) – kip



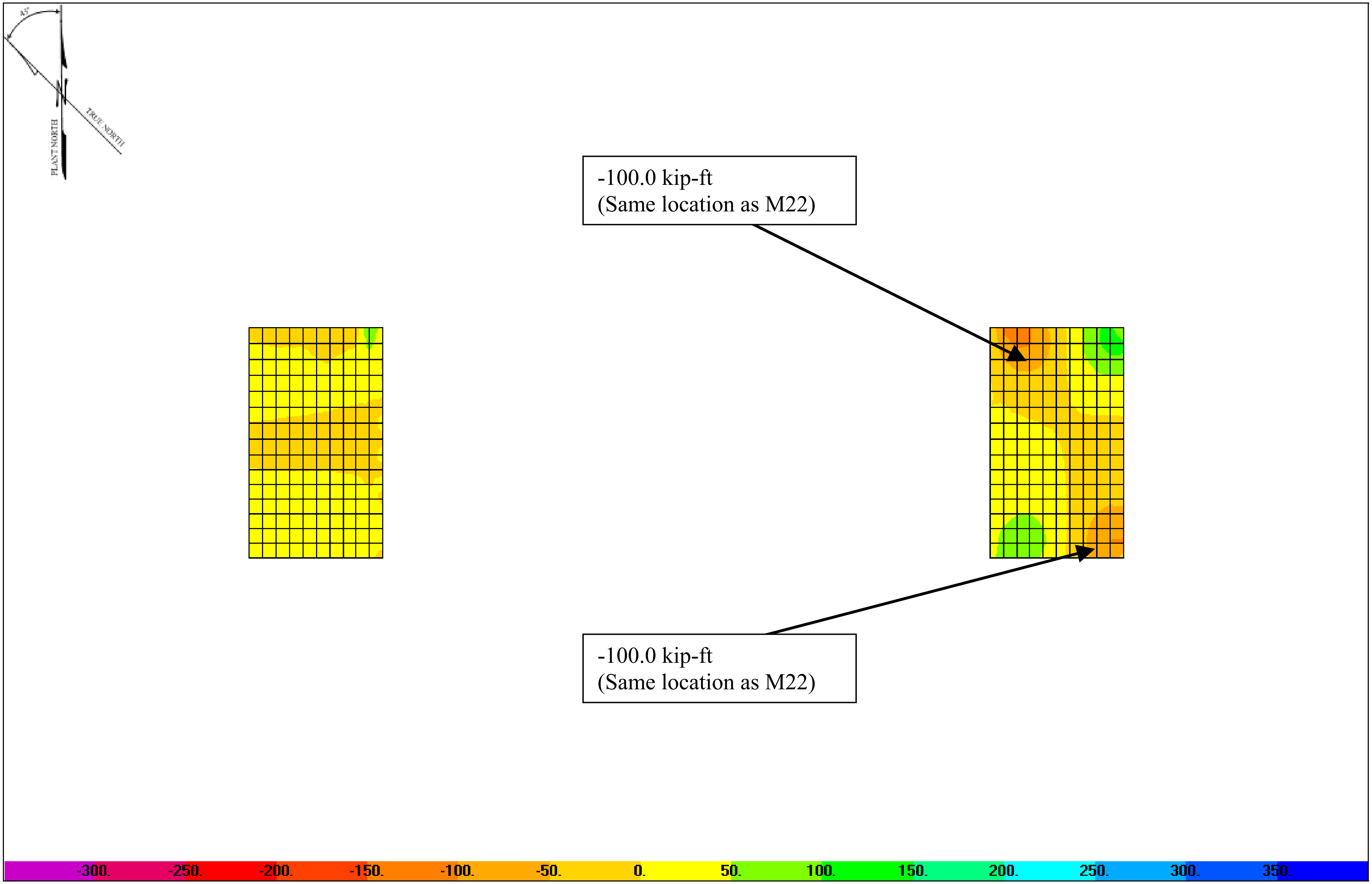
4 ft. Thick Resultant V23 Diagram – Combination 4 (DL+HX+0.4HY-0.4VZ) – kip



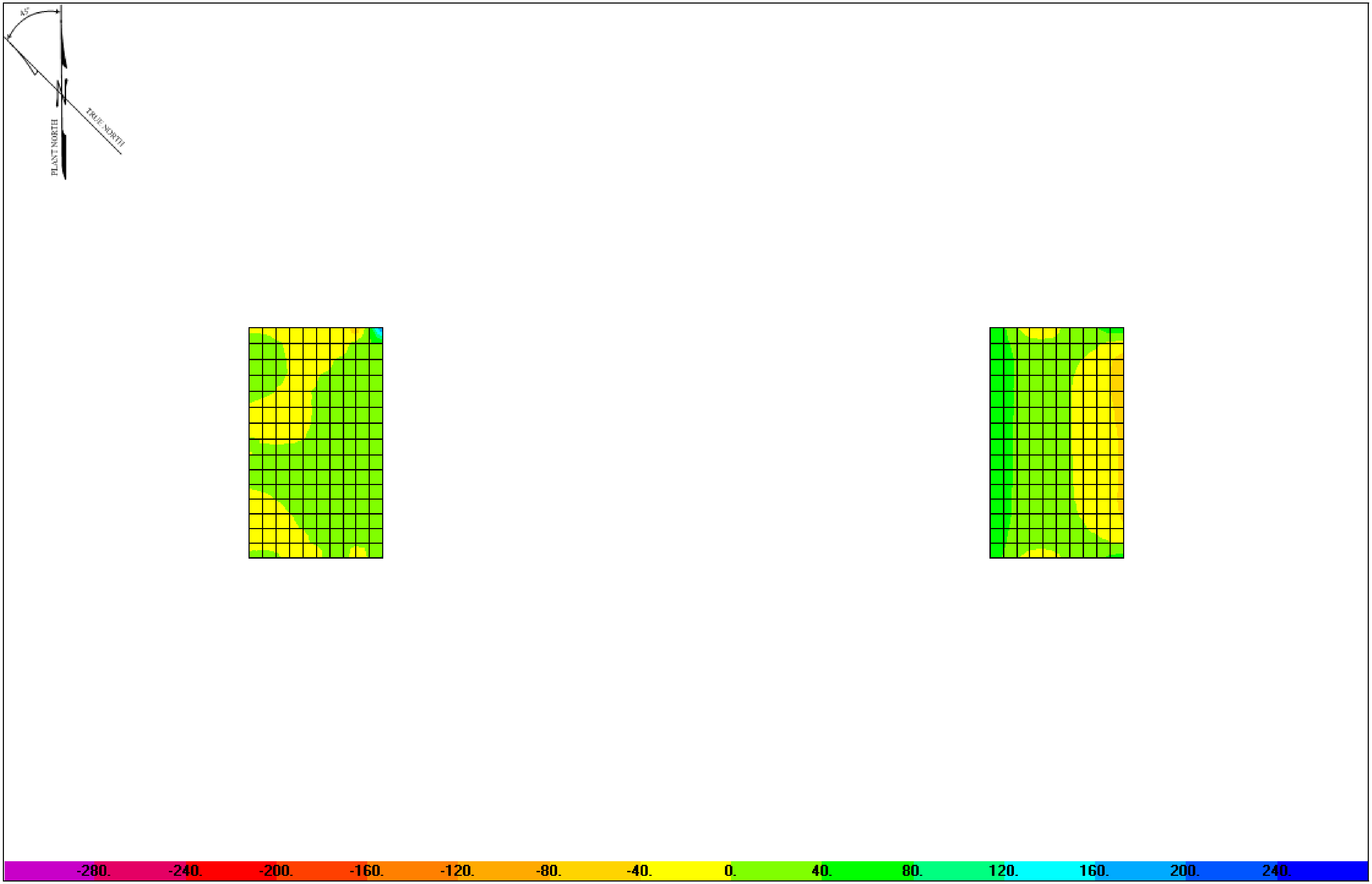
4 ft. Thick Resultant M11 Diagram – Combination 5 (DL+0.4HX+HY-0.4VZ) – kip-ft



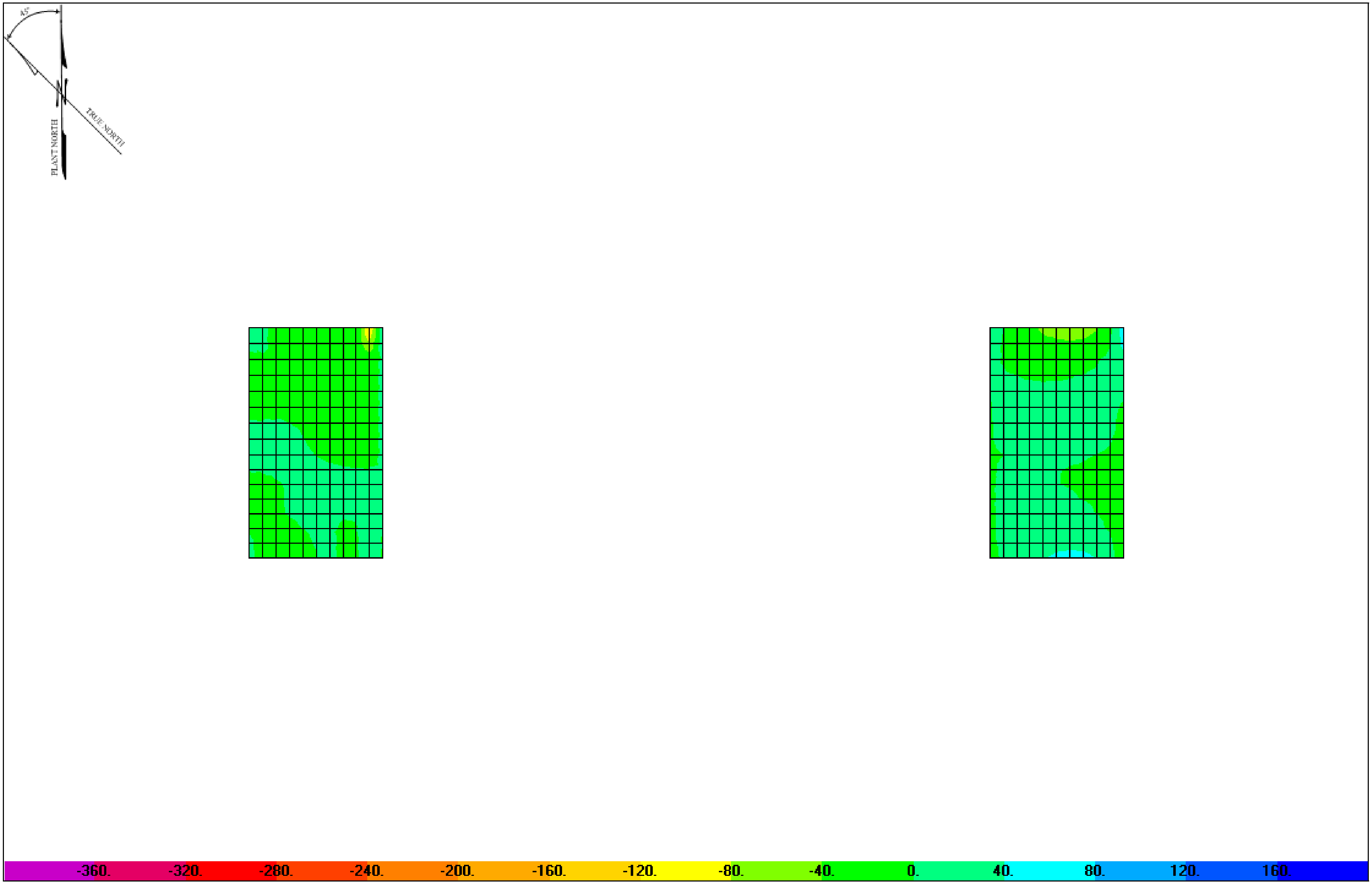
4 ft. Thick Resultant M22 Diagram – Combination 5 (DL+0.4HX+HY-0.4VZ) – kip-ft



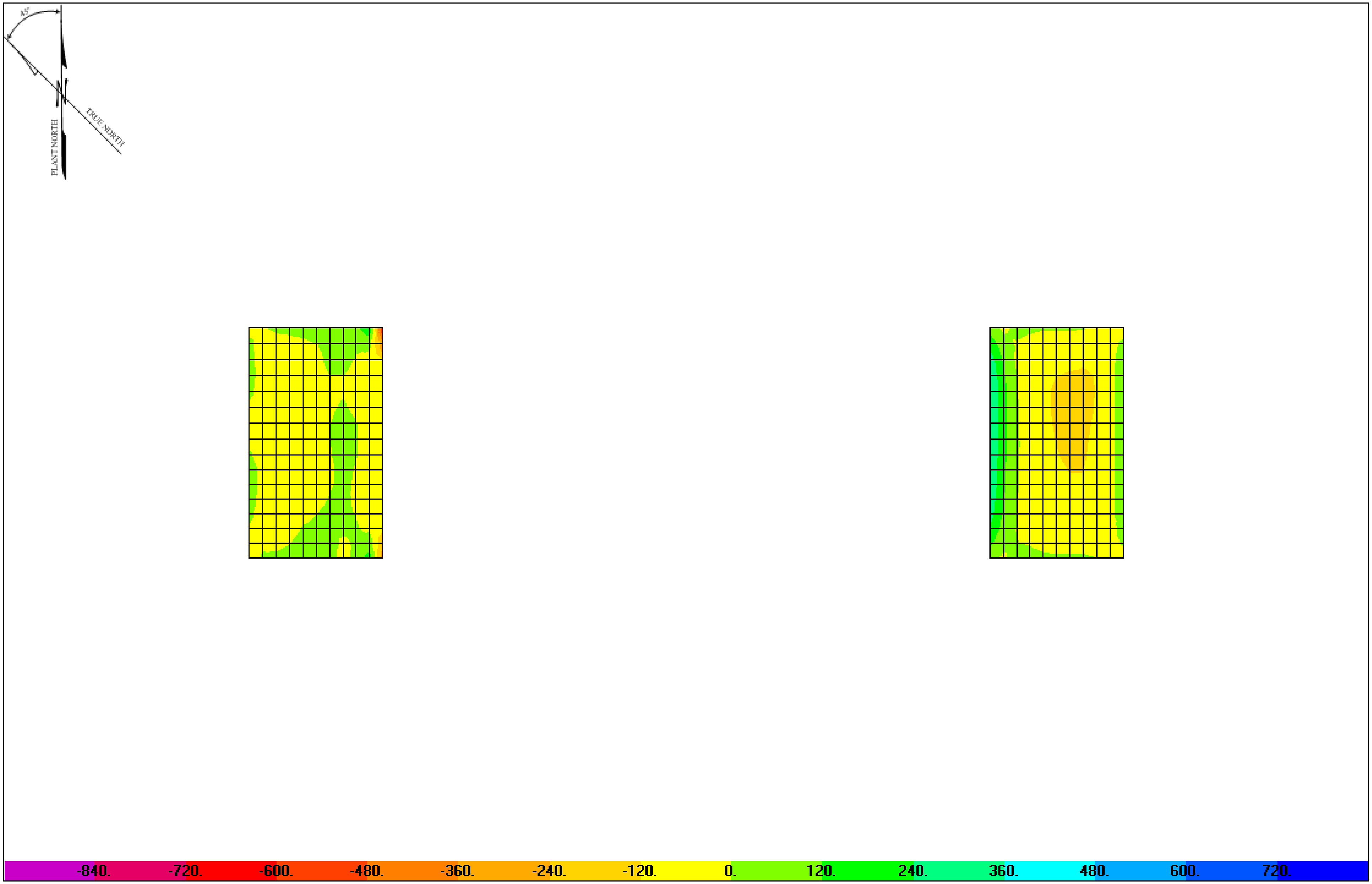
4 ft. Thick Resultant M12 Diagram – Combination 5 (DL+0.4HX+HY-0.4VZ) – kip-ft



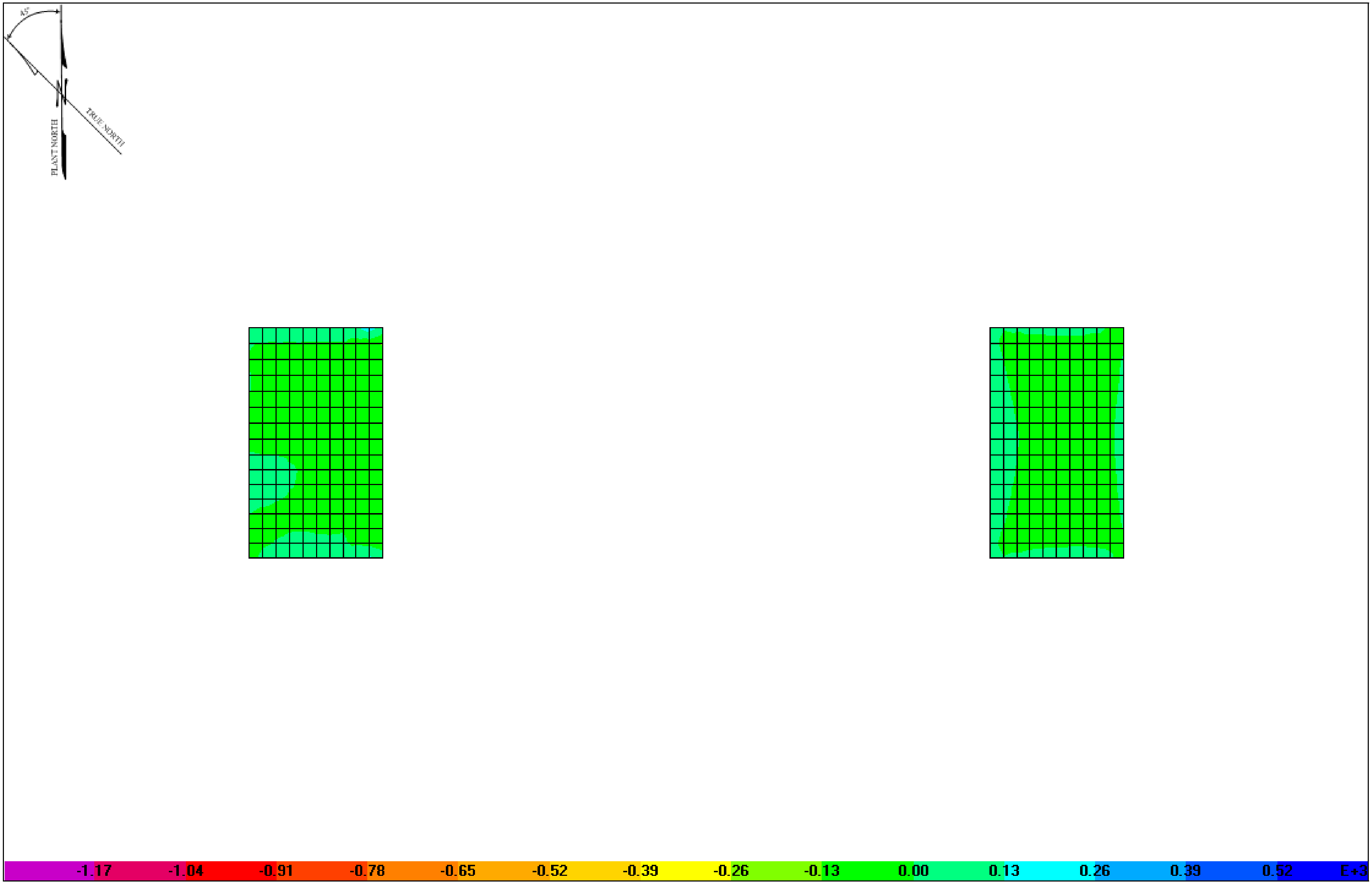
4 ft. Thick Resultant V13 Diagram – Combination 5 (DL+0.4HX+HY-0.4VZ) – kip



