November 3, 2025

Nate Gillespie, Operations Manager
Scotts Valley Water District
2 Civic Center Drive
Scotts Valley CA 95066

Re: Bethany Reservoir – Preliminary Structural Evaluation for the Replacement of the Existing Reservoir

Project No.: 22102-1

Purpose

This memo summarizes our structural evaluation to determine whether the current site can support a new tank installation of similar size to the existing tank. The evaluation was based on the Geotechnical and Geological Report prepared by Pacific Crest Engineers (PCE Report).

The site is underlain by geologic formations susceptible to ridge-top spreading, landsliding, and intense seismic shaking. Our analysis incorporated recommendations from both the geotechnical and geological reports. The geotechnical report specifically recommended a mat slab foundation for the proposed tanks.

Summary of Findings

Our analysis concluded that the site can accommodate two welded steel tanks with a combined capacity of 550,000 gallons.

Tank Diameter	Tank Capacity	Maximum Operating Level
46 ft	400,000 gallons	32.5 ft
30 ft	150,000 gallons	29 ft
Total	**550,000 gallons**	

Evaluation Approach

- A preliminary layout was developed based on available physical space and geotechnical constraints.
- Structural analysis was performed using the AWWA D100 standard for welded steel tank foundations.
- The analysis confirmed that the available foundation area is sufficient for the proposed tank sizes.

The tank layout was guided by the PCE Report, which identified suitable foundation zones and provided soil bearing capacities and spring constants for mat slab design.

We modeled the mat slab using RISA-3D, a finite element analysis program, incorporating soil springs to simulate boundary conditions.

Design Parameters

Soil Properties (From Geotech Report)	
Allowable bearing soil pressure (net)	**2.4 ksf**
Allowable bearing soil pressure (short term)	**3.3 ksf**
Subgrade Modulus	**K_1 = 800 pci**
Seismic Design Criteria	ASCE 7
Risk Category	**IV**
Seismic Importance Factor	**1.5**
Soil Site Class	**C**
Mapped Acceleration Parameters:	
S_{DS} =	**1.886**
S_{D1} =	**0.882**
S_1 =	**0.944**
Tank Roof Live Load	**20.0 psf**

46-foot Diameter Tank Geometry

Ring 1 Height (Lowest ring)	**9.25 ft**
Ring 1 Thickness	**0.31 in**
Ring 2 Height	**9.25 ft**
Ring 2 Thickness	**0.31 in**
Ring 3 Height	**9.25 ft**
Ring 3 Thickness	**0.31 in**
Ring 4 Height	**9.25 ft**
Ring 4 Thickness	**0.31 in**
Slab Dimensions	**52 ft X 52 ft x 3 ft thick**

30-foot Diameter Tank Geometry

Ring 1 Height (Lowest ring)	**8.3 ft**
Ring 1 Thickness	**0.25 in**
Ring 2 Height	**8.3 ft**
Ring 2 Thickness	**0.25 in**
Ring 3 Height	**8.3 ft**
Ring 3 Thickness	**0.25 in**
Ring 4 Height	**8.1 ft**
Ring 4 Thickness	**0.25 in**
Slab Dimensions	**34 ft X 34ft x 3 ft thick**

Additional design parameters for the tank are included in the attached calculations and site plan.

The final site layout does have limited flexibility to be adjusted during the next stages of design.

Thank you for the opportunity to assist you with your project. Should you have any questions or comments or require further assistance, please call.

Respectfully yours,

REGISTERED PROFESSIONAL ENGINEER
ROBERT RILEY
No. S5991
STRUCTURAL
STATE OF CALIFORNIA

11/03/2025

Robert Riley, S.E.

cc: Project File

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FOUNDATION PLAN

SCALE: 1/8" = 1'-0"

REV.	DESCRIPTION	BY	DATE
1	PRELIMINARY FOUNDATION PLAN	BR	11/03/2025

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224 Walnut Ave, Suite B Santa Cruz, CA 95060
Phone (831) 426-3186

DRAFT

PRELIMINARY NOT FOR CONSTRUCTION

BETHANY RESERVOIR

PREPARED AT THE REQUEST OF
SCOTTS VALLEY WATER DISTRICT
2 CIVIC CENTER DRIVE
SCOTTS VALLEY CA 95066

FOUNDATION PLAN

DRAWN BY:	NS
CHECKED BY:	BR
JOB NUMBER:	22102

SHEET

S2.0

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30 Foot Diameter Tank Calculations

224 Walnut Avenue, Suite B • Santa Cruz, CA • 831.426.3186 • www.m-me.com

Tanks information

Tank Name	Bethany 30 foot Diameter		
Tank Address			
Tank Coordinates			

Seismic Design of Water Storage Tanks - (AWWA D100-21)

Welded Steel Ground Supported Flat Bottomed Tank

Steel Material Properties – Steel ASTM A 283 Grade C

Yield Strength	F_y=	**30 ksi**	
Compression Strength	F_{cy}=	**30 ksi**	
Ultimate Tensile Strength	F_u=	**55 ksi**	
Maximum Design Tensile Stress	F_t=	**15 ksi**	Section 3.2 (Tbl 5)
Modulus of Elasticity	E=	**29000 ksi**	
Joint Efficiency	Je=	**0.85**	
Poissons Ratio	n=	**0.3**	
Shear Modulus	Gm =	11154 ksi	
Steel Density	g_s =	**490.0 pcf**	

Concrete Material Properties

Type of foundation	**Slab or Pile Cap**		
Concrete Compression Strength		f'c =	**3.0 ksi**
Rebar Yield Strength		F_{yr} =	**60 ksi**
Concrete unit weight		g_c =	**150.0 pcf**
Strength reduction factor – Tension		$\emptyset_T$ =	**0.9**
Strength reduction factor – Bending		$\emptyset_B$ =	**0.9**

Soil Properties

Soil unit weight	g_s =	**120.0 pcf**	
Allowable bearing soil pressure (net)	q_{bra} =	**1.5 ksf**	
Bearing pressure short-term increase	ST =	**1.33**	
Allowable bearing soil pressure (short term)	qbrgST = qbrg * ST =	2.00 ksf	
Coefficient of lateral earth pressure (0 if geotech report values are used)	k =	**0.333**	
Active pressure from calculation	Pac = k *gsoil =	40.0 pcf	
Active pressure per Geotech report (0 if given as a coefficient)	Pag=	**0.0 pcf**	
Active pressure	Use Pa = Pac	40.0 pcf	
Coefficient of friction from calc (ASD)	mc = 0.7*Tan(30°)=	0.404	Section A13.2
Coefficient of friction from Geotech report (0 if using AWWA coefficient)	mg =	**0**	
Coefficient of friction	**m = if(mg >0 , mg, mc)=**	**0.404**	
Passive Pressure per Geotech report	PPg=	**200.0 pcf**	

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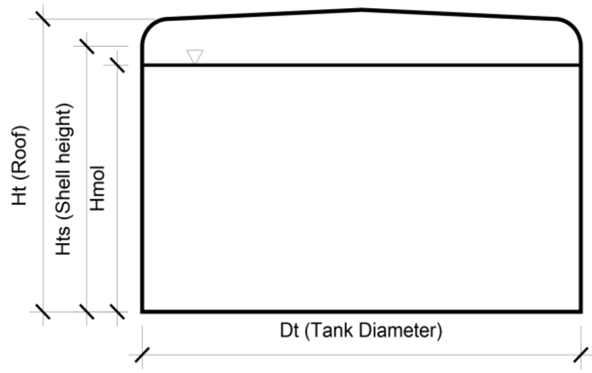
Tank Properties

Tank Diameter	Dt =	**30.0 ft**
Shell Height	Hts =	**33.0 ft**
Roof Height	Ht =	**36.0 ft**
Torus Height(radius)	Htor =	3.0 ft
Water Height (maximum operating level H)	Hmol =	**29.0 ft**
Tank Radius	Rt= Dt/2 =	15.0 ft