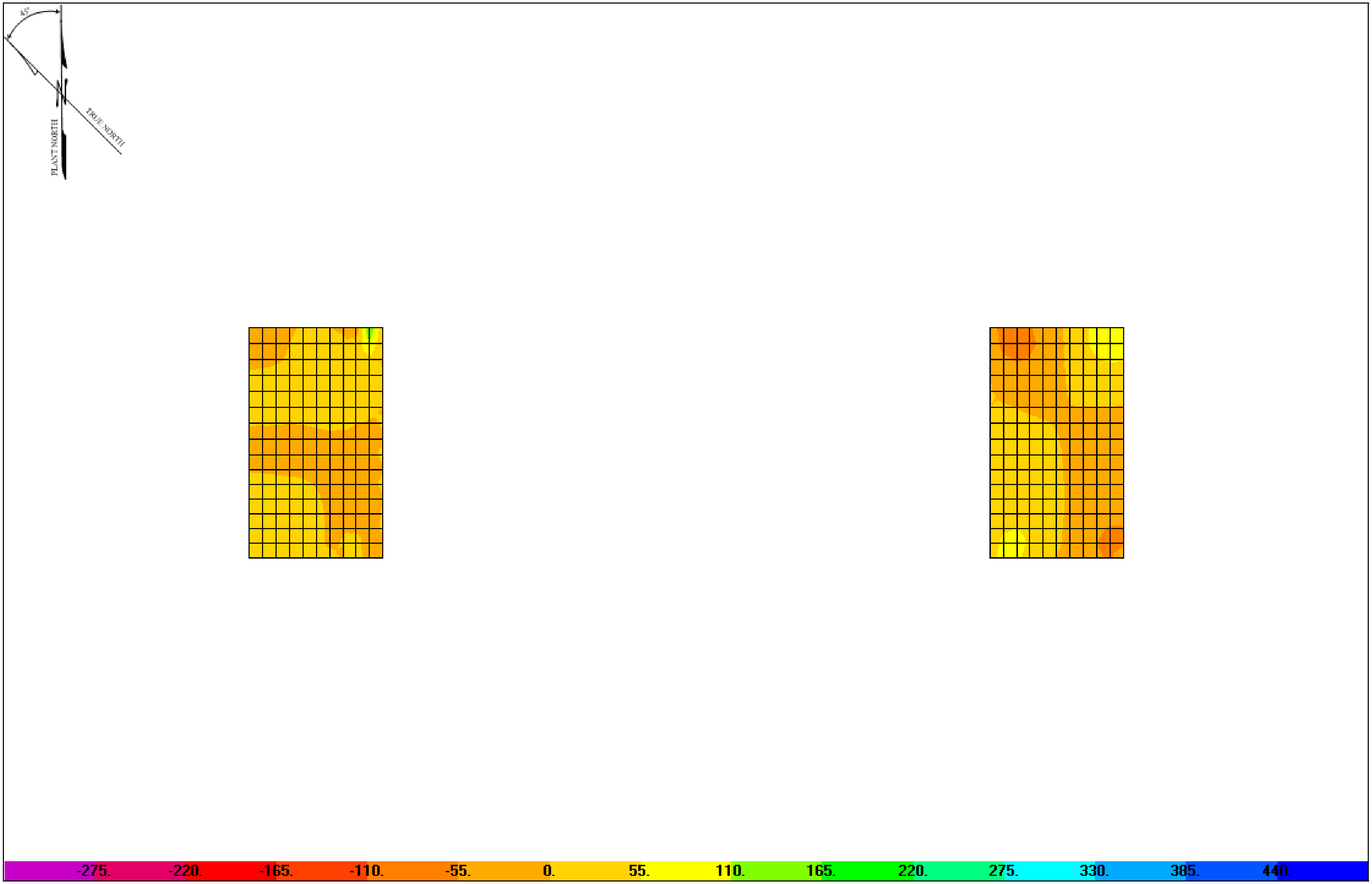
4 ft. Thick Resultant V23 Diagram – Combination 5 (DL+0.4HX+HY-0.4VZ) – kip



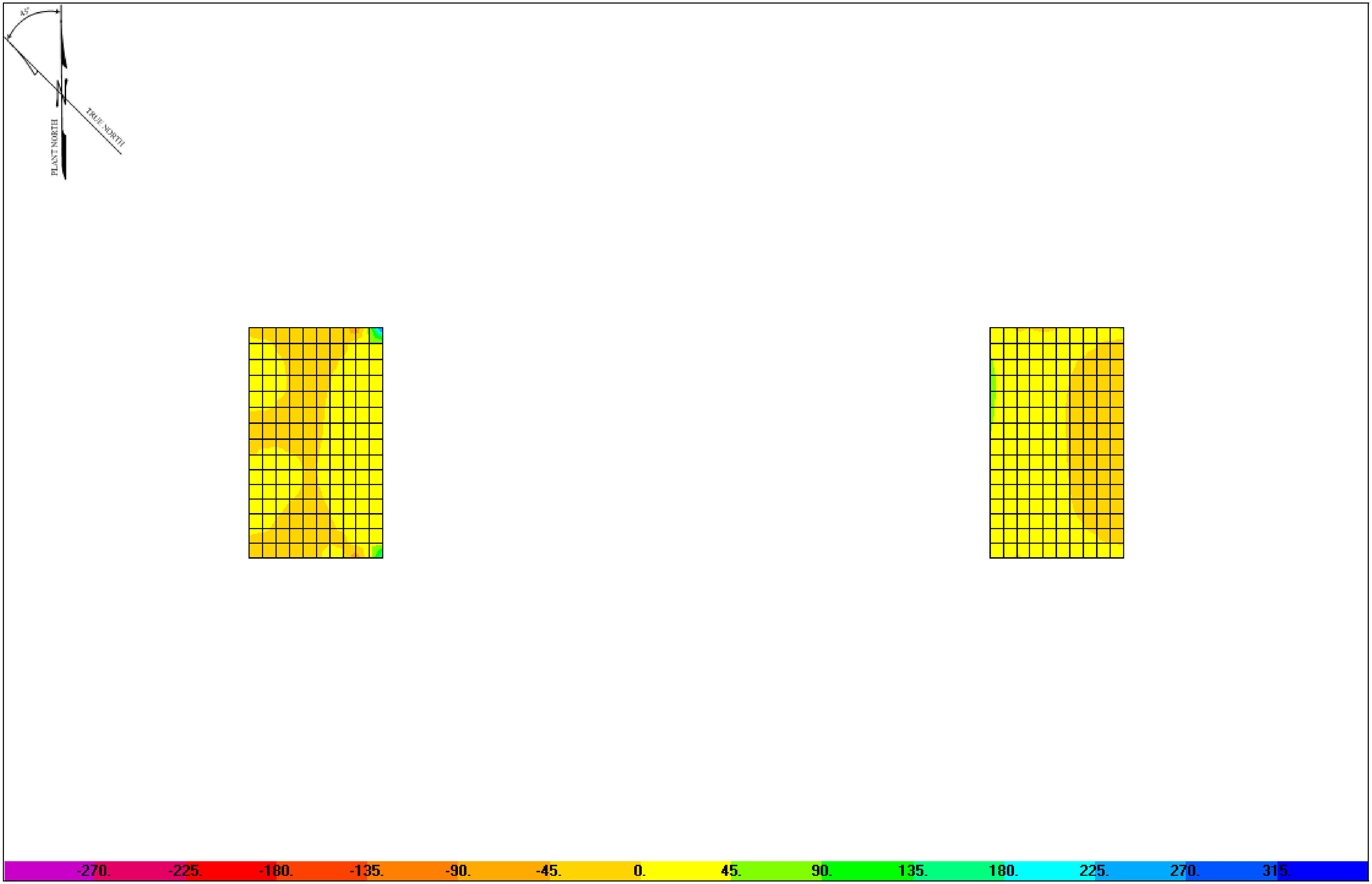
4 ft. Thick Resultant M11 Diagram – Combination 6 (DL-0.4HX+HY-0.4VZ) – kip-ft



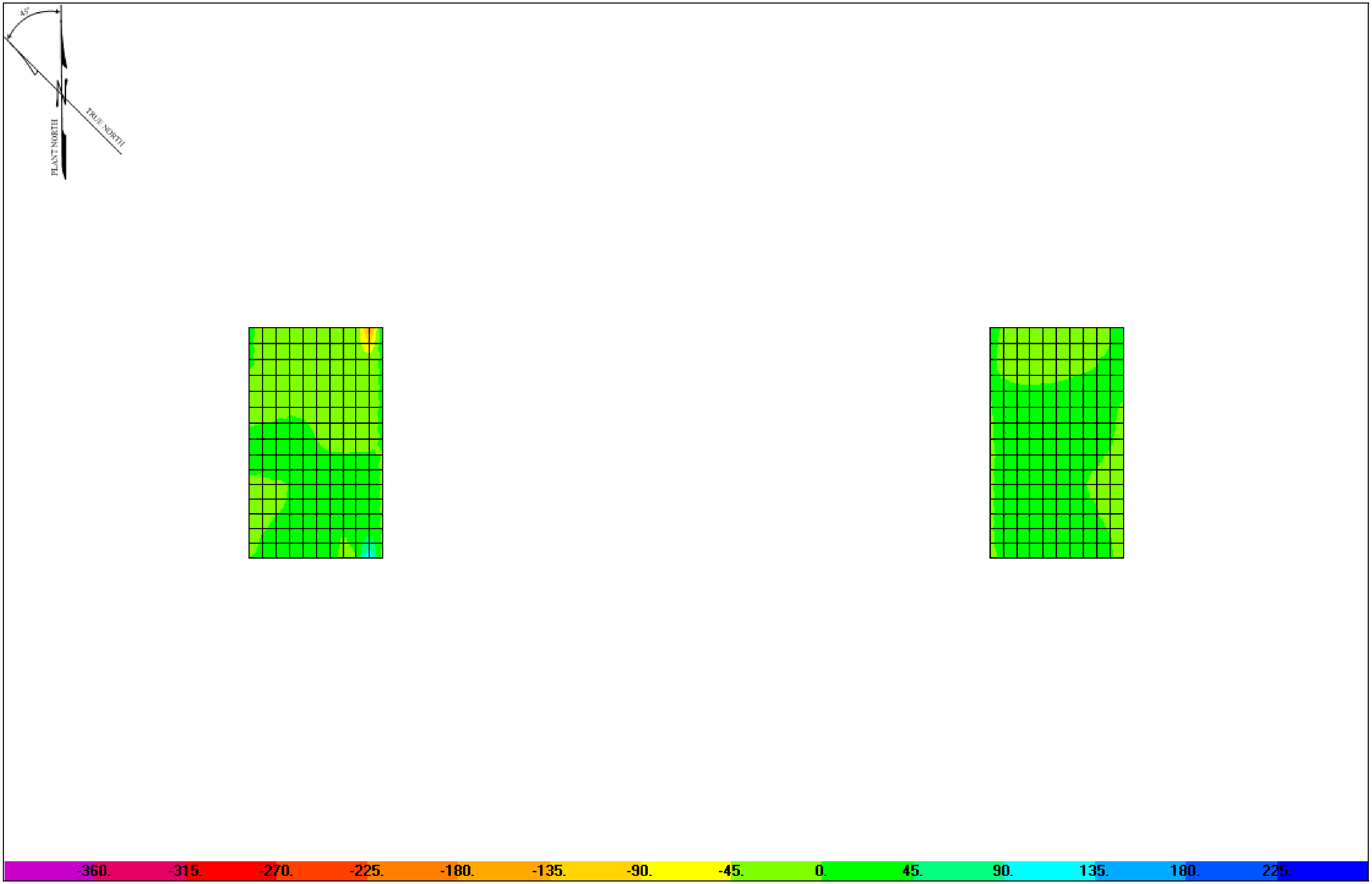
4 ft. Thick Resultant M22 Diagram – Combination 6 (DL-0.4HX+HY-0.4VZ) – kip-ft



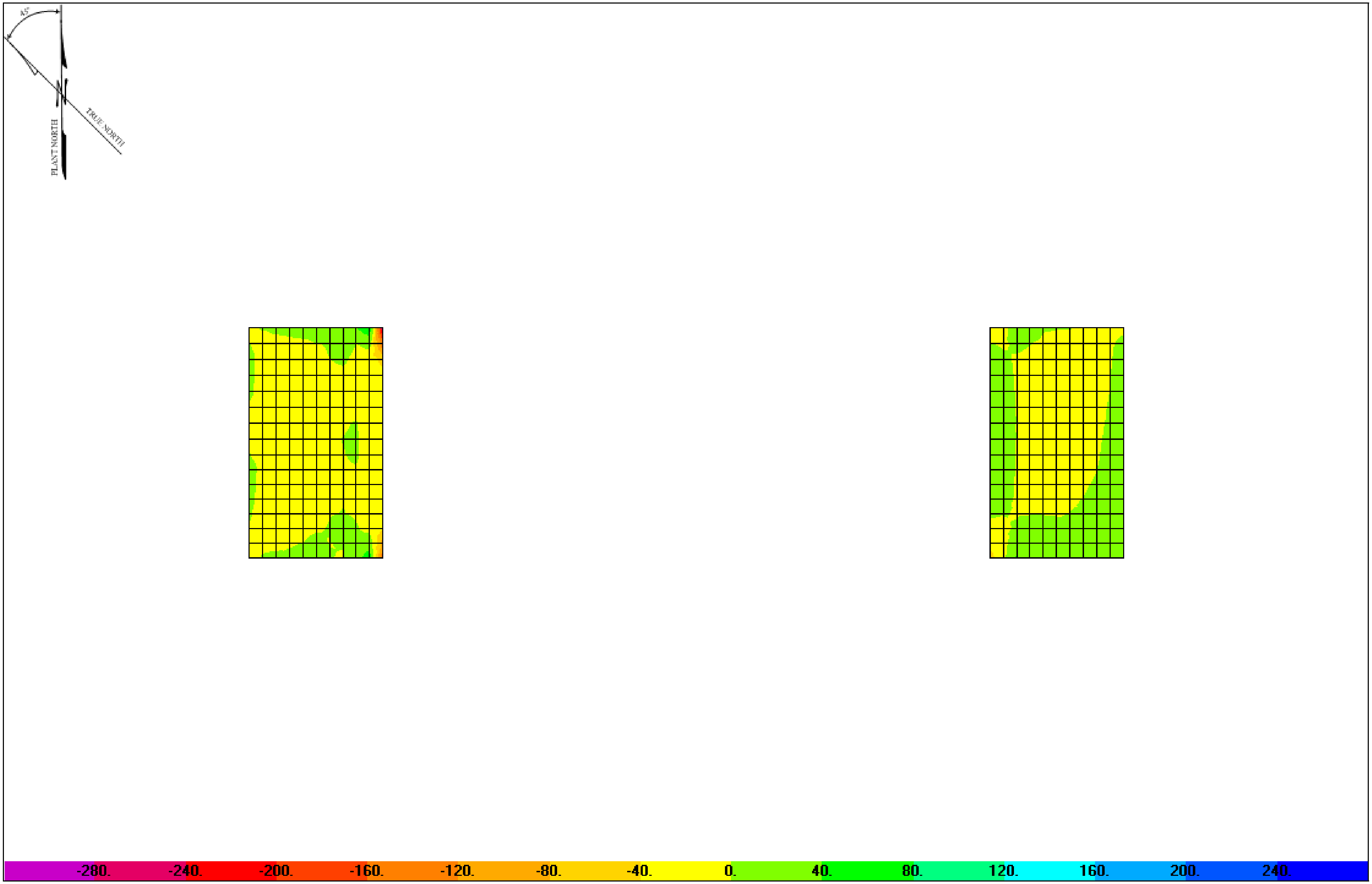
4 ft. Thick Resultant M12 Diagram – Combination 6 (DL-0.4HX+HY-0.4VZ) – kip-ft



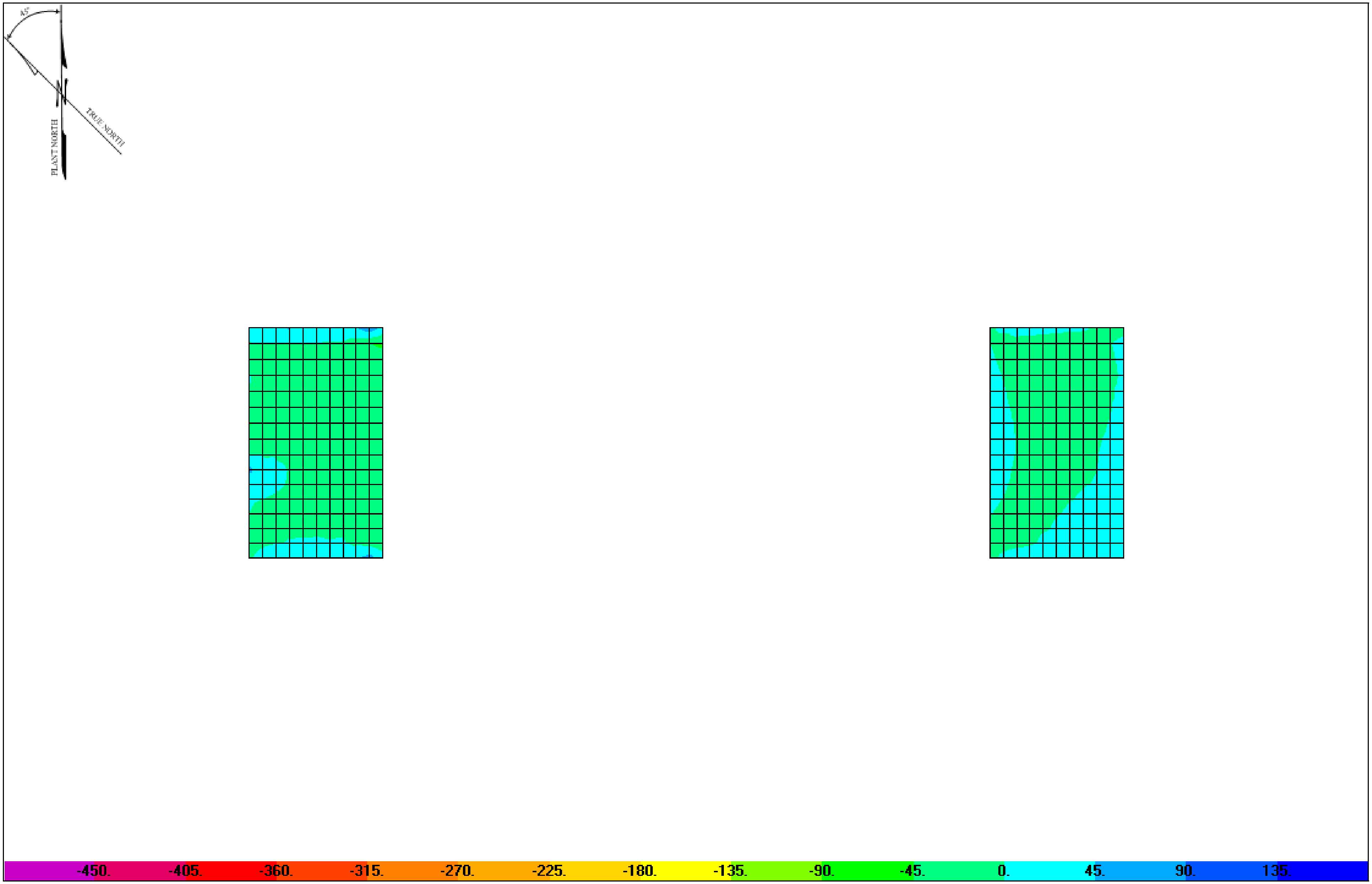
4 ft. Thick Resultant V13 Diagram – Combination 6 (DL-0.4HX+HY-0.4VZ) – kip



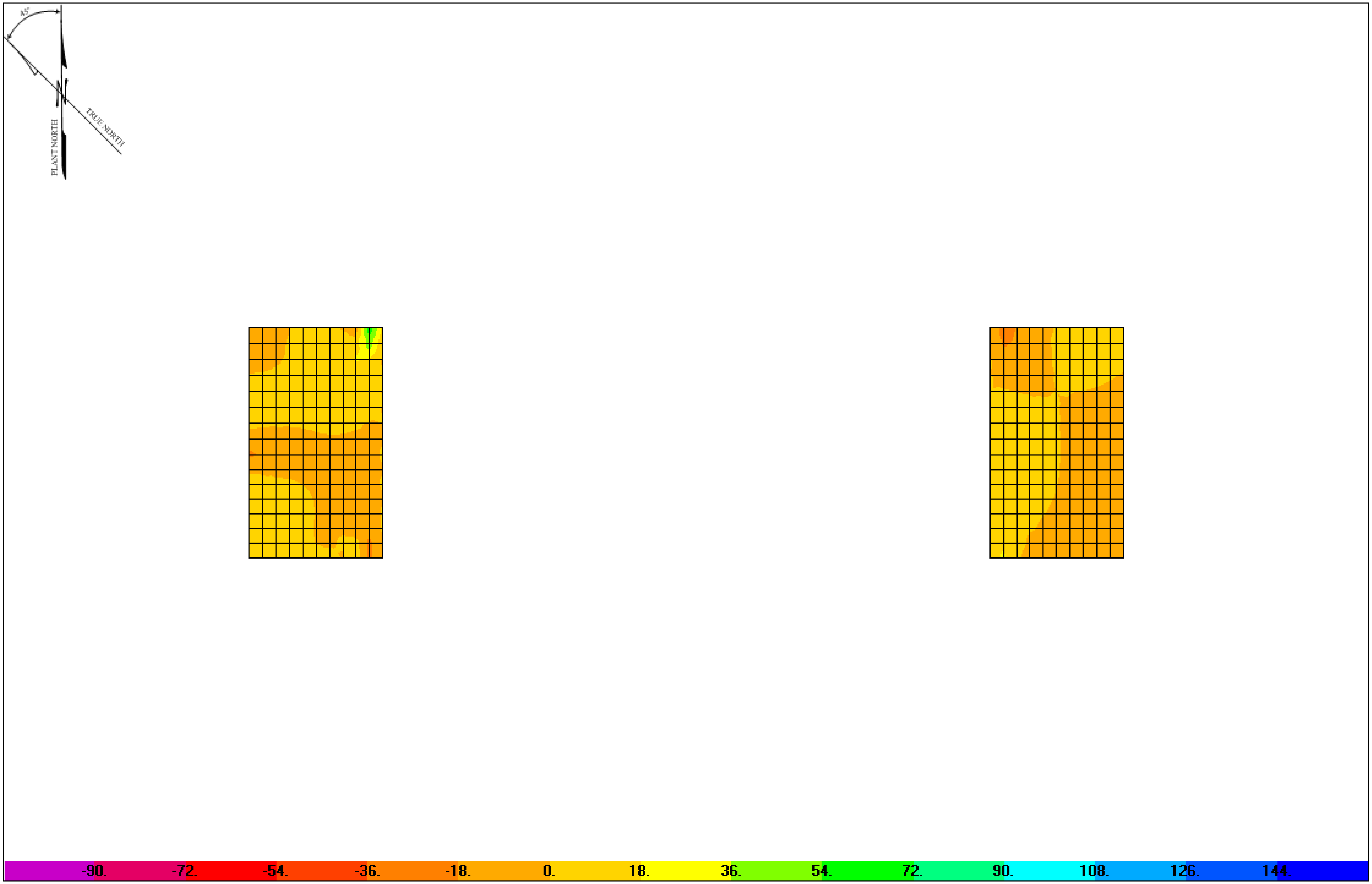
4 ft. Thick Resultant V23 Diagram – Combination 6 (DL-0.4HX+HY-0.4VZ) – kip



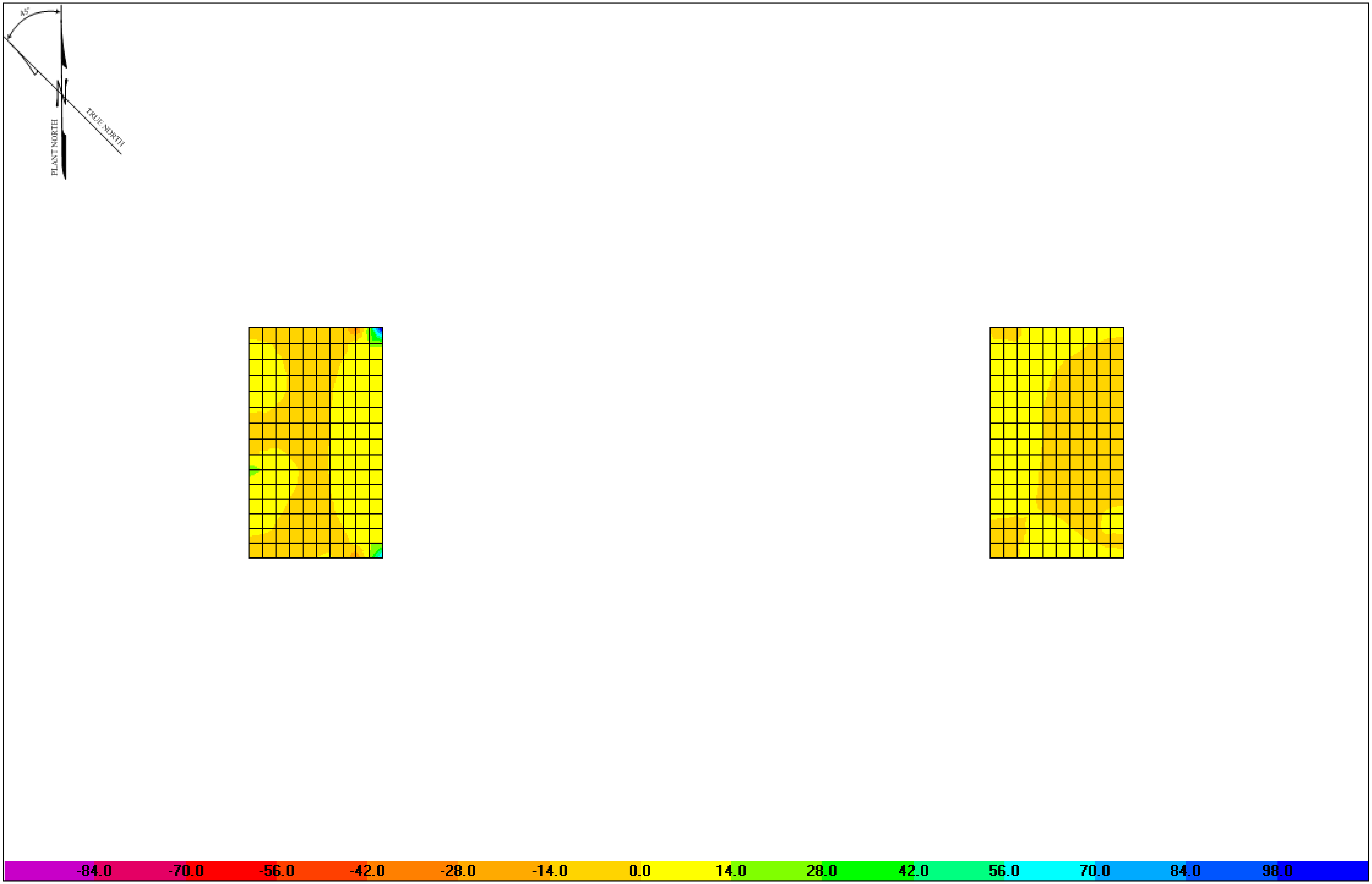
4 ft. Thick Resultant M11 Diagram – Combination 7 (DL-0.4HX+0.4HY+VZ) – kip-ft



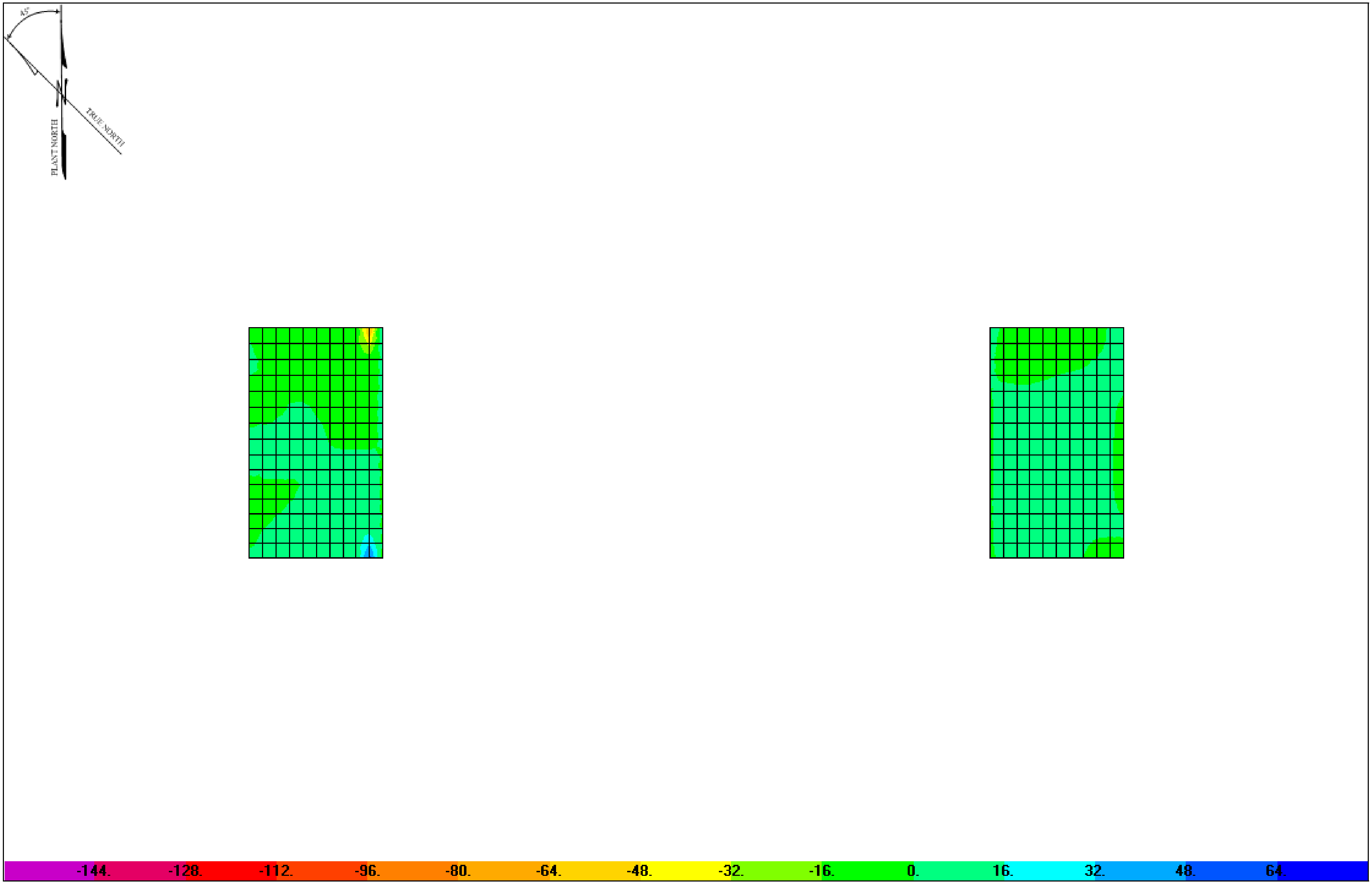
4 ft. Thick Resultant M22 Diagram – Combination 7 (DL-0.4HX+0.4HY+VZ) – kip-ft



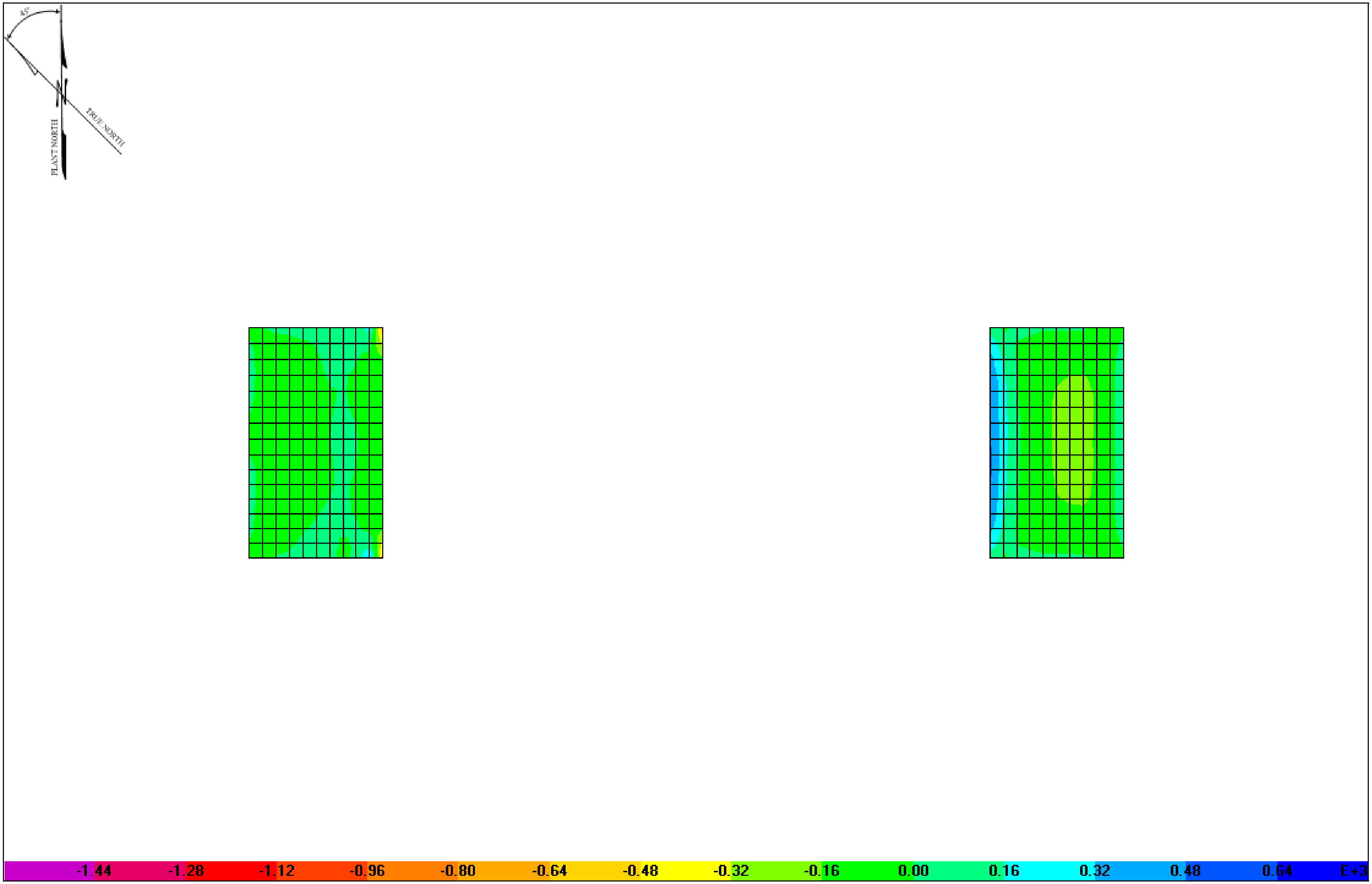
4 ft. Thick Resultant M12 Diagram – Combination 7 (DL-0.4HX+0.4HY+VZ) – kip-ft