Water Volume		
	Vw = (π * Dt^2 * Hmol) / 4 =	20499 ft^3
Tank Capacity	C = 7.48052 * Vw =	153342.4 gallons
Tank Roof Area	Ar = (π * Dt^2) / 4 =	707 ft^2
Tank Circumference	Ct = (π * Dt) =	94.2 ft

Tank Roof Dead Load

Rafter Weight	wrft =	**25.0 #/ft**
Rafter Length	Lrft =	**23.0 ft**
Rafter quantity	Nrft =	**20**
Total weight of rafters		
	Wrftr = wrft * Lrft * Nrft/1000 =	11.50 kips
Tank Rafter Depth	Rd=	**10.00 in**
Tank roof plate thickness	tplrf =	**0.25 in**
Tank roof plate weight	wplrf = tplrf * gs/12 =	10.21 psf
Plate Area - Roof area - torus projected area		
	Arpl =(π(Dt-2*Htor)^2)/4 =	452 ft^2
Weight of roof plate	Wplrf = Arpl * wplrf/1000 =	4.6 kips
Area of torus plate	Ator = π*Htor/2*Ct =	444 ft^2
Weight of torus plate	Wpltor = Ator*wplrf/1000 =	4.5 kips
Tank Roof Weight – Total Dead Load	Wr = Wrftr + Wplrf+Wpltor =	20.7 kips
Tank Roof Load – Total Dead Load	wr = Wr/Arpl =	45.7 psf

Tank Roof Live Load	wLL =	**20.0 psf**
# of Bearing points	Bp=	**2**

1 = Tank shell only, no interior supports
2 = Tank shell and center column
3 = Tank shell, intermediate column line at midpoint, and center column

Plate Distribution Factor to outer shell

plDf= if(Bp<=1,1,if(Bp <= 2 , 0.75 , 0.4375)) = 0.75

Rafter Distribution Factor to outer shell

rftDf= if(Bp<=1,0,if(Bp<=2,0.5,0.25)) = 0.5

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Tank Roof Weight – On Shell

WrsDL = rftDf * Wrftr + plDf * Wplrf = 9.21 kips

Tank Roof Live Load – On Shell

WrsLL = plDf * Ar * wLL = 10.60 kips

Water Density gw = **62.4 pcf**

Water Specific Gravity G_w = **1**

Total Water Weight Ww = Vw * gw/1000 = 1279.1 kips

Water Weight per ft2 wp = Hmol * gw/1000 = 1.81 ksf

Water Weight available to resist uplift (For ground supported tanks = 0, Sec 3.8.5.3)

WwUplift= **0.00 kips**

Tank Shell Geometry

# of Rings Rno = **4**

Ring 1 Height (Lowest ring)	R1h =	**8.30 ft**	
Ring 1 Thickness	R1t =	**0.25 in**	
Ring 1 Area	R1a=R1h *R1t/12 =	0.17 ft^2	
Ring 1 y-bar	R1y=R1h *.5=	4.2 ft	
Ring 2 Height	R2h =	**8.30 ft**	
Ring 2 Thickness	R2t =	**0.25 in**	
Ring 2 Area	R2a=R2h *R2t/12=	0.17 ft^2	
Ring 2 y-bar	R2y=R1h+R2h *.5=	12.5 ft	
Ring 3 Height	R3h =	**8.30 ft**	
Ring 3 Thickness	R3t =	**0.25 in**	
Ring 3 Area	R3a=R3h *R3t/12 =	0.17 ft^2	
Ring 3 y-bar	R3y=R1h+R2h+R3h *.5=	20.8 ft	
Ring 4 Height	R4h = 0 ft	**8.10 ft**	33.00 ft
Ring 4 Thickness	R4t = .0 in	**0.25 in**	**OK**
Ring 4 Area	R4a=R4h *R4t =	0.17 ft^2	-
Ring 4 y-bar	R4y=R1h+R2h+R3h+R4h *.5=	29.0 ft	

Average Tank Shell Thickness

tave = (R1a + R2a + R3a+ R4a)/Hts = 0.25 in

Tank Shell Weight

WshlDL = 2*π*R*(R1a + R2a + R3a+ R4a)*gs/1000 = 31.75 kips

Tank Bottom Thickness tbott = **0.25 in**

Tank Bottom Annulus Thickness tanul = **0.25 in**

Tank Bottom Actual Thickness (including corrosion)

ts = **0.25 in**

Tank Bottom Annulus Width

L = .216 * tanul*(Fy/(Hmol *Gw)^.5 = 1.737 ft (Eq 13-34)

Tank Bottom Weight (Section 3.8.5.3)

Wf = Ar * tbott * gs/(12*1000) = 7.22 kips

Seismic Design Criteria ASCE 7

Risk Category		**IV**	(Section 3.1.1)
Seismic Importance Factor	IE =	1.5	(Table 21)
Soil Site Class		**C**	
Mapped Acceleration Parameters:			
	S_{DS} =	**1.886**	
	SD1 =	**0.882**	
	S1 =	**0.944**	

Response Modification Factors:

Type of Tank: (Table 24 Section 13.2.5)

Self-Anchored Tank

Impulsive R_{isa} = **2.5**

Mechanically Anchored Tank

Impulsive R_{ima}= **3**

Convective R_c = **1.5**

Determine Natural Periods

Damping Scaling Factor (Section 13.2.6.3.2 – convert from 5% to 0.5%)

K = **1.5**

Impulsive Natural Period (Section 13.5)

Ti = **0 sec**

Convective (Sloshing Wave) Period

Tc = 2 *π *(Dt/(3.68 *32.2 *tanh(3.68 *Hmol/Dt))) = 3.16 sec (Eq. 13-18)

Region-Dependent Transition Period

T_L = **12 sec** (Fig. 19)

T_S = SD1 / SDS = 0.47 sec

Determine Design Accelerations – General Procedure (Section 13.2.6)

Design Spectral Impulsive Acceleration

Ti<=TS then Sai = SDS =	1.886	Eq. 13-5
Ts<Ti<=TL then Sai = SD1/(Ti) =	-	Eq. 13-6
Ti>TL then Sai = TL*SD1/(Ti)^2) =	-	Eq. 13-7
Therefore, Sai =	**1.886**	

Design Spectral Convective Acceleration

Tc <= TL then Sac = K*SD1/Tc =	0.418	Eq. 13-8
Tc > TL then Sac = K*TL*SD1/Tc^2 =	1.586	Eq. 13-9
Therefore, Sac =	**0.418**	

Self-anchored

Impulsive Accel, max, (ASD)	Ai_maxsa = 0.7*Sai * IE / (Risa) =	0.792	(Eq 13-13)
Impulsive Accel, min,	Ai_minsa = 0.36 *S1 * IE / (Risa) =	0.204	(Eq 13-13)
Impulsive Accel,	**Aisa = max(Ai_maxsa,Ai_minsa) =**	**0.792**	

Mechanically anchored

Impulsive Accel, max, (ASD)	Ai_maxma =0.7* Sai * IE / (Rima) =	0.660	(Eq 13-13)
Impulsive Accel, min,	Ai_minma = 0.36 *S1 * IE / (Rima) =	0.170	(Eq 13-13)
Impulsive Accel,	**Aima = max(Ai_maxma,Ai_minma) =**	**0.660**	

Convective Design Acceleration (ASD)

Ac = 0.70 *Sac *1 sec *(IE / (Rc)) = 0.293 (Eq 13-14)

Vertical Design Acceleration (Section 13.5.4.3)

Responses limited by buckling (STR) **Av1 = 0.48 * SDS = 0.905**

Responses not limited by buckling (STR) **Av2 = 0.19 * SDS = 0.358**

<u>Impulsive and Convective Weights</u> (Section 13.5.2)

Wi - effective impulsive weight - tank contents that moves in unison with the tank shell

Dt/Hmol >= 1.333, Wi (1) =
tanh(0.866 *Dt/Hmol) *Ww/(0.866 *Dt/Hmol)= 1019.9 kips (Eq 13-20)

Dt/Hmol < 1.333, Wi (2)= (1 – 0.218 *Dt/Hmol)) *Ww = 990.7 kips (Eq 13-21)

Dt/Hmol < 1.33, therefore use Eq 13-21, Wi = Wi(2) = 990.7 kips

Wc - Effective Convective Weight - the first mode sloshing contents of the tank

Wc =(0.23 *Dt/Hmol) *tanh(3.67 *Hmol/Dt) *Ww = 303.8 kips (Eq 13-22)

Determine Moment Arms from Bottom of Tank:

Height to Tank Shell C.G.