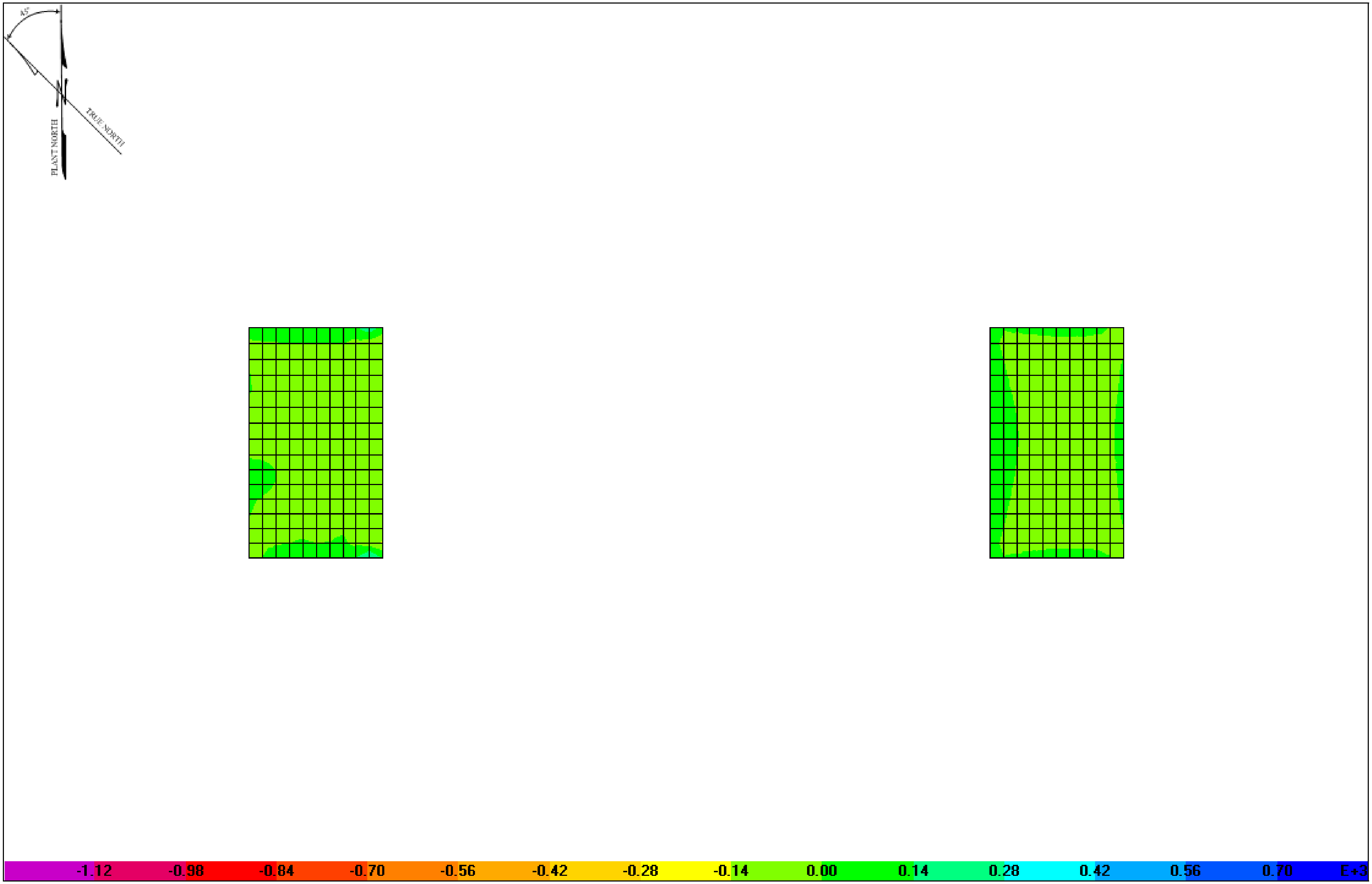
4 ft. Thick Resultant V13 Diagram – Combination 7 (DL-0.4HX+0.4HY+VZ) – kip



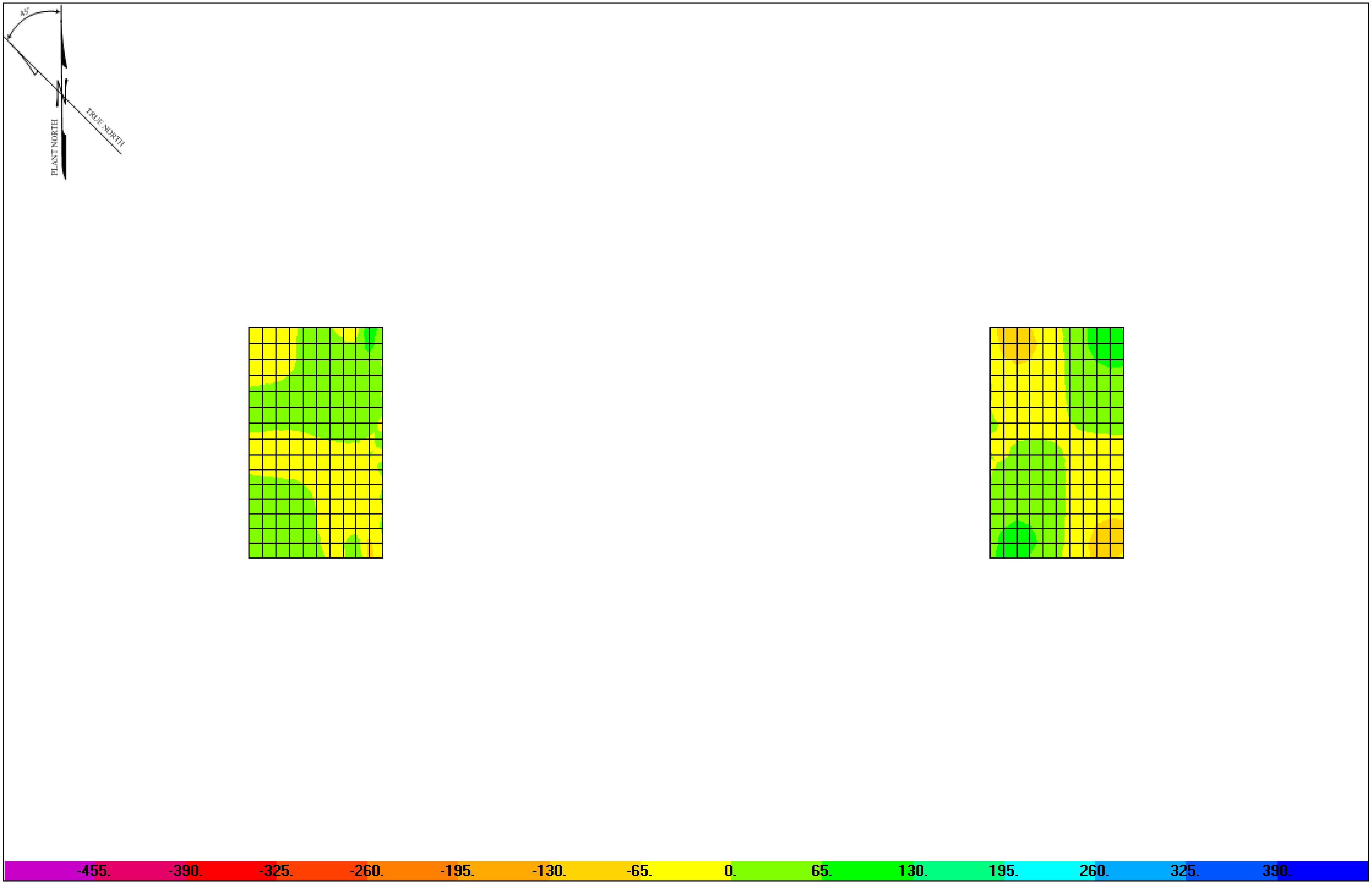
4 ft. Thick Resultant V23 Diagram – Combination 7 (DL-0.4HX+0.4HY+VZ) – kip



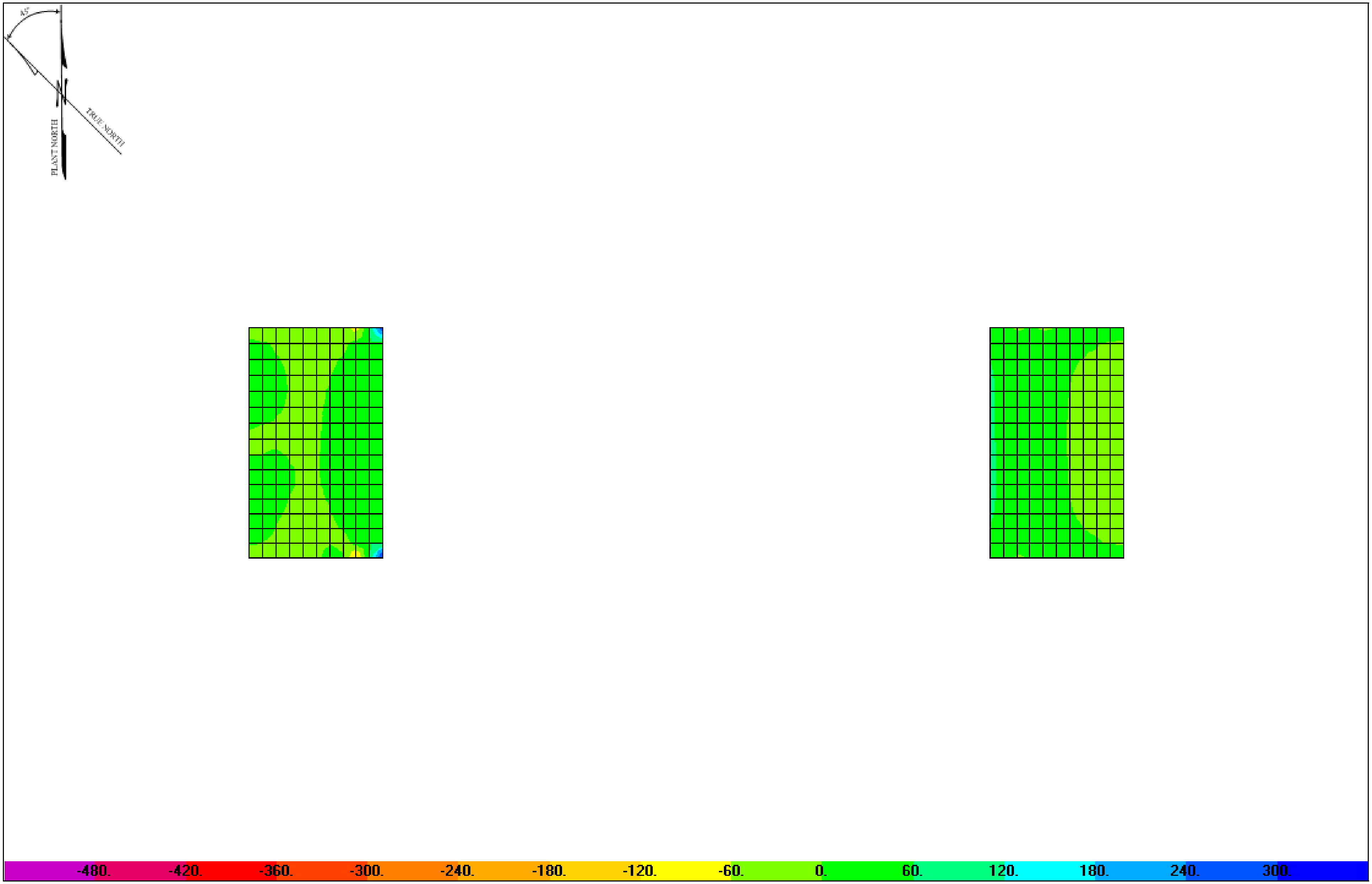
4 ft. Thick Resultant M11 Diagram – Combination 8 (DL-0.4HX+0.4HY-VZ) – kip-ft



4 ft. Thick Resultant M22 Diagram – Combination 8 (DL-0.4HX+0.4HY-VZ) – kip-ft



4 ft. Thick Resultant M12 Diagram – Combination 8 (DL-0.4HX+0.4HY-VZ) – kip-ft



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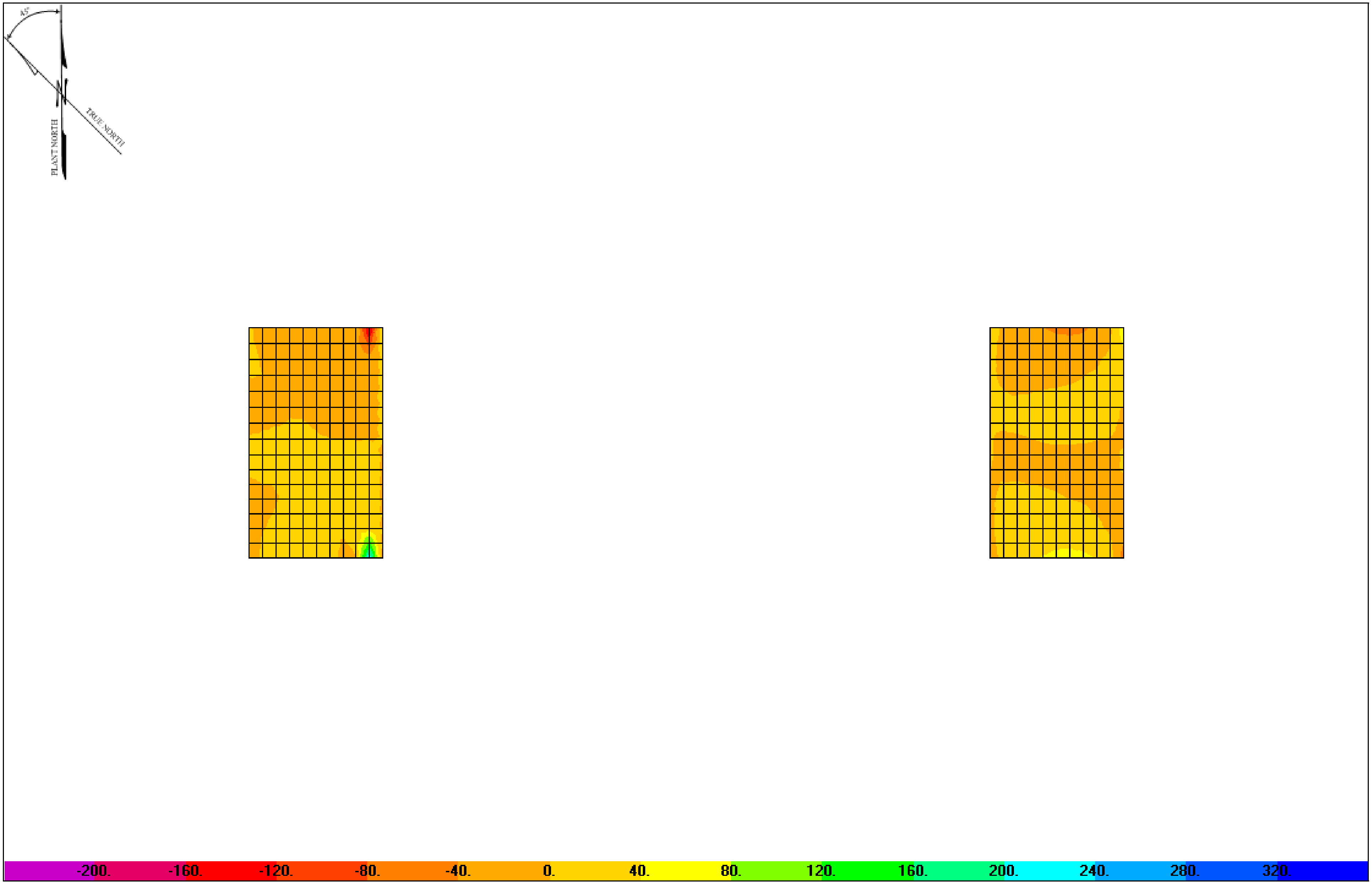
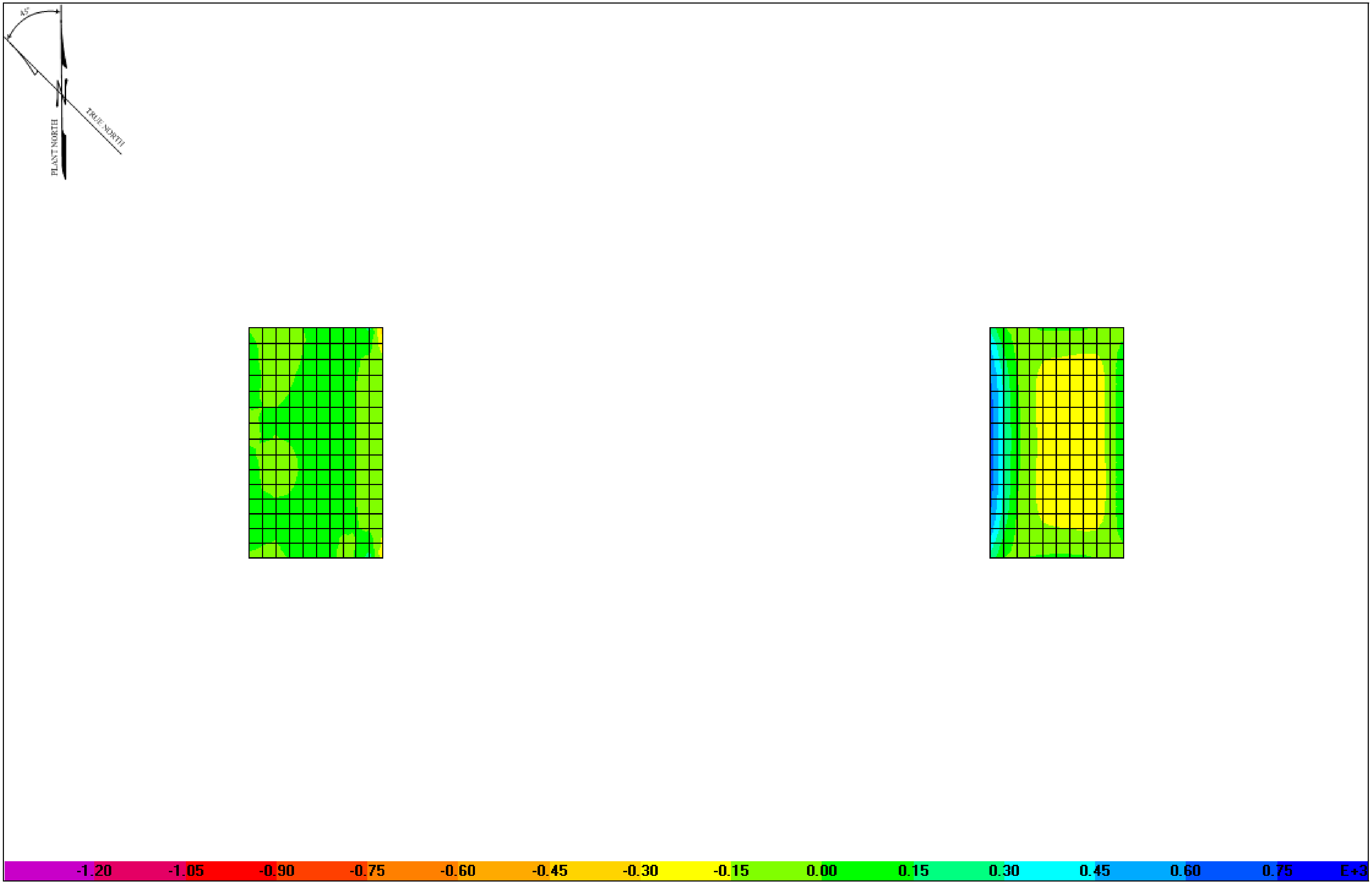
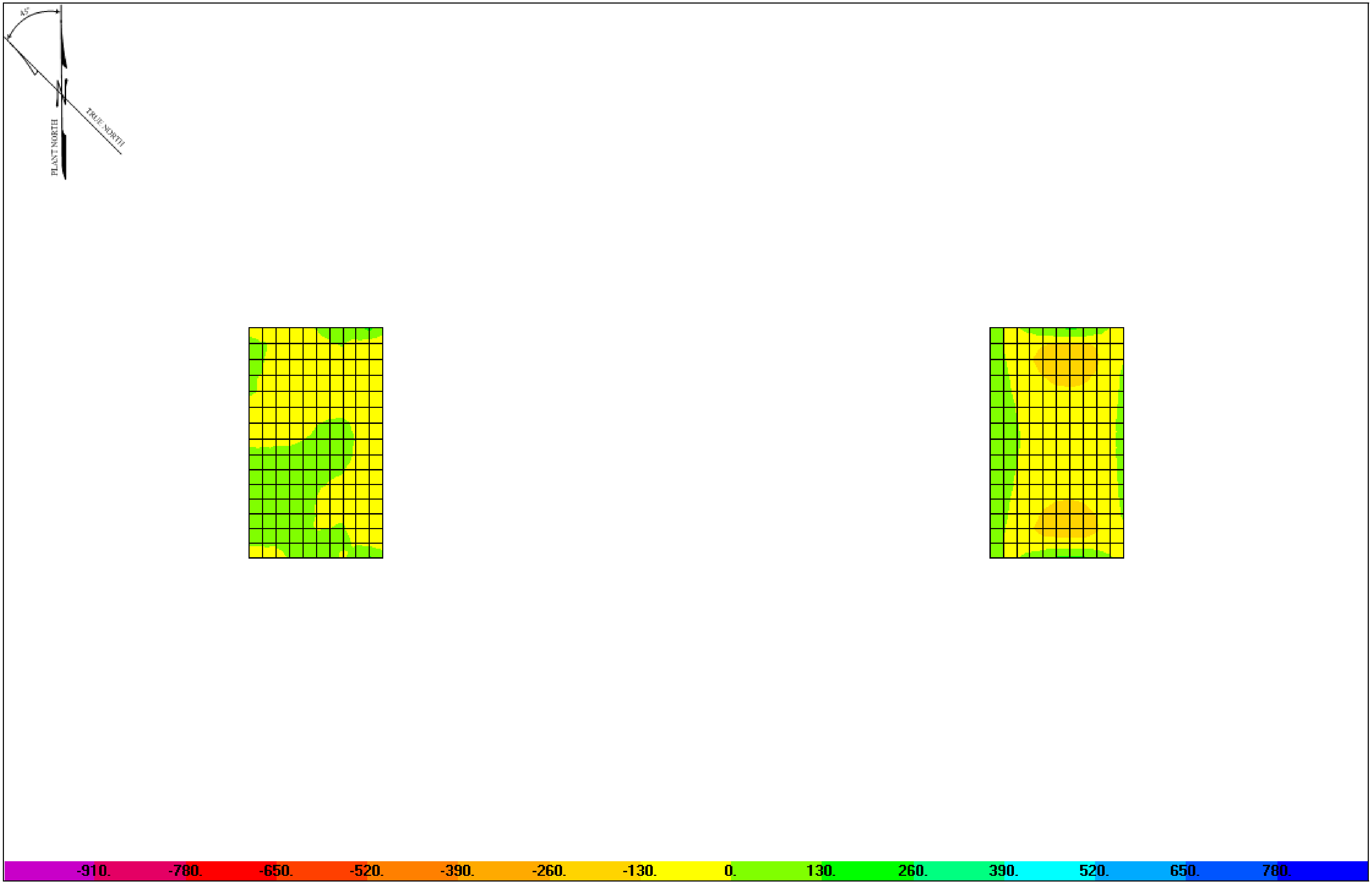


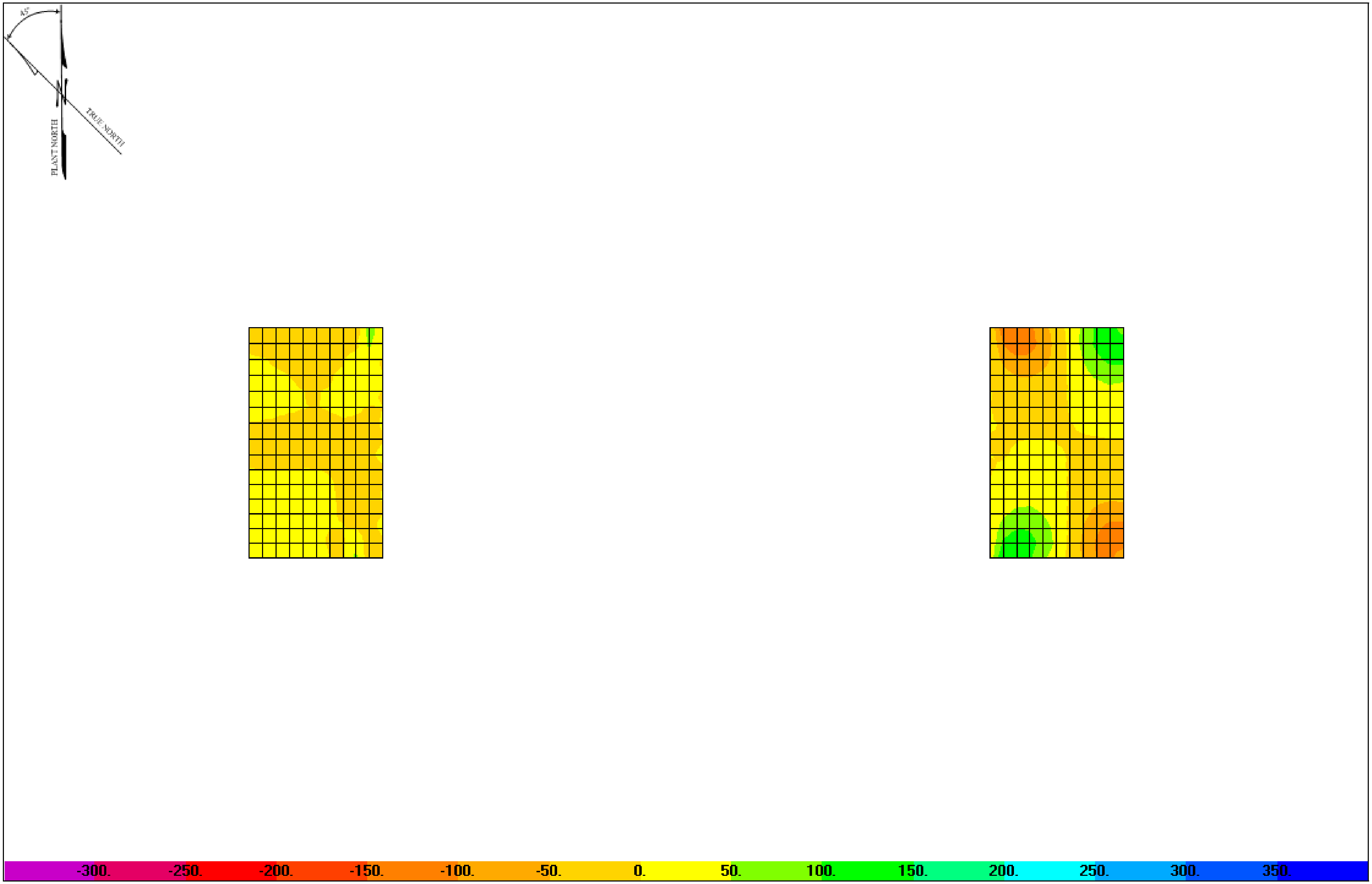
4 ft. Thick Resultant V23 Diagram – Combination 8 (DL-0.4HX+0.4HY-VZ) – kip



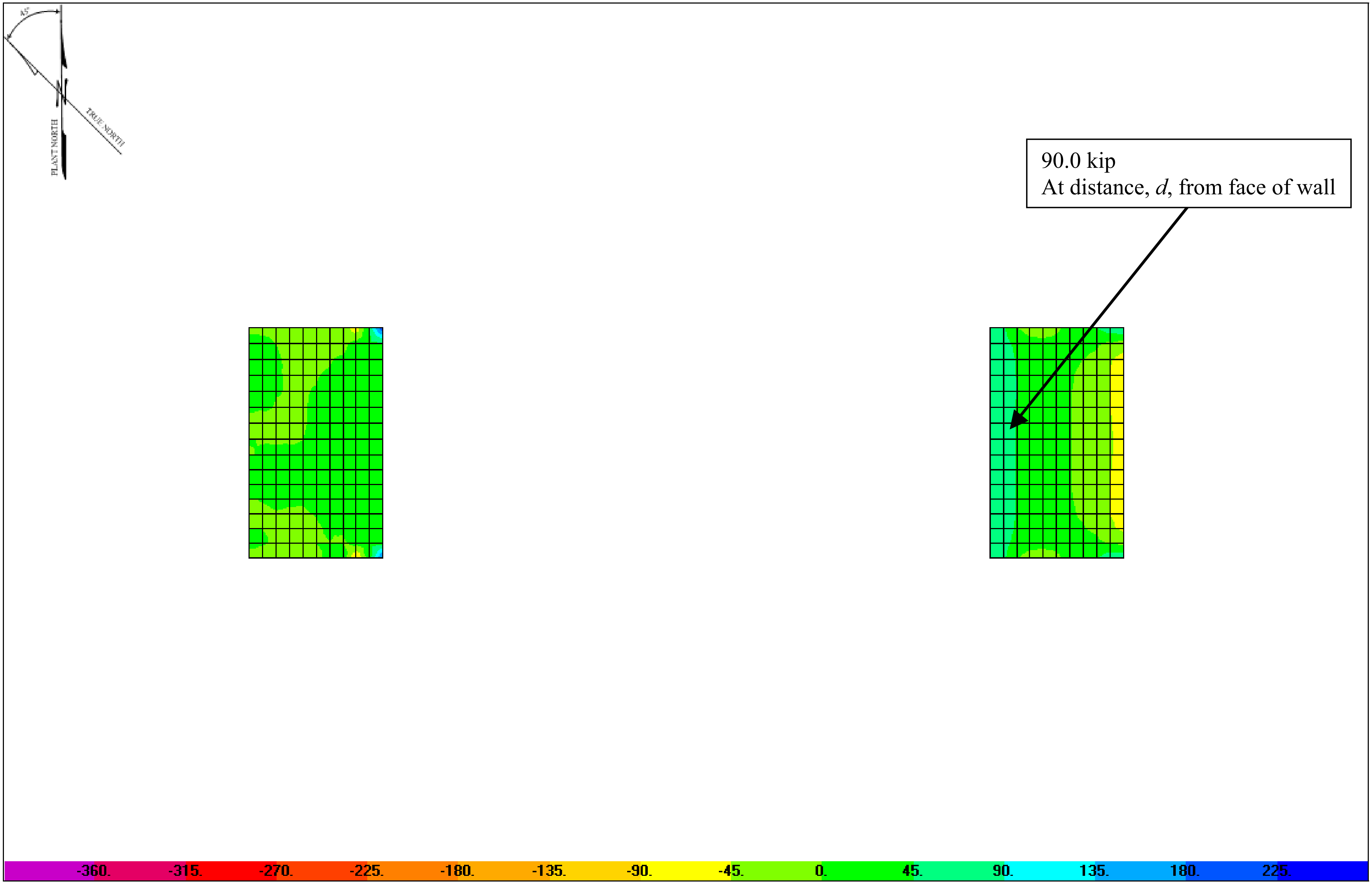
4 ft. Thick Resultant M11 Diagram – Combination 9 (DL+0.4HX+0.4HY-VZ) – kip-ft



4 ft. Thick Resultant M22 Diagram – Combination 9 (DL+0.4HX+0.4HY-VZ) – kip-ft



4 ft. Thick Resultant M12 Diagram – Combination 9 (DL+0.4HX+0.4HY-VZ) – kip-ft



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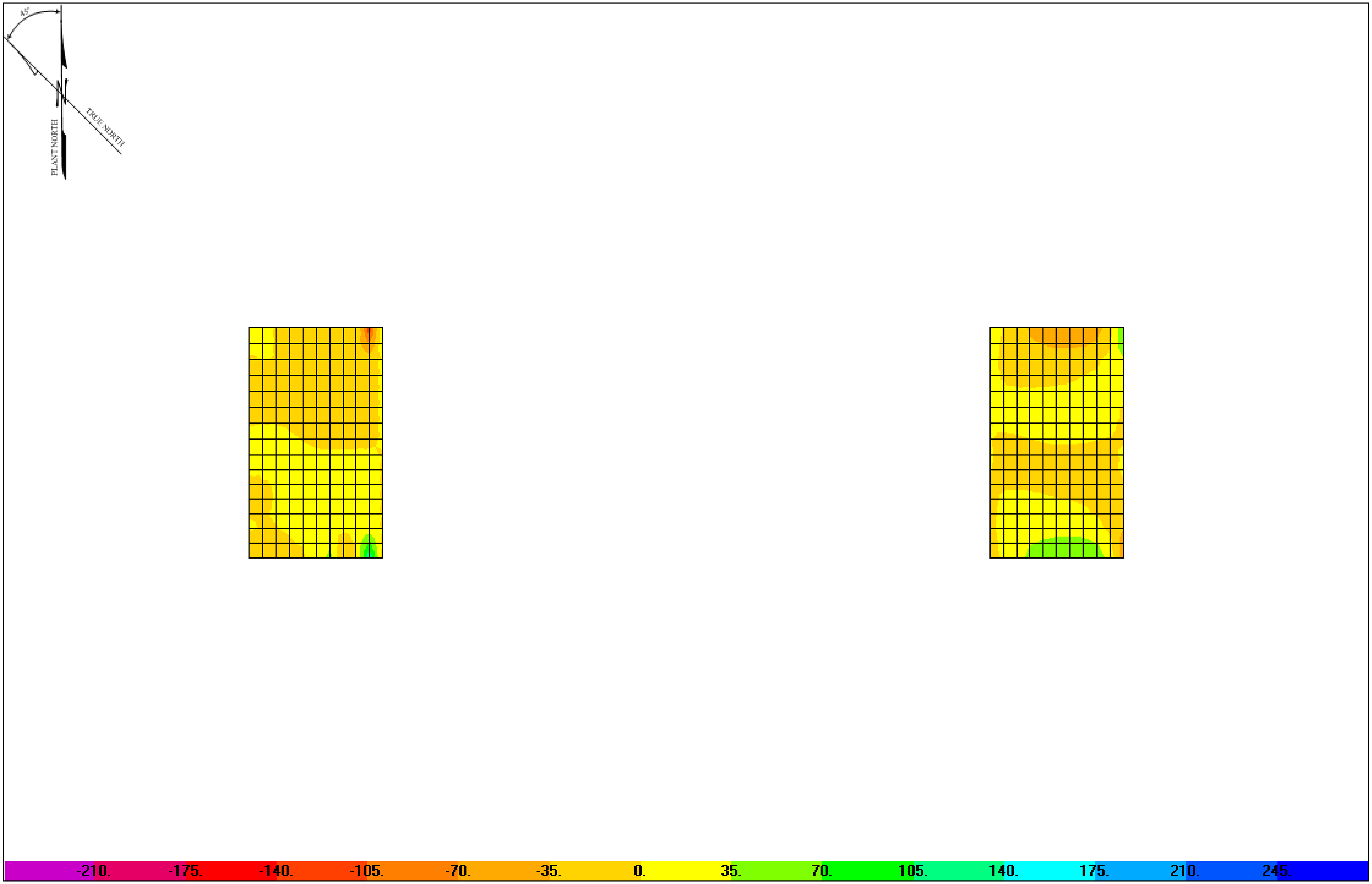
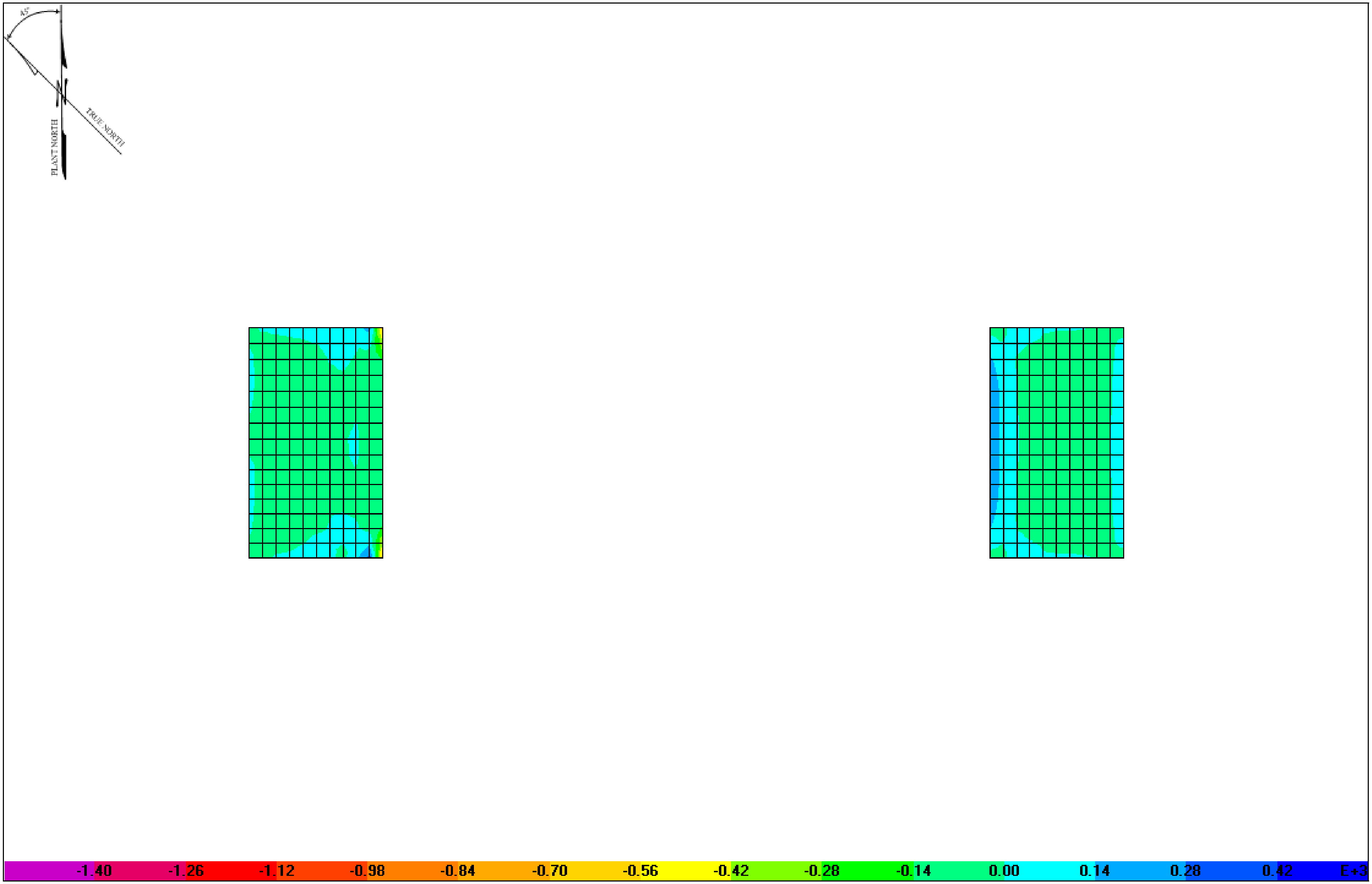
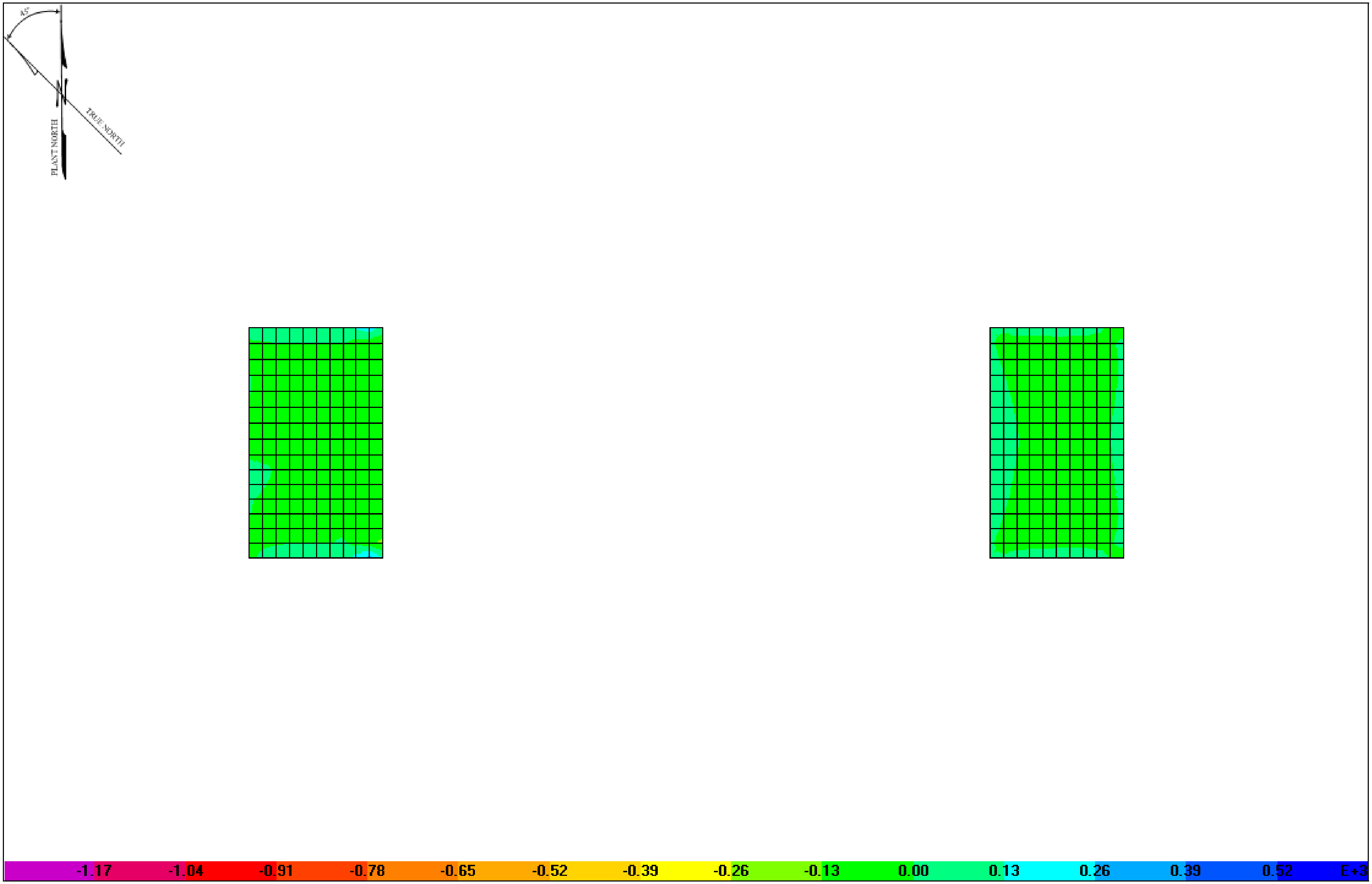