Xs = (R1a *R1y+R2a *R2y+R3a *R3y+R4a *R4y)/(R1a+R2a+R3a+R4a)

Xs = 16.5 ft

Height to Roof and Torus **Xr = Ht = 36.0 ft**

<u>Impulsive and Convective Centroids</u>

Tank Aspect Ratio: Dt/Hmol = 1.034

Ring Foundations

Height to Centroid of Impulsive Weight

Dt/Hmol >= 1.333 Xi (1) = 0.375 * Hmol = 10.9 ft

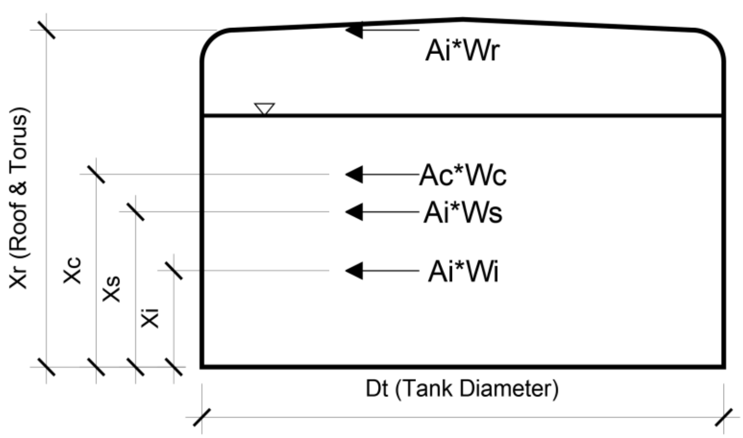
Dt/Hmol < 1.333 Xi (2) = (.5-0.094*Dt/Hmol)Hmol = 11.7 ft

Therefore, Xi = 11.7 ft

Height to Centroid of Convective Weight (Eq 13-26)

Xc = (1 – ((cosh(3.67 *Hmol/Dt))-1)/((3.67 *Hmol/Dt) *sinh(3.67 *Hmol/Dt))) *Hmol

Xc = 21.3 ft



Slab or Pile Cap Foundations

Height to Centroid of Impulsive Weight

Dt/Hmol >= 1.333

Ximf(1) = 0.375 (1+1.333(0.866(Dt/Hmol)/(tanh(0.866(Dt/Hmol)-1) * Hmol = N/A Dt/Hmol< 1.33

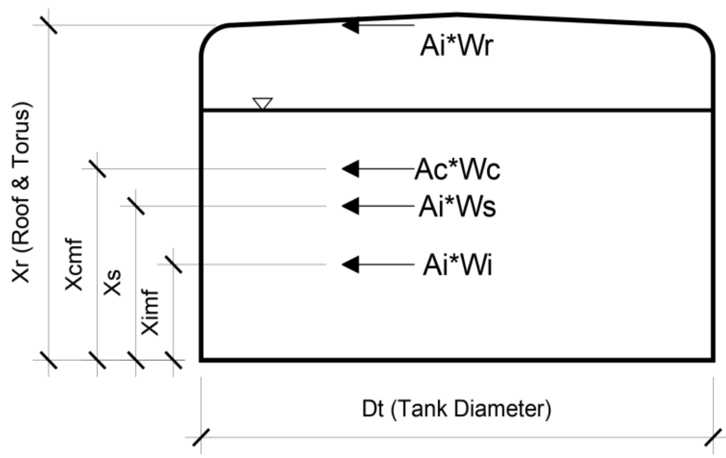
Dt/Hmol < 1.333 Ximf (2) = (.5+0.06*Dt/Hmol)Hmol = 16.3 ft

Therefore, Ximf = 16.3 ft

Height to Centroid of Convective Weight (Eq 13-26)

Xc = (1 – ((cosh(3.67 *Hmol/Dt))-1.937)/((3.67 *Hmol/Dt) *sinh(3.67 *Hmol/Dt))) *Hmol

Xcmf = 21.72 ft



Overturning Moment

Design OT Moment @ Bott of Tank Shell: Sec 13.5.2

Self-anchored

Ring Foundation

Ms sa(1) =((Aisa *(Ws *Xs+Wr *Xr+Wi *Xi))2 + (Ac *Wc *Xc)2)^0.5 = (Eq 13-19)

Ms_sa = 10344 Kip-ft

Slab or Pile cap

Mmf sa(2) =((Aisa *(Ws *Xs+Wr *Xr+Wi *Ximf))2 + (Ac *Wc *Xcmf)2)^0.5 = (Eq 13-28)

Mmf_sa= 13930 Kip-ft

Mechanically anchored

Ring Foundation

Ms ma =((Aima *(Ws*Xs+Wr*Xr+Wi*Xi))^2 + (Ac*Wc*Xc)^2)^0.5 = (Eq 13-19)

Ms_ma = 8683 Kip-ft

Slab or Pile cap

Mmf ma =((Aima *(Ws*Xs+Wr*Xr+Wi*Ximf))^2 + (Ac*Wc*Xcmf)^2)^0.5 = (Eq 13-19)

Mmf_ma = 11657 Kip-ft

Resistance to overturning: (Sec 13.5.4.1.1)

Tank shell and roof portion

Total **Wt =(WshDL+WrsDL) = 41.0 kips**

per foot of circumference **wt =(Wt)/Ct = 0.43 kip/ft** (Eq 13-37)

Tank bottom or annulus

Use the lesser of tanul or R1t, tb = 0.25 in

Contents Minimum of WL (1) or WL (2) (Eq 13-33)

WL (1) = 7.9tb(FyHG)^0.5 = 1.84 kip/ft

WL (2) = 1.28HDG = 1.11 kip/ft

Use wL = 1.11 kip/ft

Overturning ratio "J"

Calculation for determinging J uses the overturning moment for a self-anchored tank and Av2 for responses not limited by buckling.

Overturning Ratio

J = Ms_sa*1000/(Dt^2 *(((1-0.4 *Av2) *wt)+WL))= 7.735 (Eq 13-32)

J<0.785	No uplift
0.785 <= J <= 1.54	Uplift, but stable- anchors are not required
J > 1.54	Anchors are required

J = 7.73 > 1.54, Uplift occurs and Anchors are required

Tank anchored for tension loading? **Yes** -

Freeboard	Section 13.6		
Convective Design Acceleration			
Risk Cat II & III			
Tc<=4	Af(2.1) = K * SD1Ie/Tc =	NA	(Eq 13-50)
Tc>4	Af(2.2) = 4K * SD1Ie/Tc^2 =	NA	(Eq 13-51)
Risk Cat = IV			
Tc<=TL	Af(4.1) = K * SD1/Tc =	0.42	(Eq 13-52)
Tc>TL	Af(4.2)= K * SD1TL/Tc^2 =	NA	(Eq 13-53)
	Therefore, Af =	**0.42**	
Sloshing Wave Height	d = 0.42 * Dt * Af * 1 sec =	5.3 ft	(Eq 13-49)
Rafter Depth	Rd =	10.00 in	
Freeboard Provided	d prov=Ht-Hmol-Rd=	6.2 ft	-
Maximum Operating Level permitted			
	Hmol(max) = Ht-Rd– d =	29.9 ft	

Hmol = 29 ft <= Hmol(max) **OK, adequate freeboard is provided**

Tension Anchorage			Section 3.8
Bolt diameter	d =	**1.00 in**	-
Bolt diameter - min	dmin =	1.00 in	
Anchor bolt eccentricity	e =	**5.50 in**	-
Coeff of thermal expansion	Et =	**0.0000065**	
Difference in temperature	T =	**50 Deg F**	
Anchor bolt eccentricity minimum	emin = 2.125 +d/2 + 6(Et)(Dt)T =	4.82 in	
Number of Anchors	N =	**10**	-
Maximum spacing of Anchors	Sanchmax =	10.0 ft	Section 3.8.1.2.1#2
Minimum number of Anchors	Nmin =	6	Section 3.8.1.3
Anchor circle diameter	Dac = Dt + 2*e/12 =	30.9 ft	
Anchor Spacing	S_anch = π * Dac/N =	9.7 ft	-
Anchor circle circumference	Cac = Dac *π	97.1 ft	

Anchor design loads

Anchor Tension – Strength Load Combo — Ps = 0.9 DL – Ev + Eh — Section 3.8.8.1

Use Av2 - response not limited by buckling

Anchor Tension Load

Ps = 1/N((4*Ms_ma/(Dac) -Wt(0.9-0.4Av))= 109.2 kips (Eq 3-40)

Shear anchorage

Allowable Lateral Shear

Vallow = m *(Ws+Wr+Wi+Wc) *(1-0.4 *Av2) = 466.3 kips

Design shear @ top of foundation

Self - Anchored (ASD)

Vf_sa =0.7*((Ai_sa *(Ws+Wr +Wi))^2 + (Ac *Wc)^2)^.5 = NA

-

Mechanically anchored

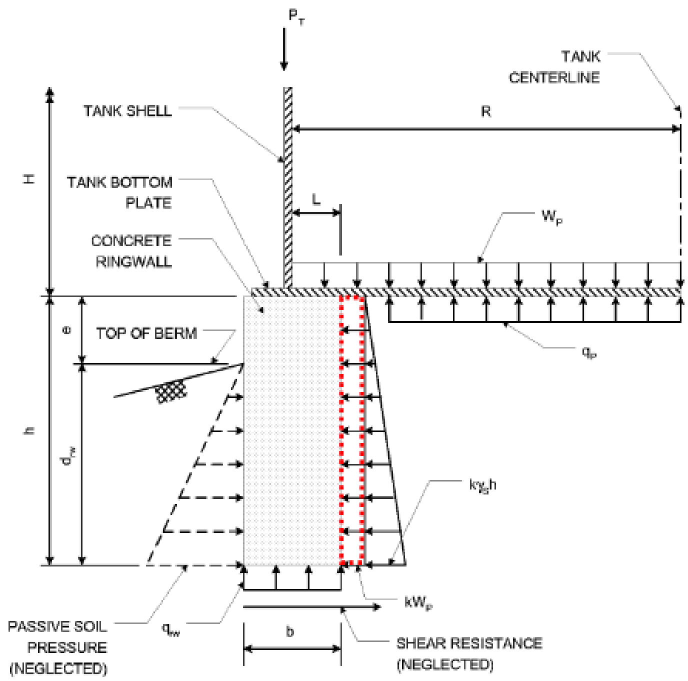
Vf_ma = 0.7*((Ai_ma *(Ws+Wr +Wi))^2 + (Ac *Wc)^2)^.5 = 486.0 kips

Vallow < Vf, Mechanical shear anchors are reqd

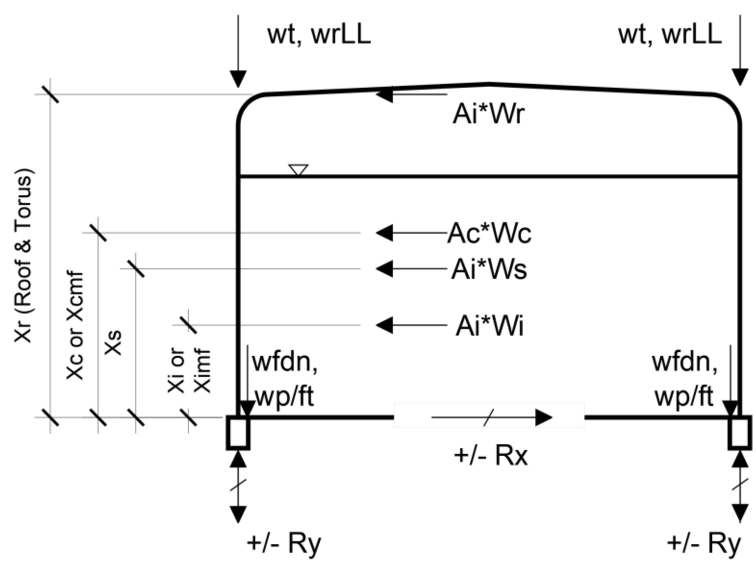
Tank anchored for Shear? **Yes** -

Foundation -

The foundation analysis and design is based upon the Process Industry Practices (PIP) "Guidelines for Tank Foundation Designs, PIP STE3021



Ringwall Loading for Unanchored Tank



For bearing pressure calcs for the weight of the foundation below grade, use:

Net Unit Weight = gn = gc - gs = 30.0 pcf

For resistance to uplift calcs use: **Full Unit Weight = gc =** 150.0 pcf

Basic Load Cases

		w	P total = w*Ct
Dead Load (bearing) (DL_brg)			
Ring or Pile cap Foundation (bearing)	wfd_brg =	0.60 kip/ft	56.5 kips
Piers/Spier (bearing)	Wpier_brg/spier =	0.24 kip/ft	22.4 kips
Tank (wt)	wt =	0.43 kip/ft	41.0 kips
Product (wp) (bearing w/EQ LC)	wp =	4.98 kip/ft	469.0 kips

Dead Load (Uplift Resistance on Foundation)			
Ring or Pile cap Foundation (uplift)	wfdn =	1.80 kip/ft	169.6 kips
Piers/Spier (uplift)	Wpie/spier =	1.19 kip/ft	111.8 kips
Tank (wt)	wt =	0.43 kip/ft	41.0 kips
Product (wp) (uplift)	wL =	1.11 kip/ft	105.0 kips

Roof Live (RLL)	wRLL = WrsLL/Ct =	0.11 kip/ft	10.6 kips

	Mot =		
Seismic (bearing) (EL)			
Vertical Load from Mot	EL1= (Mot/Sf)=	0.00 kip/ft	0.0 kips
Vertical Load (wt)	EL2 = 0.7 * 0.4 * Av * wt =	0.04 kip/ft	4.1 kips
Vertical Load (wp)(bearing)	EL3 = 0.7 * 0.4 * Av * wp =	0.50 kip/ft	47.1 kips

Seismic (uplift) (EL)			
Vertical Load from Mot	EL1= (Mot/Sf)=	0.00 kip/ft	0.0 kips
Vertical Load (wt)	EL2 = 0.7 * 0.4 * Av * wt =	-0.04 kip/ft	-4.1 kips
Vertical Load (wp)(uplift)	EL3 = 0.7 * 0.4 * Av * wL =	-0.11 kip/ft	-10.5 kips

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Slab Foundations - Anchored Load Combinations

ASD Load Combinations

Tank Circumference	Ct = 94.2478 ft		
Total number of points (Max 20)	pts = 20	OK	-
Distance between points	Spts 4.7124 ft		

Slab Foundation Parameters

Slab depth	ds = 2.0 ft
Slab Plan Dimensions - width	ws = 32.0 ft
Slab Plan Dimensions - length	ls = 32.0 ft
Foundation height above grade	es = 0.5 ft
Inside of tank shell to edge of fdn	L = 1.0 ft