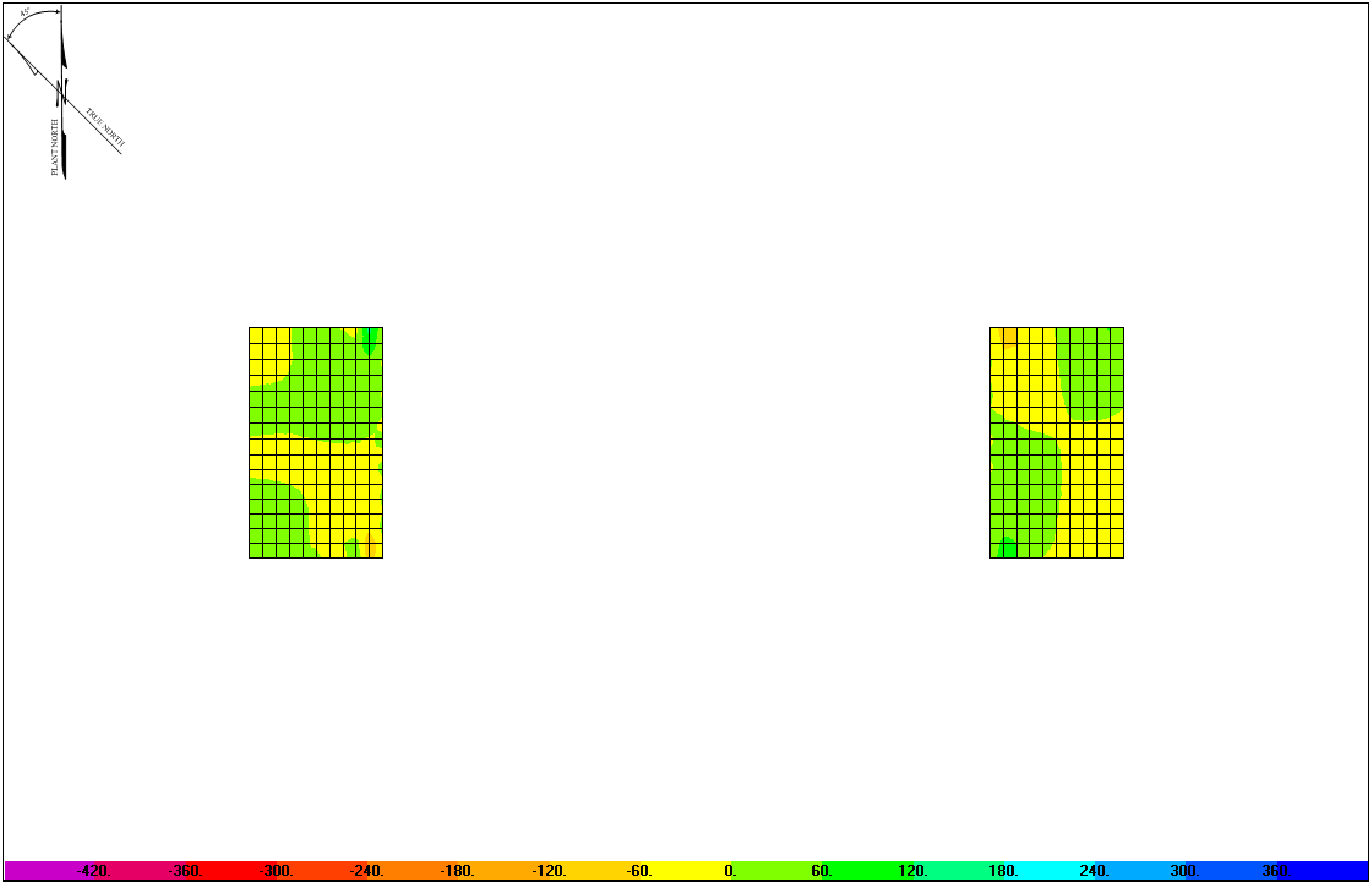
4 ft. Thick Resultant V23 Diagram – Combination 9 (DL+0.4HX+0.4HY-VZ) – kip



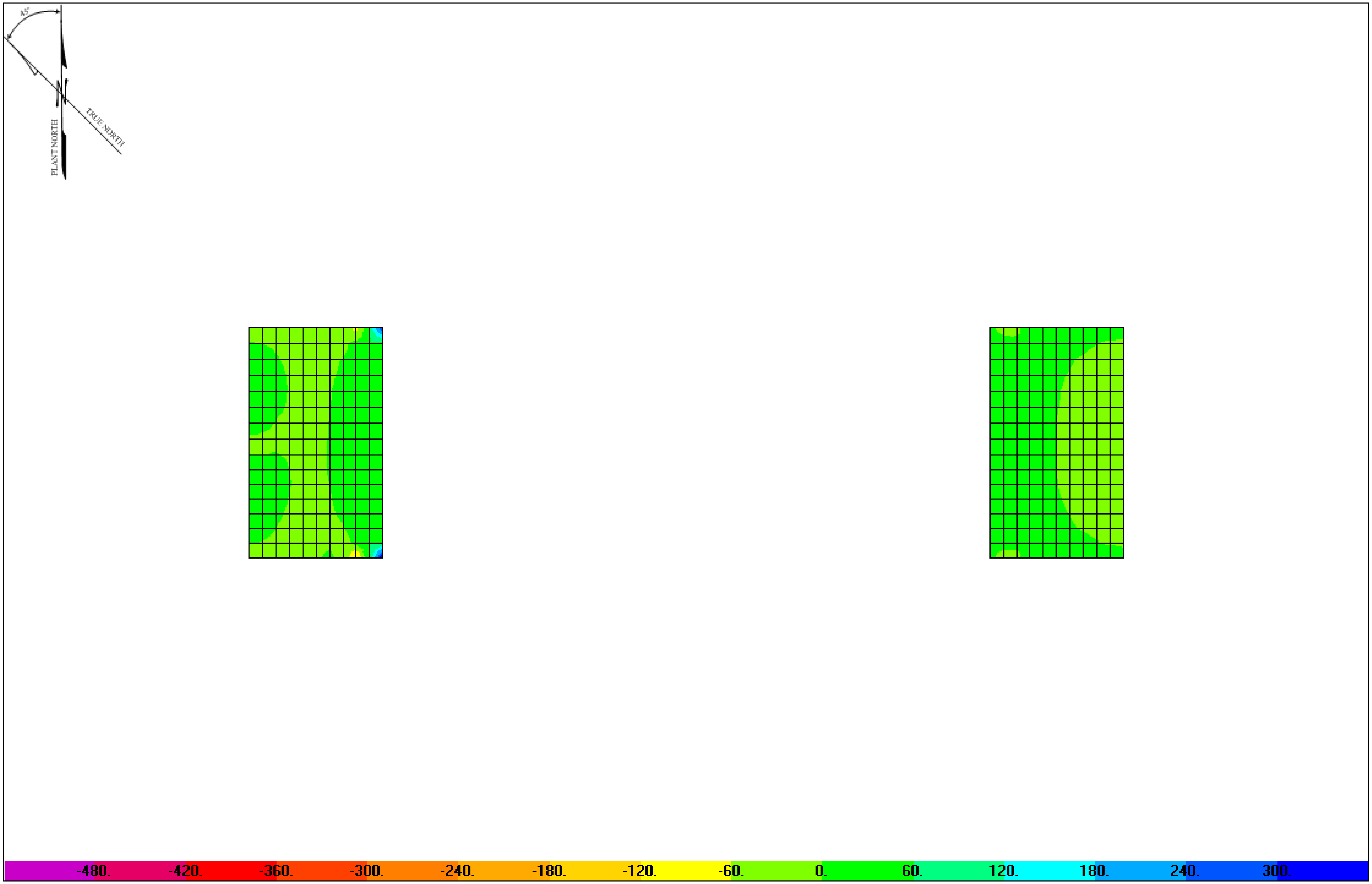
4 ft. Thick Resultant M11 Diagram – Combination 10 (DL-HX+0.4HY-0.4VZ) – kip-ft



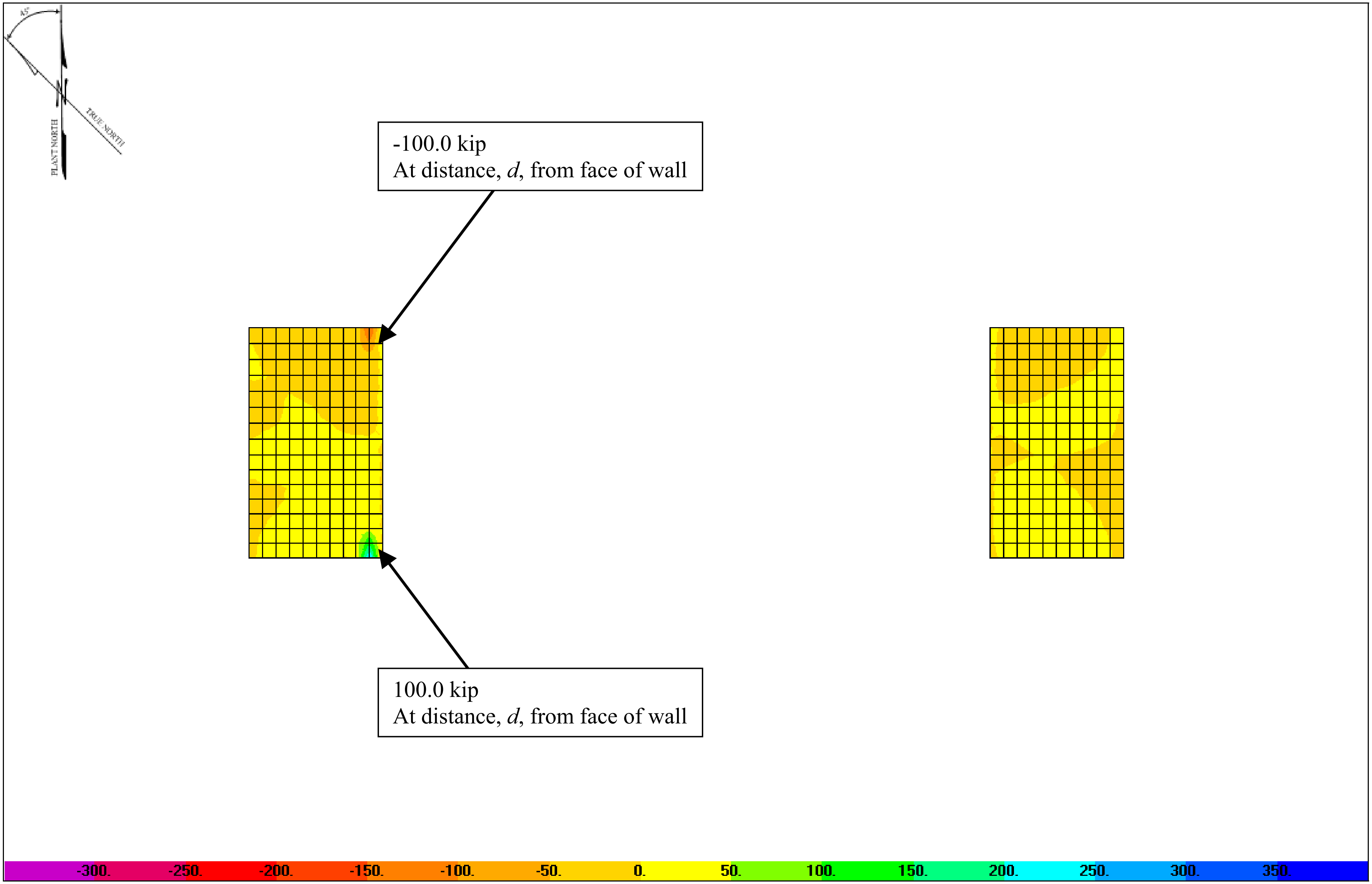
4 ft. Thick Resultant M22 Diagram – Combination 10 (DL-HX+0.4HY-0.4VZ) – kip-ft



4 ft. Thick Resultant M12 Diagram – Combination 10 (DL-HX+0.4HY-0.4VZ) – kip-ft



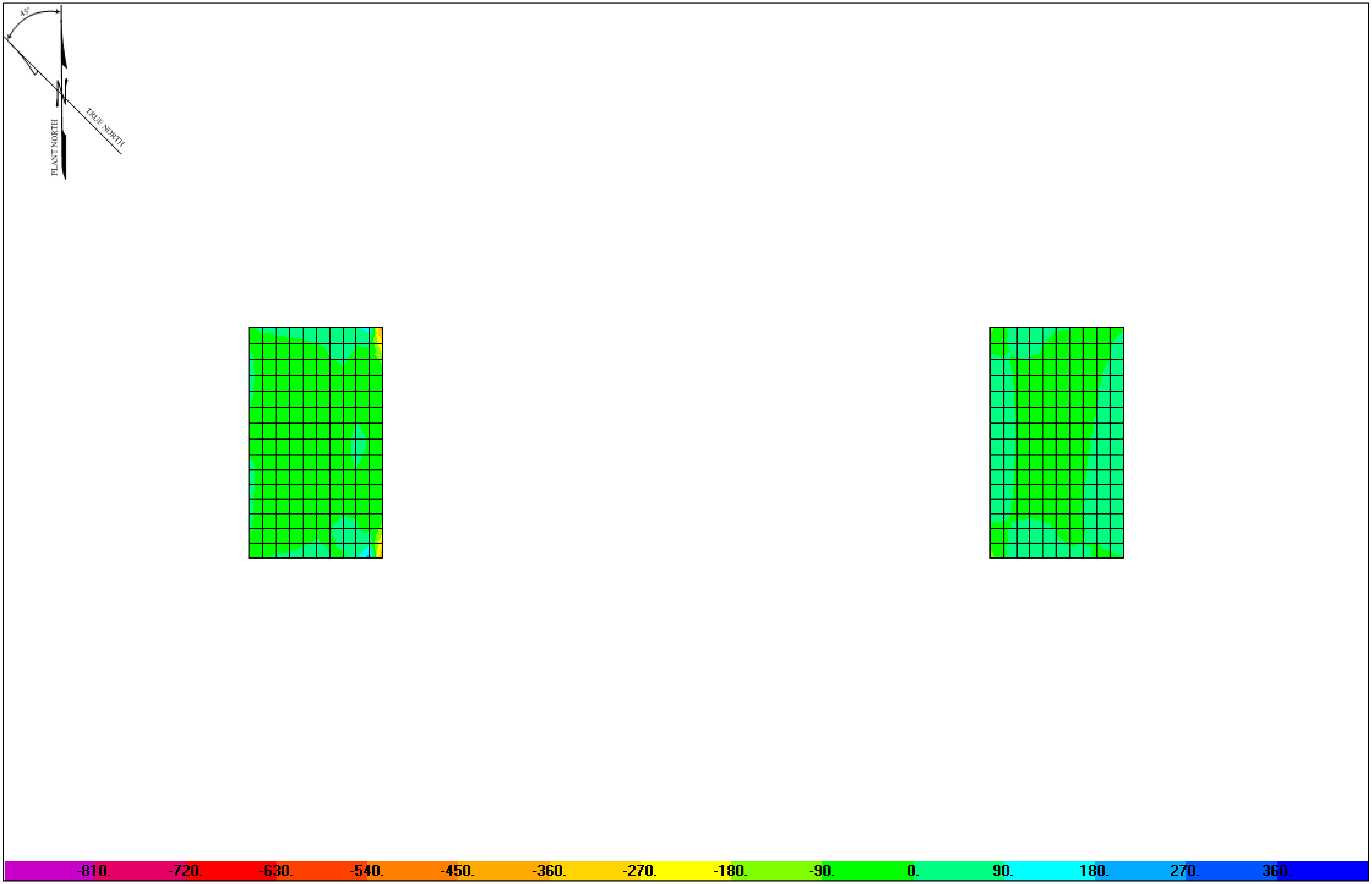
4 ft. Thick Resultant V13 Diagram – Combination 10 (DL-HX+0.4HY-0.4VZ) – kip