Slab weight	Wfdn_slab = ds*ws*ls*gc =	307.2 kips
Foundation weight above grade	Wfdn_slab_a = e*ws*ls*gc/1000 =	76.8 kips
Foundation weight net below grade	Wfdn_slab_n = (ds-es)*ws*ls*(gn)/1000 =	46.1 kips

For Slab Foundations use Mot = Mmf_ma = **11657 Kip-ft**

Overturning Stability Ratio 0.5D(WT +Wfd + Wg)/Mot > 2.0

WT = Ws + Wr + Wp+ Wf

Shell	Ws = 31.7 kips
Roof	Wr = 20.7 kips
Product	Wp = 1279.1 kips
Floor	Wf = 7.2 kips
Foundation	wfdn_slab = 307.2 kips
Soil	Wg = 0.0 kips
	1645.9 kips

0.5D(WT +Wfd + Wg)/Mot = 2.1 OK >2

Gravity Loads

		w	P = w*Spts
Foundation Above Grade	wfd_a =	0.30 kip/ft	1.414 kips
Tank (wt)	wt =	0.43 kip/ft	2.048 kips
Product (wp)	wp =	1.8 ksf	
Live Load	wRLL = WrsLL/Ct =	0.11 kip/ft	0.5 kips

Seismic Load Combinations

Reference API 650 Annex E Section E6.2.3 Foundations

Use Av2 - response not limited by buckling

Sf = π*(Dt^2)/4 = D^2/1.273 = 706.9

LC2 = wfdn_brg + wt(1+ 0.7*0.4Av)+1.273*Mmf_ma/D^2

LC3 = 0.6*wfd + wt(0.6-0.7*).4Av - 1.273*Mmf_ma/D^2

MME
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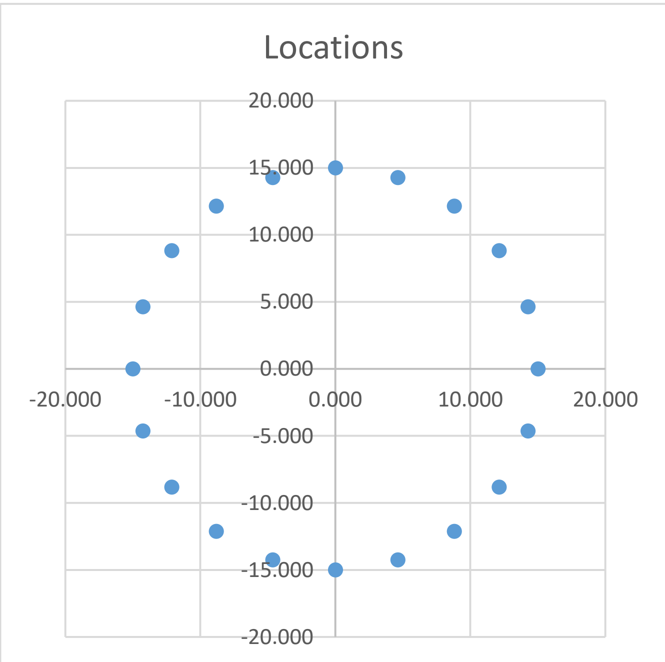
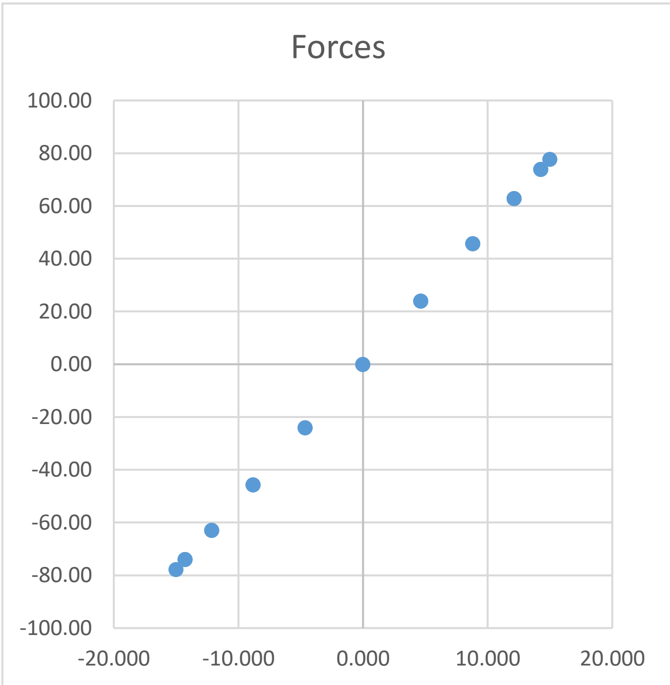
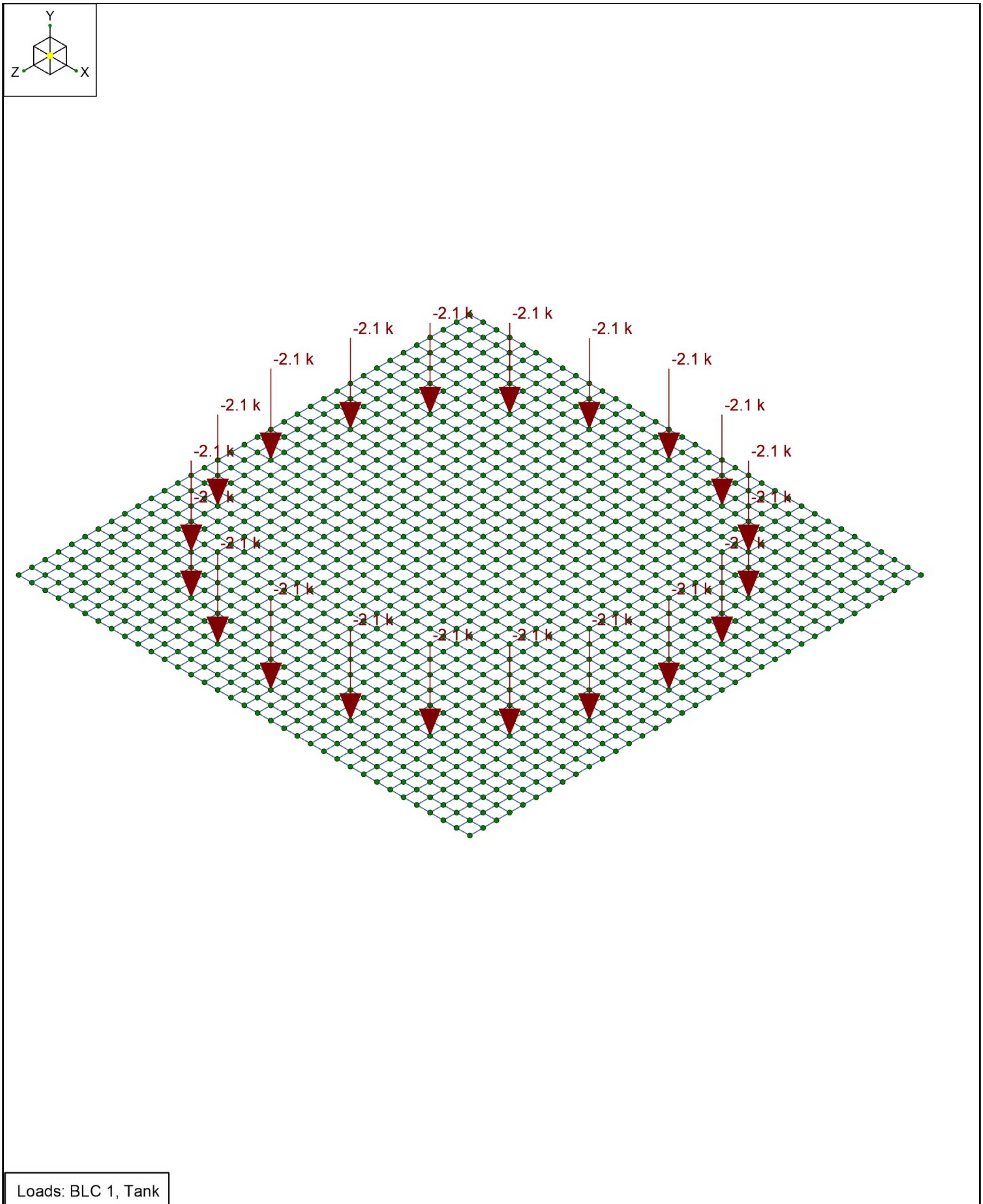
	Θ Angle	Nodes	D_tank*COS(Θ)/2 X = C	D_tank*sin(Θ)/2 y	Ev (ASD) = Spts*Mot*(C/I)	Ev (STR) = EV(ASD)/0.7
0	0.000	P1	15.000	0.000	77.71	111.019
1	0.314	P2	14.266	4.635	73.91	105.585
2	0.628	P3	12.135	8.817	62.87	89.816
3	0.942	P4	8.817	12.135	45.68	65.255
4	1.257	P5	4.635	14.266	24.01	34.307
5	1.571	P6	0.000	15.000	0.00	0.000
6	1.885	P7	-4.635	14.266	-24.01	-34.307
7	2.199	P8	-8.817	12.135	-45.68	-65.255
8	2.513	P9	-12.135	8.817	-62.87	-89.816
9	2.827	P10	-14.266	4.635	-73.91	-105.585
10	3.142	P11	-15.000	0.000	-77.71	-111.019
11	3.456	P12	-14.266	-4.635	-73.91	-105.585
12	3.770	P13	-12.135	-8.817	-62.87	-89.816
13	4.084	P14	-8.817	-12.135	-45.68	-65.255
14	4.398	P15	-4.635	-14.266	-24.01	-34.307
15	4.712	P16	0.000	-15.000	0.00	0.000
16	5.027	P17	4.635	-14.266	24.01	34.307
17	5.341	P18	8.817	-12.135	45.68	65.255
18	5.655	P19	12.135	-8.817	62.87	89.816
19	5.969	P20	14.266	-4.635	73.91	105.585
					0.00	0.000



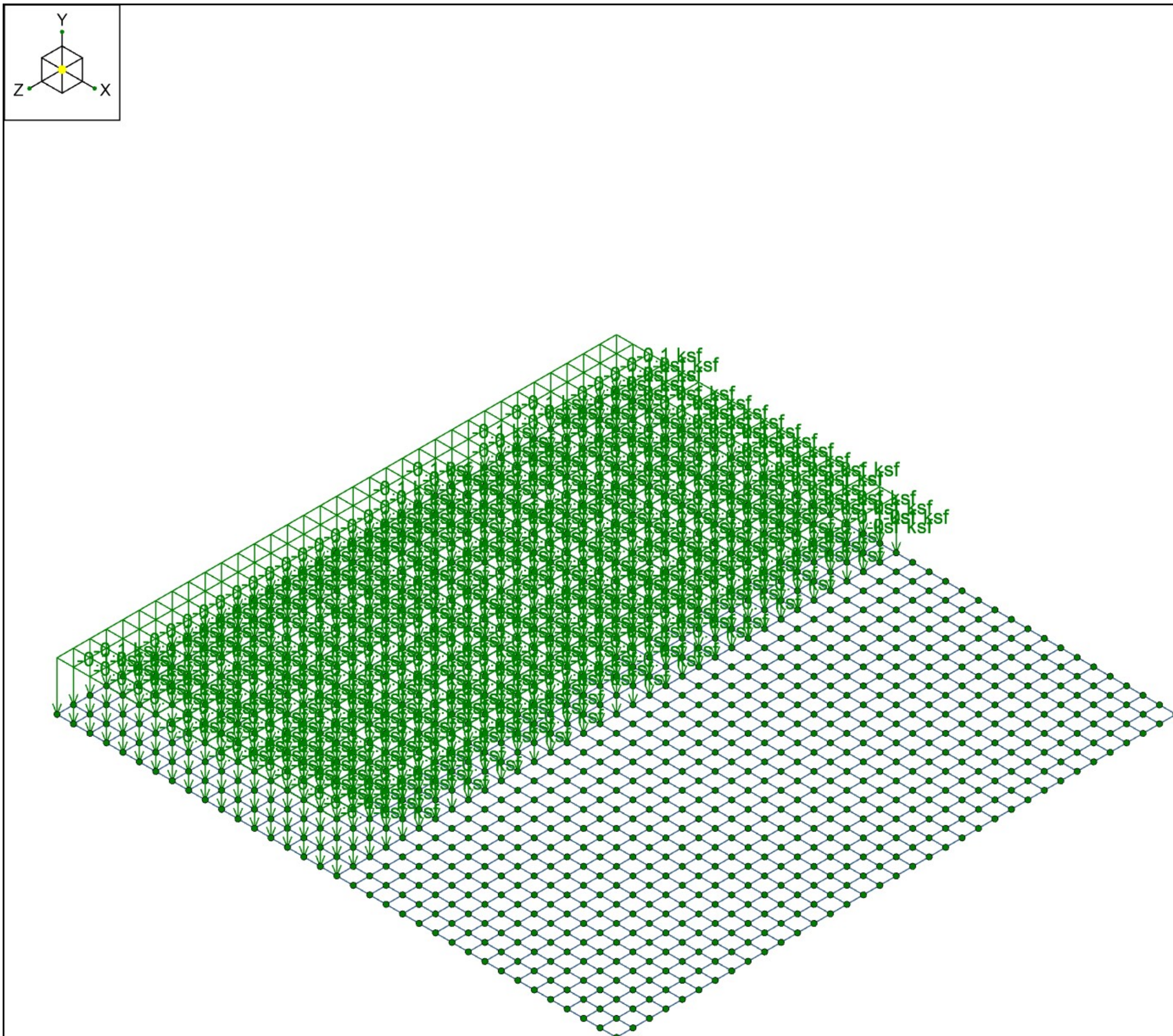


Check of applied forces vs moment

	Nodes	X = C	Ev (ASD) = Spts*Mot*(C/I)	M (ASD)	
0	P1	15.00	77.7 kips	1166 Kip-ft	
1	P2	14.27	73.9 kips	1054 Kip-ft	
2	P3	12.14	62.9 kips	763 Kip-ft	
3	P4	8.82	45.7 kips	403 Kip-ft	
4	P5	4.64	24.0 kips	111 Kip-ft	
5	P6	0.00	0.0 kips	0 Kip-ft	
6	P7	-4.64	-24.0 kips	111 Kip-ft	
7	P8	-8.82	-45.7 kips	403 Kip-ft	
8	P9	-12.14	-62.9 kips	763 Kip-ft	
9	P10	-14.27	-73.9 kips	1054 Kip-ft	
10	P11	-15.00	-77.7 kips	1166 Kip-ft	
11	P12	-14.27	-73.9 kips	1054 Kip-ft	
12	P13	-12.14	-62.9 kips	763 Kip-ft	
13	P14	-8.82	-45.7 kips	403 Kip-ft	
14	P15	-4.64	-24.0 kips	111 Kip-ft	
15	P16	0.00	0.0 kips	0 Kip-ft	
16	P17	4.64	24.0 kips	111 Kip-ft	
17	P18	8.82	45.7 kips	403 Kip-ft	
18	P19	12.14	62.9 kips	763 Kip-ft	
19	P20	14.27	73.9 kips	1054 Kip-ft	
				11657 Kip-ft	OK