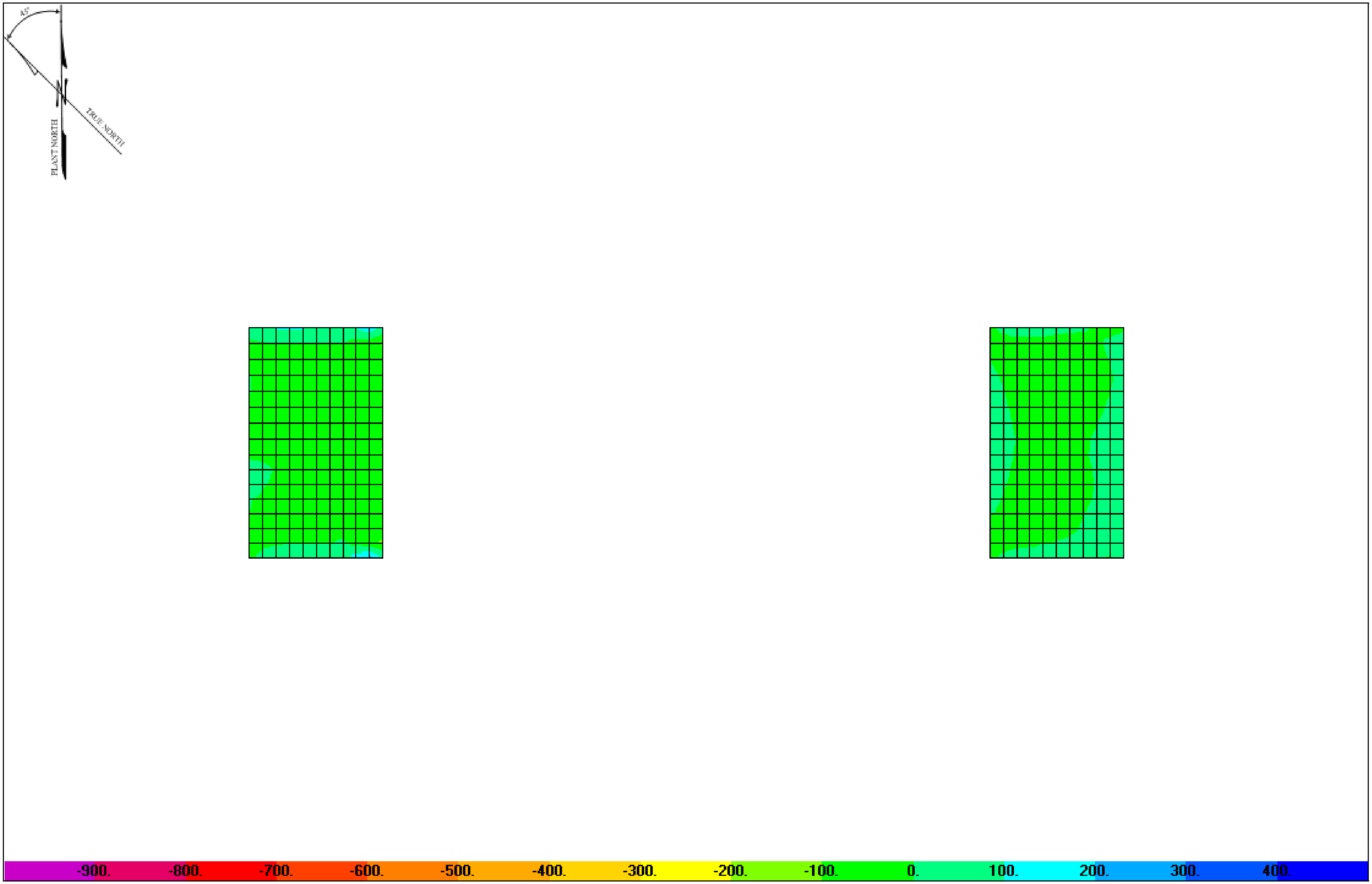
-100.0 kip
At distance, *d*, from face of wall

100.0 kip
At distance, *d*, from face of wall

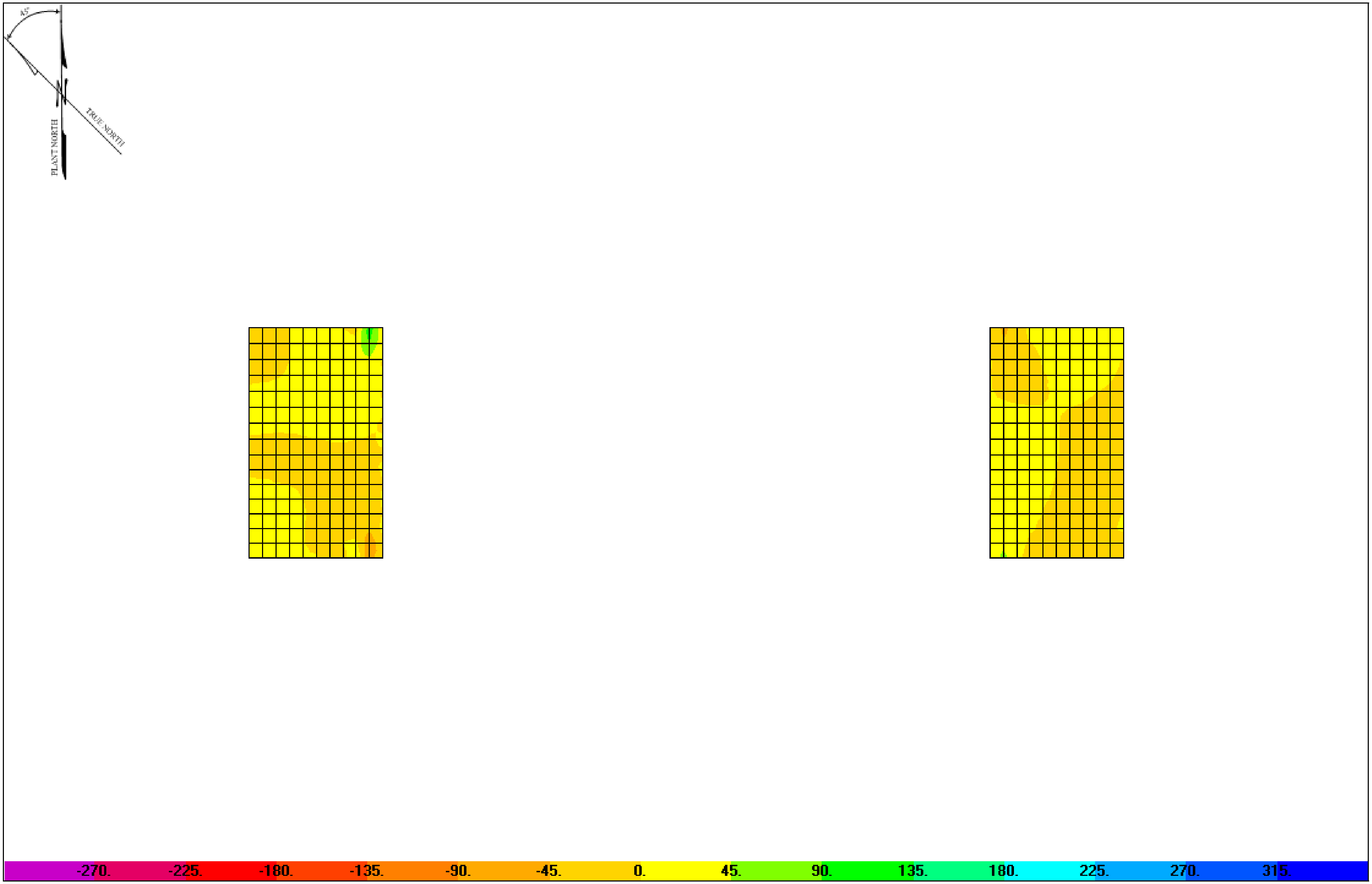
4 ft. Thick Resultant V23 Diagram – Combination 10 (DL-HX+0.4HY-0.4VZ) – kip



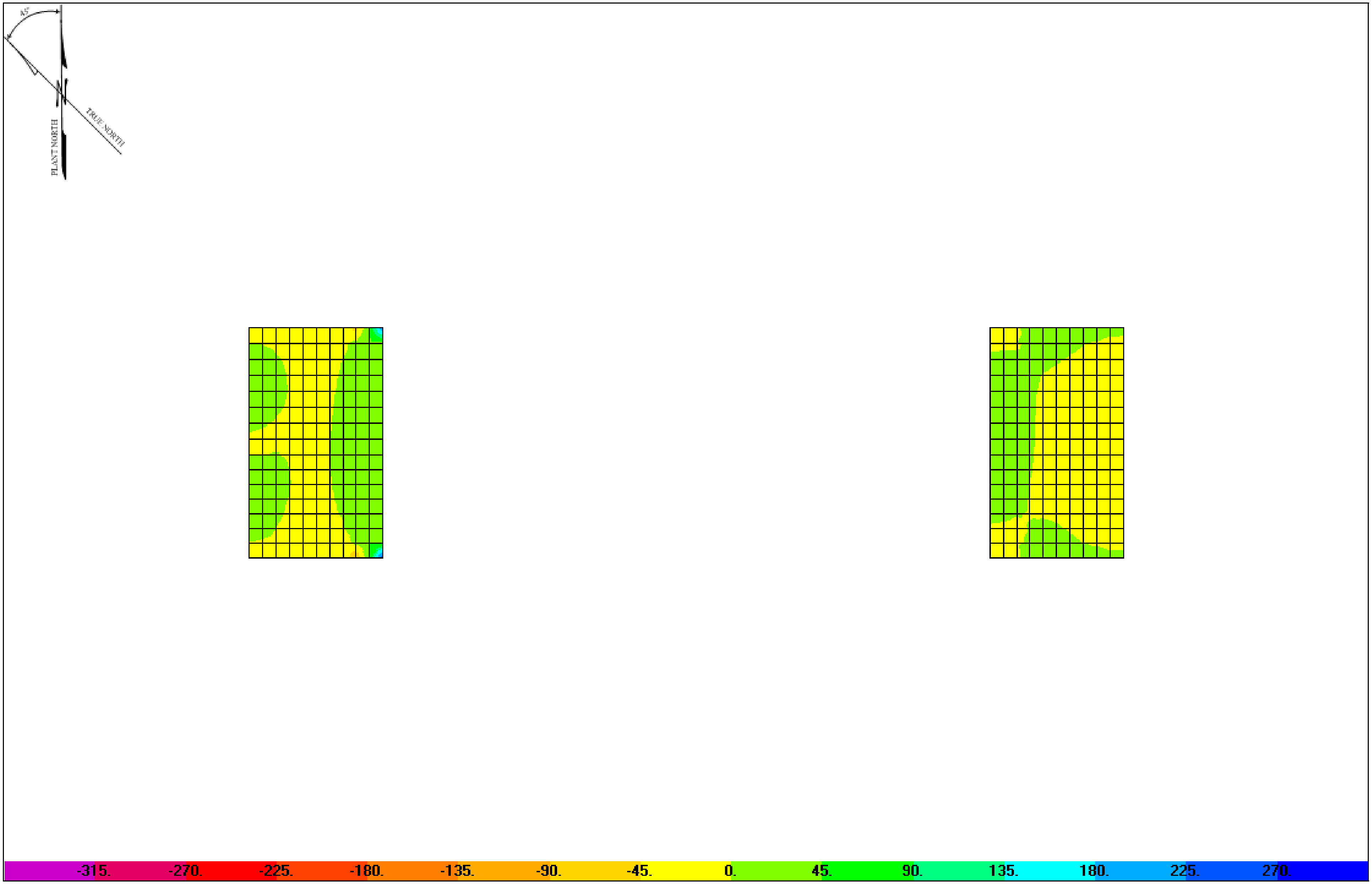
4 ft. Thick Resultant M11 Diagram – Combination 11 (DL-HX+0.4HY+0.4VZ) – kip-ft



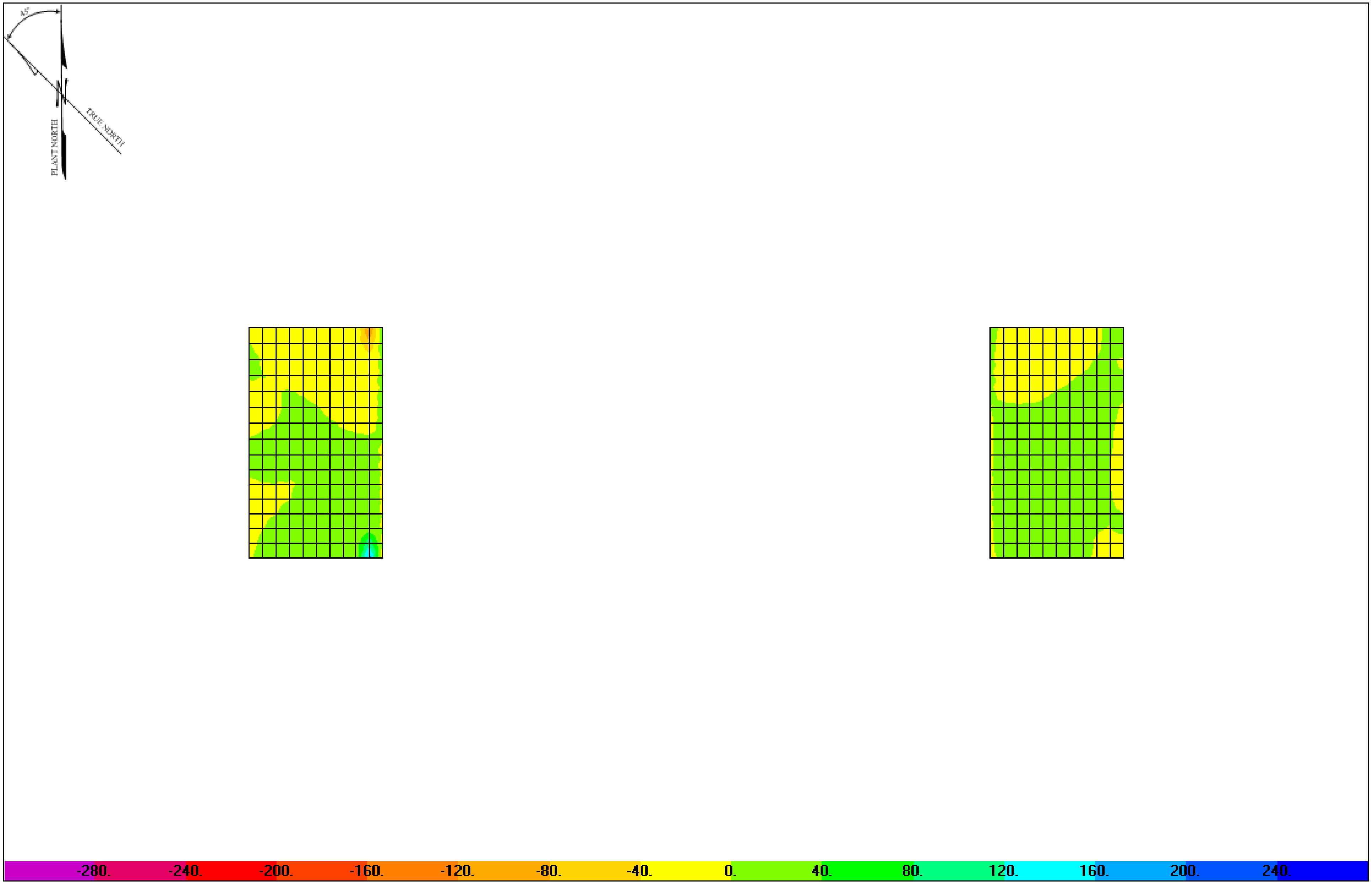
4 ft. Thick Resultant M22 Diagram – Combination 11 (DL-HX+0.4HY+0.4VZ) – kip-ft