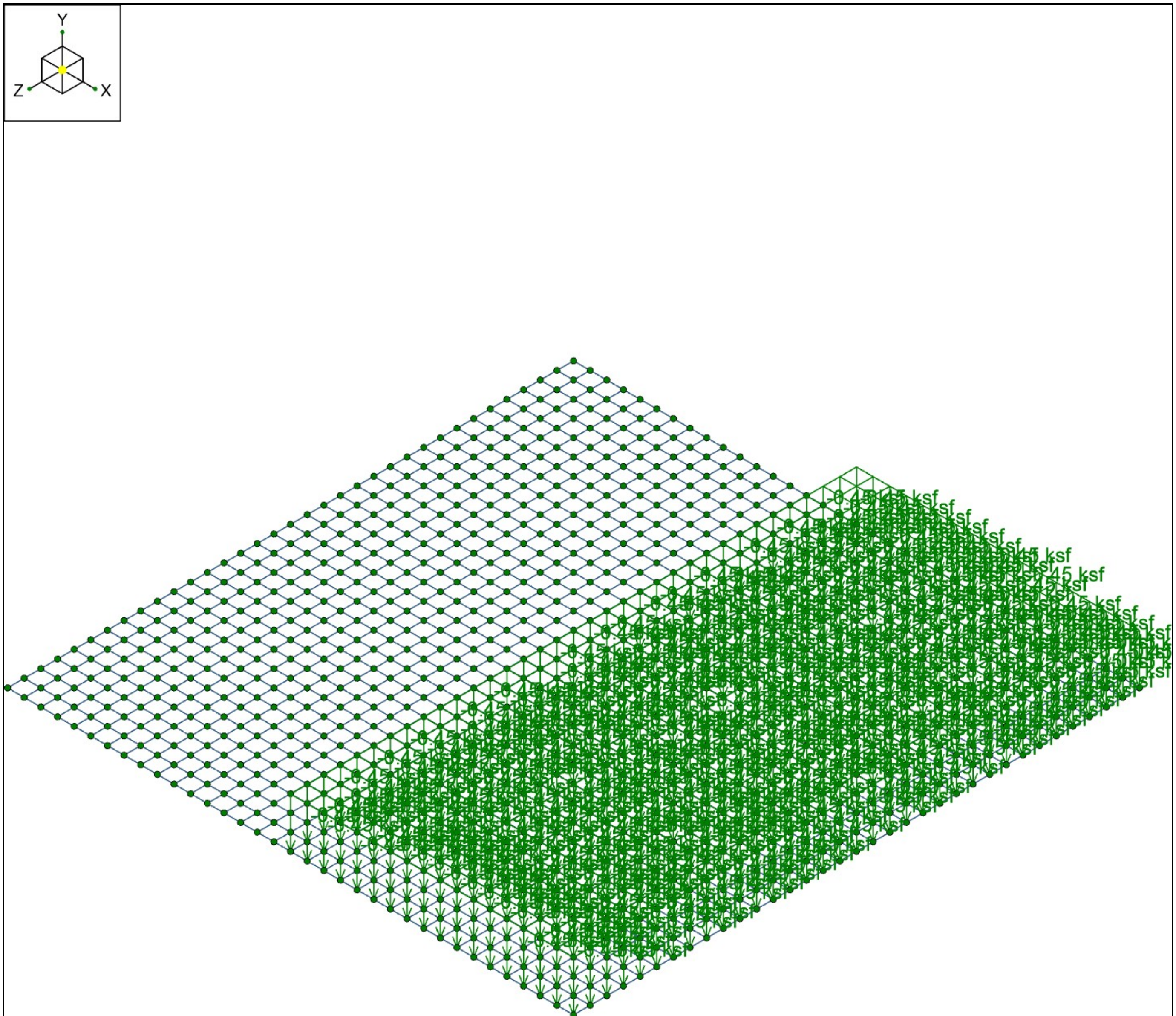


MME	MME	Bethany Tank 30 Foot Diameter	SK-1
	Bob Riley		Nov 03, 2025 at 02:28 …
	22102		30 foot diameter tank.r3d



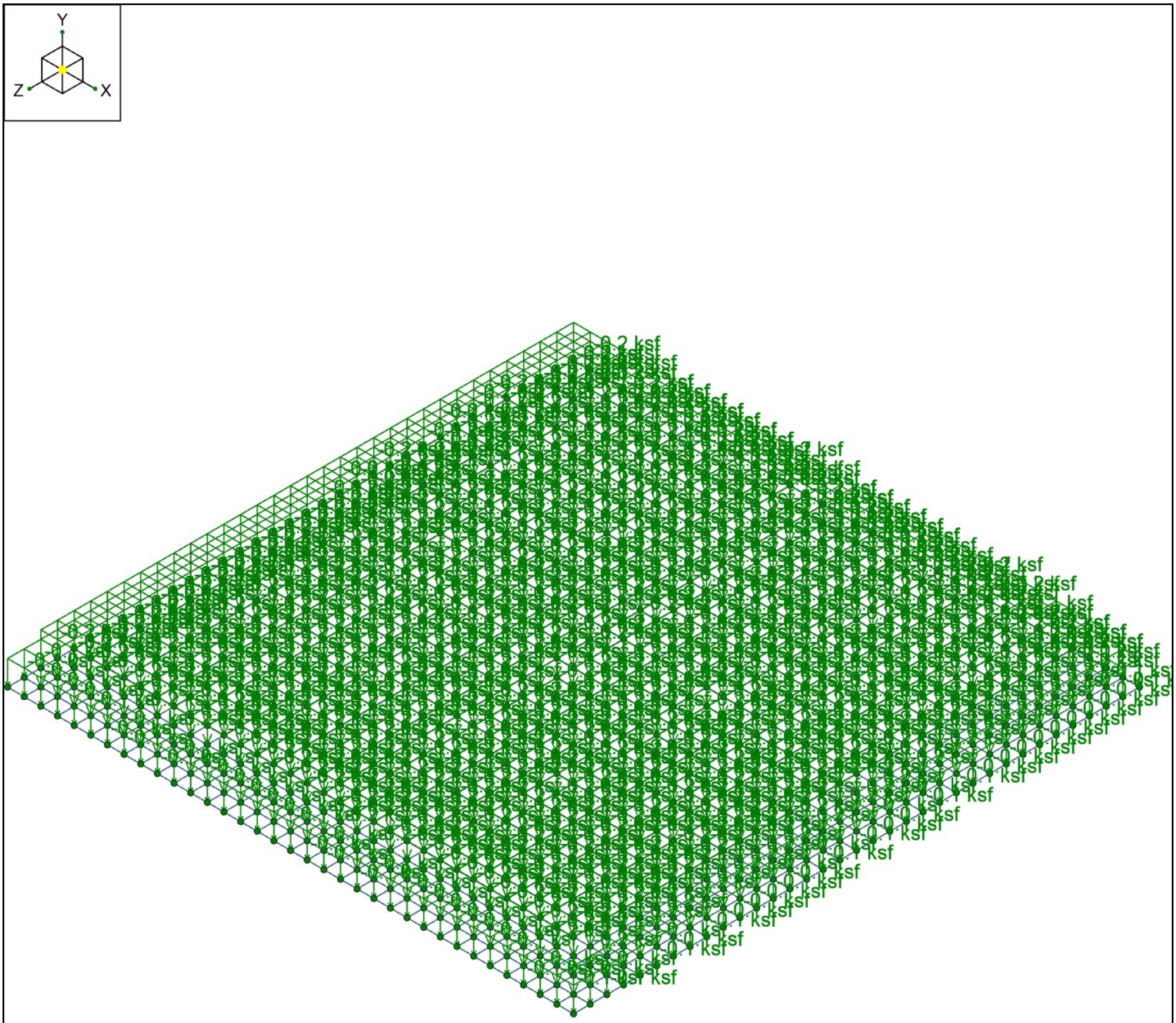
Loads: BLC 2, Foundation Net Down

MME	MME	Bethany Tank 30 Foot Diameter	SK-6
	Bob Riley		Nov 03, 2025 at 02:3…
	22102		30 foot diameter tank.…