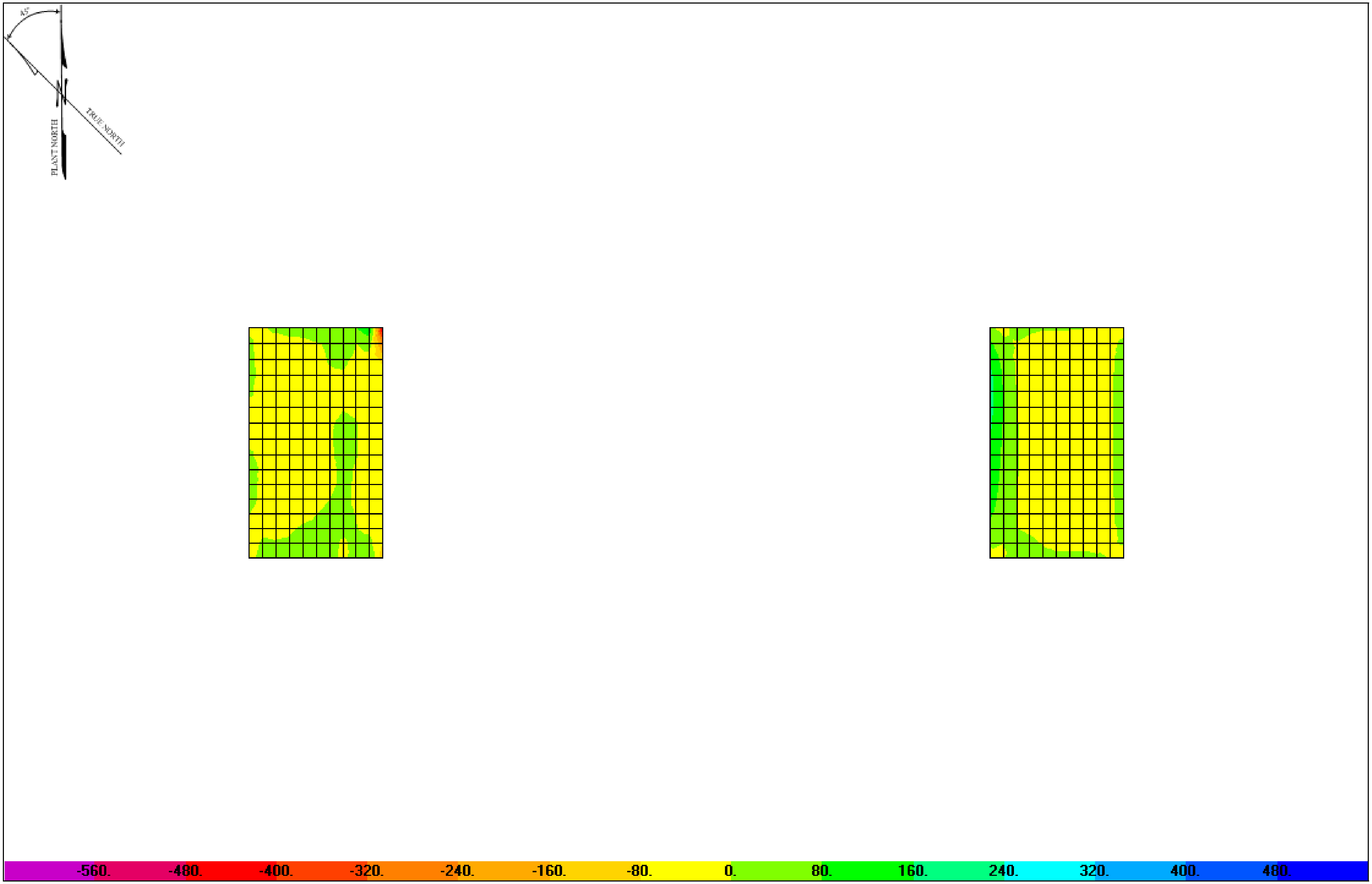
4 ft. Thick Resultant M12 Diagram – Combination 11 (DL-HX+0.4HY+0.4VZ) – kip-ft



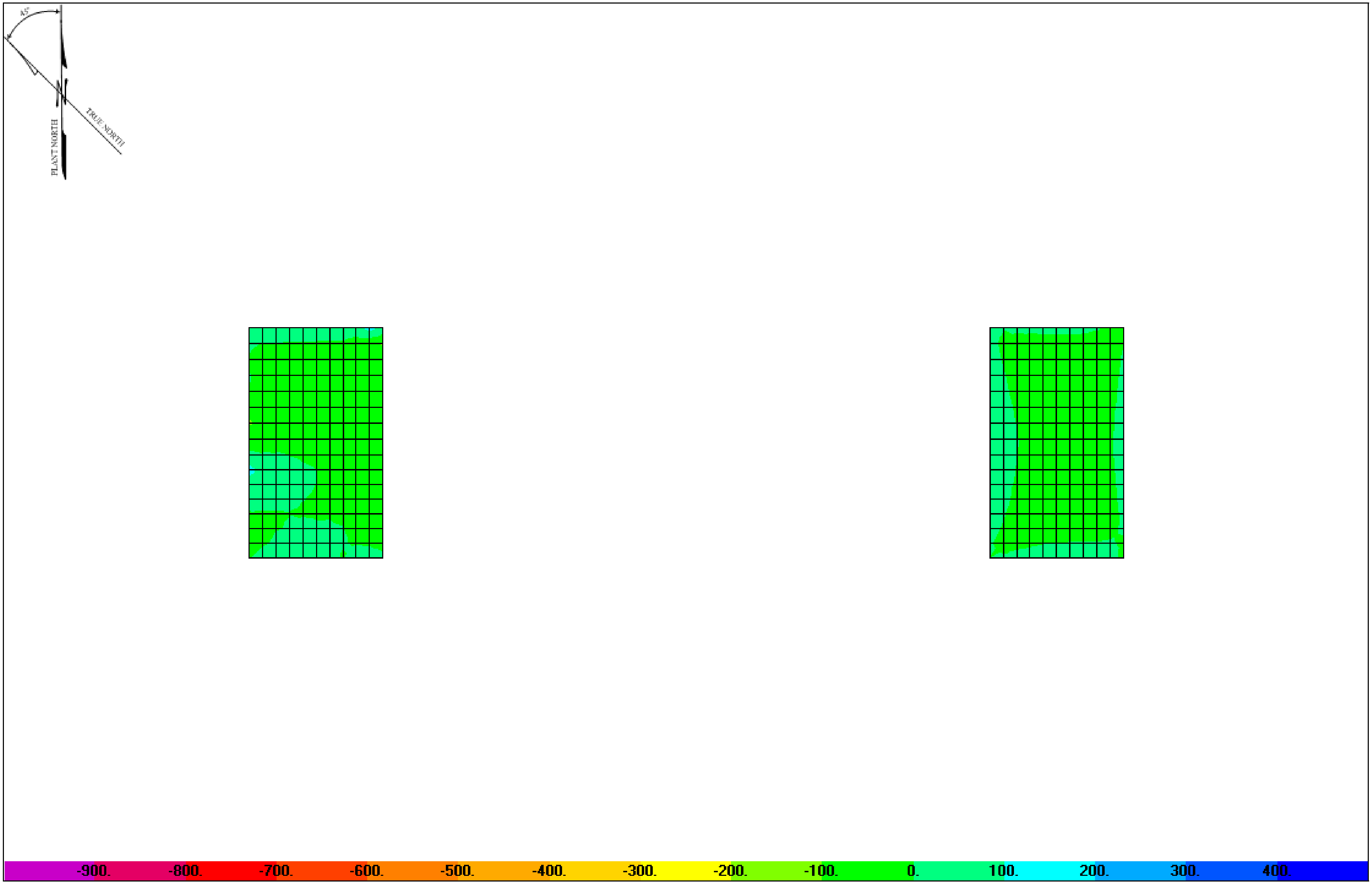
4 ft. Thick Resultant V13 Diagram – Combination 11 (DL-HX+0.4HY+0.4VZ) – kip



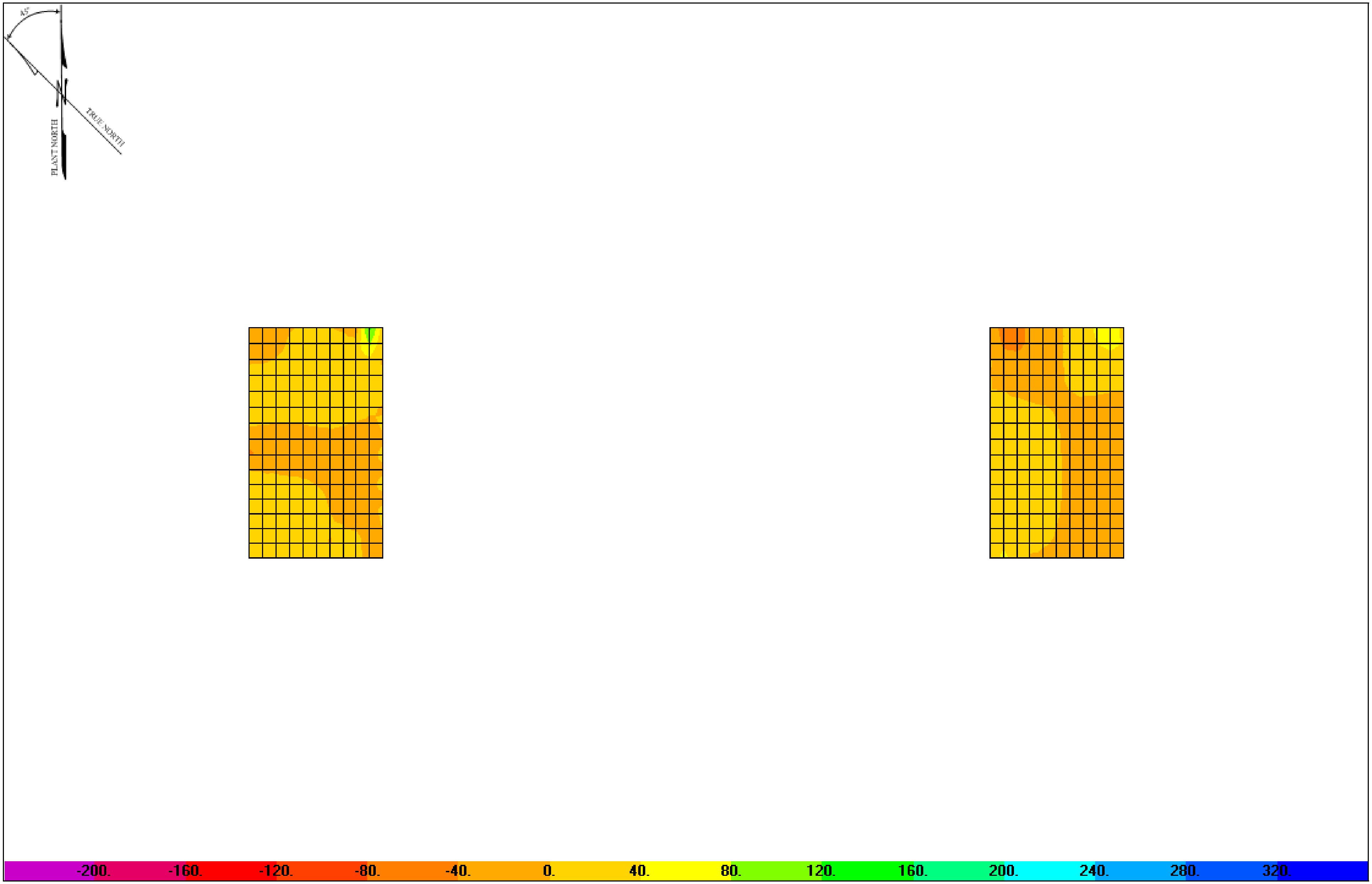
4 ft. Thick Resultant V23 Diagram – Combination 11 (DL-HX+0.4HY+0.4VZ) – kip



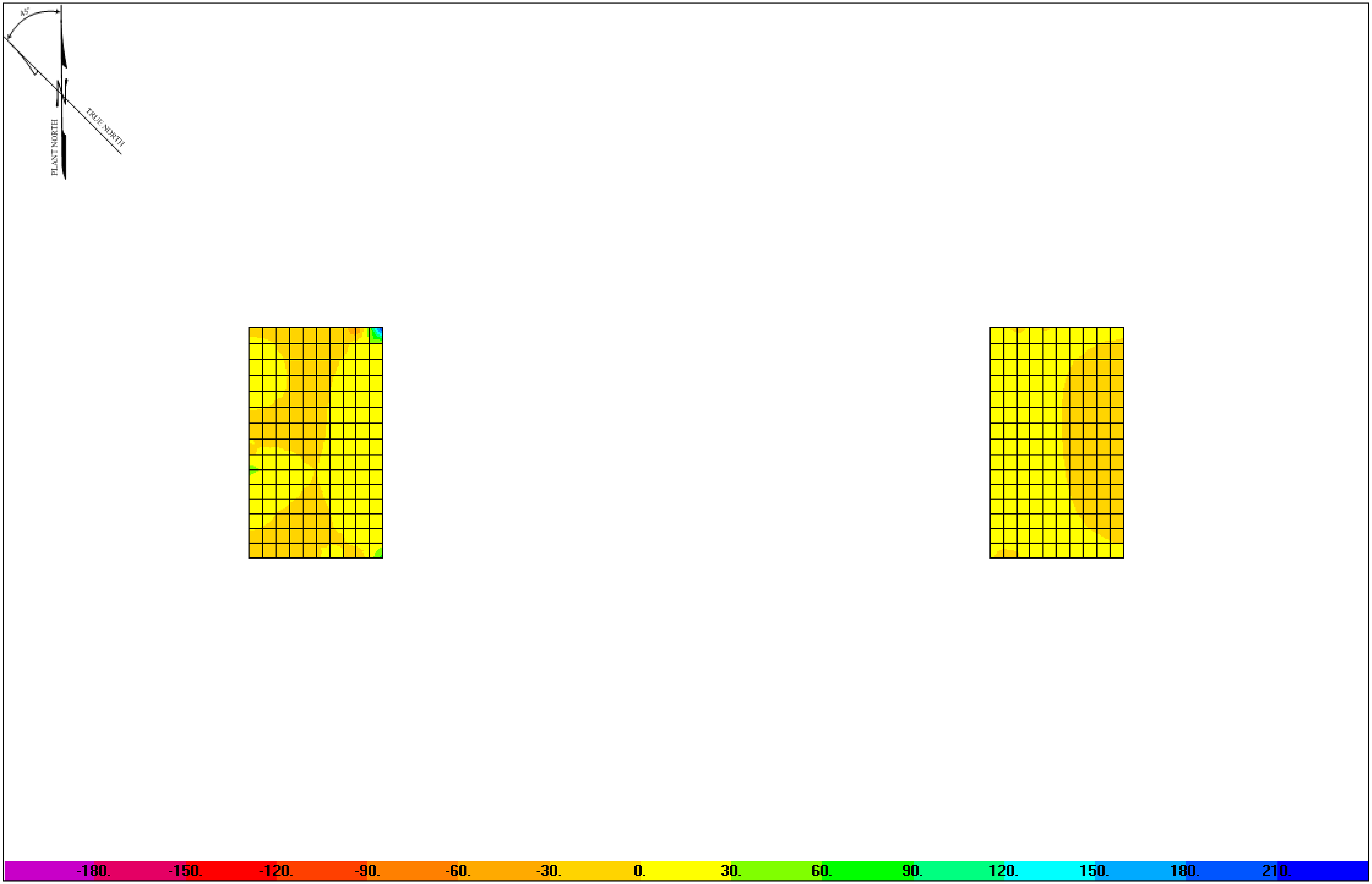
4 ft. Thick Resultant M11 Diagram – Combination 12 (DL-0.4HX+HY+0.4VZ) – kip-ft



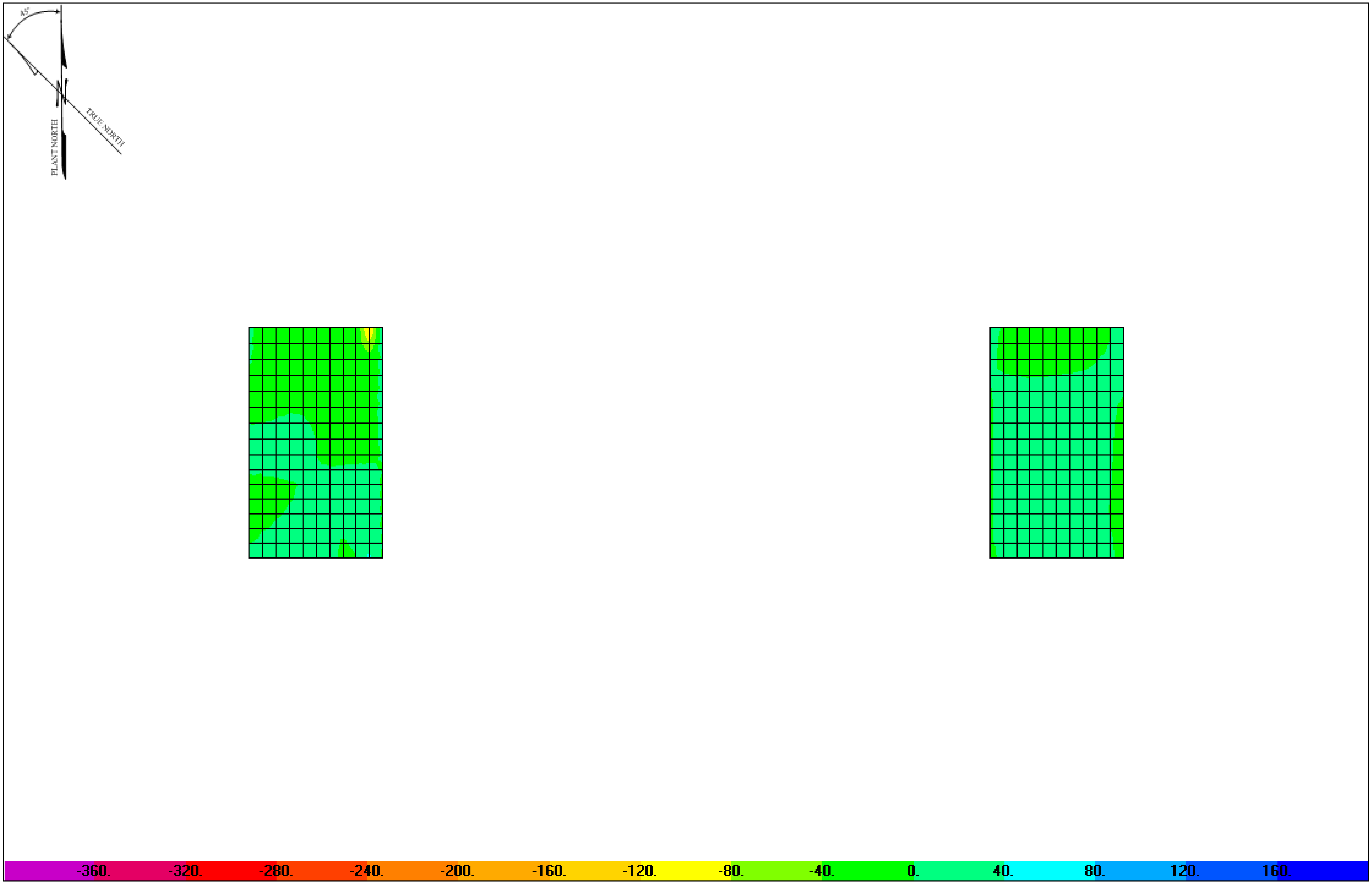
4 ft. Thick Resultant M22 Diagram – Combination 12 (DL-0.4HX+HY+0.4VZ) – kip-ft



4 ft. Thick Resultant M12 Diagram – Combination 12 (DL-0.4HX+HY+0.4VZ) – kip-ft



4 ft. Thick Resultant V13 Diagram – Combination 12 (DL-0.4HX+HY+0.4VZ) – kip



4 ft. Thick Resultant V23 Diagram – Combination 12 (DL-0.4HX+HY+0.4VZ) – kip