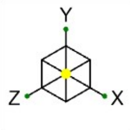
Loads: BLC 3, Foundation Full uplift

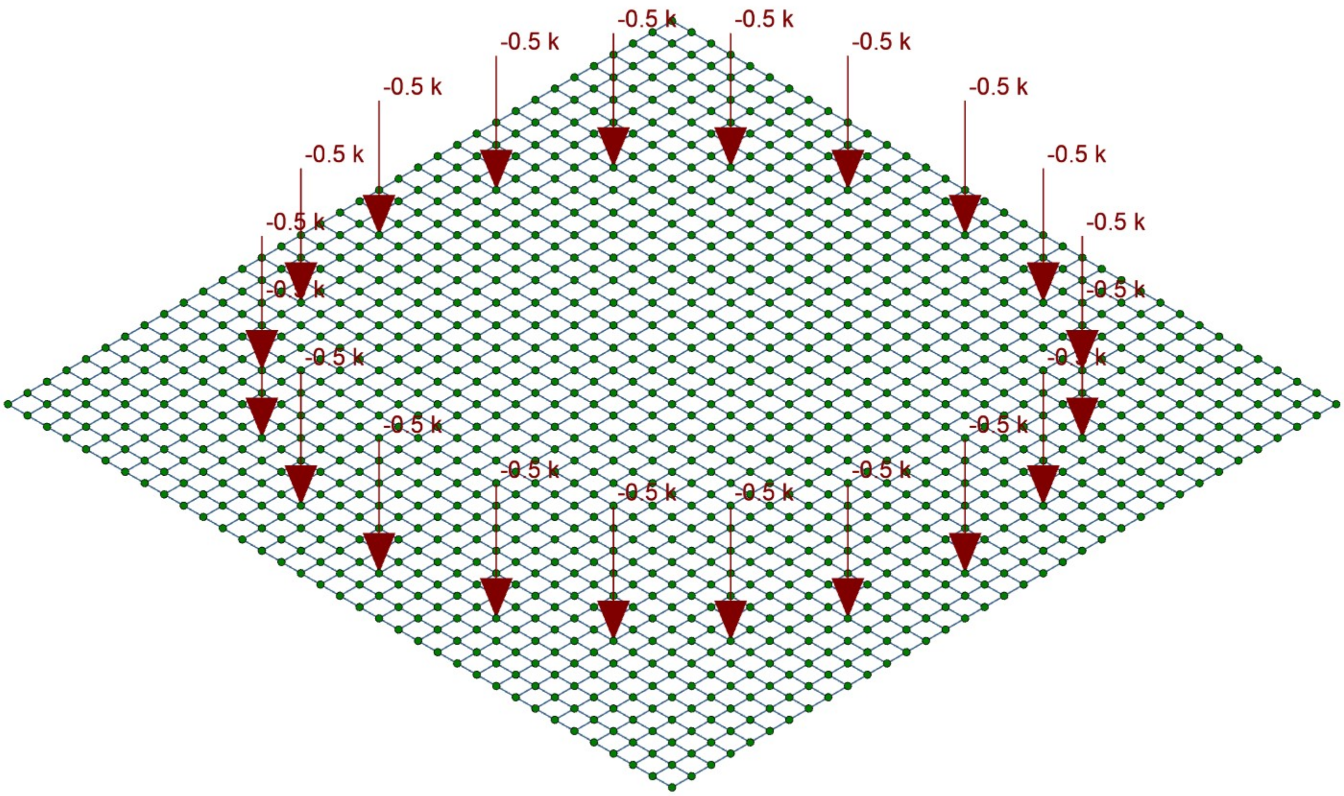
MME	MME	Bethany Tank 30 Foot Diameter	SK-7
	Bob Riley		Nov 03, 2025 at 02:3…
	22102		30 foot diameter tank.…



Loads: BLC 4, Founation Net All

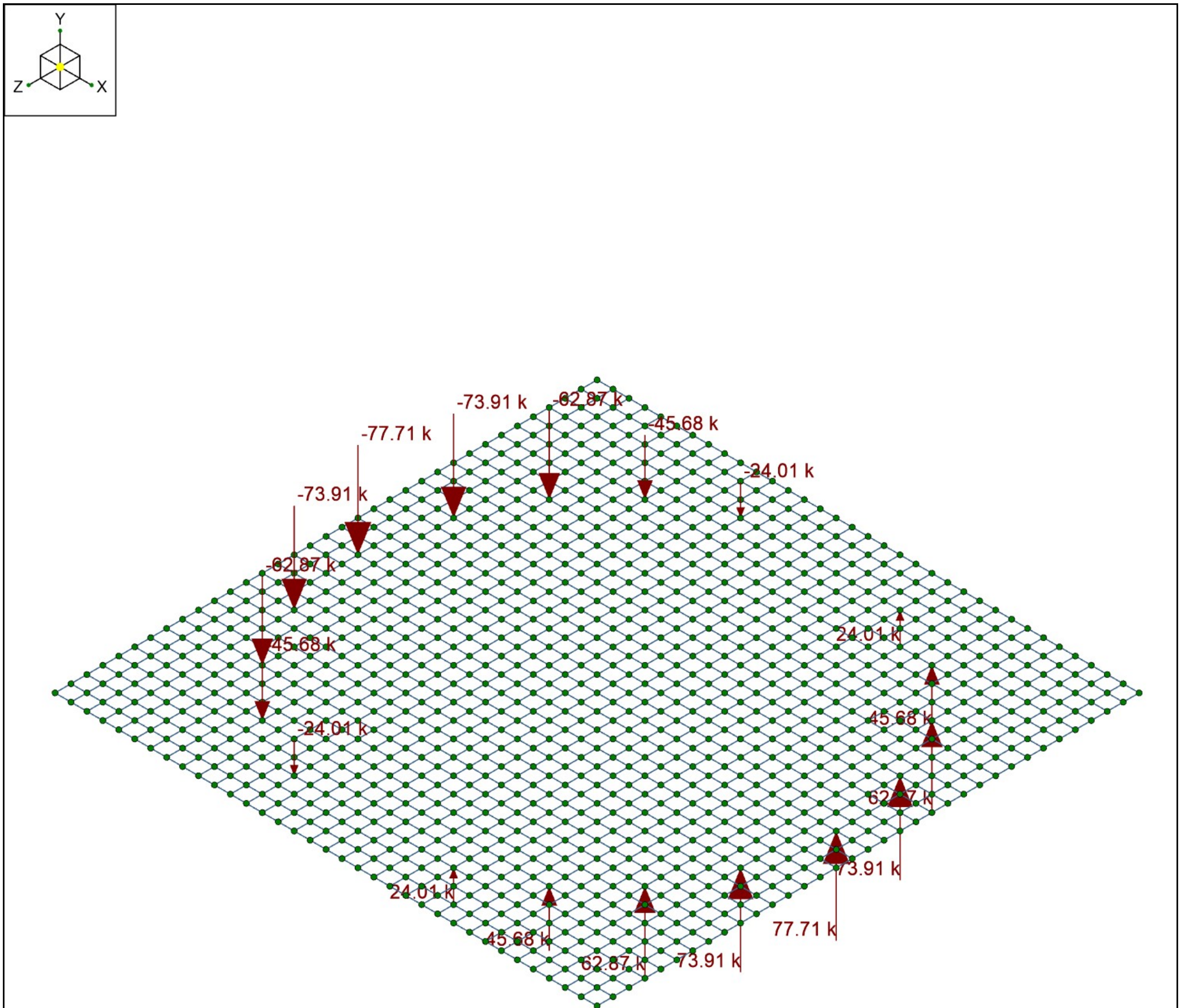
MME	MME	Bethany Tank 30 Foot Diameter	SK-8
	Bob Riley		Nov 03, 2025 at 02:3…
	22102		30 foot diameter tank.…





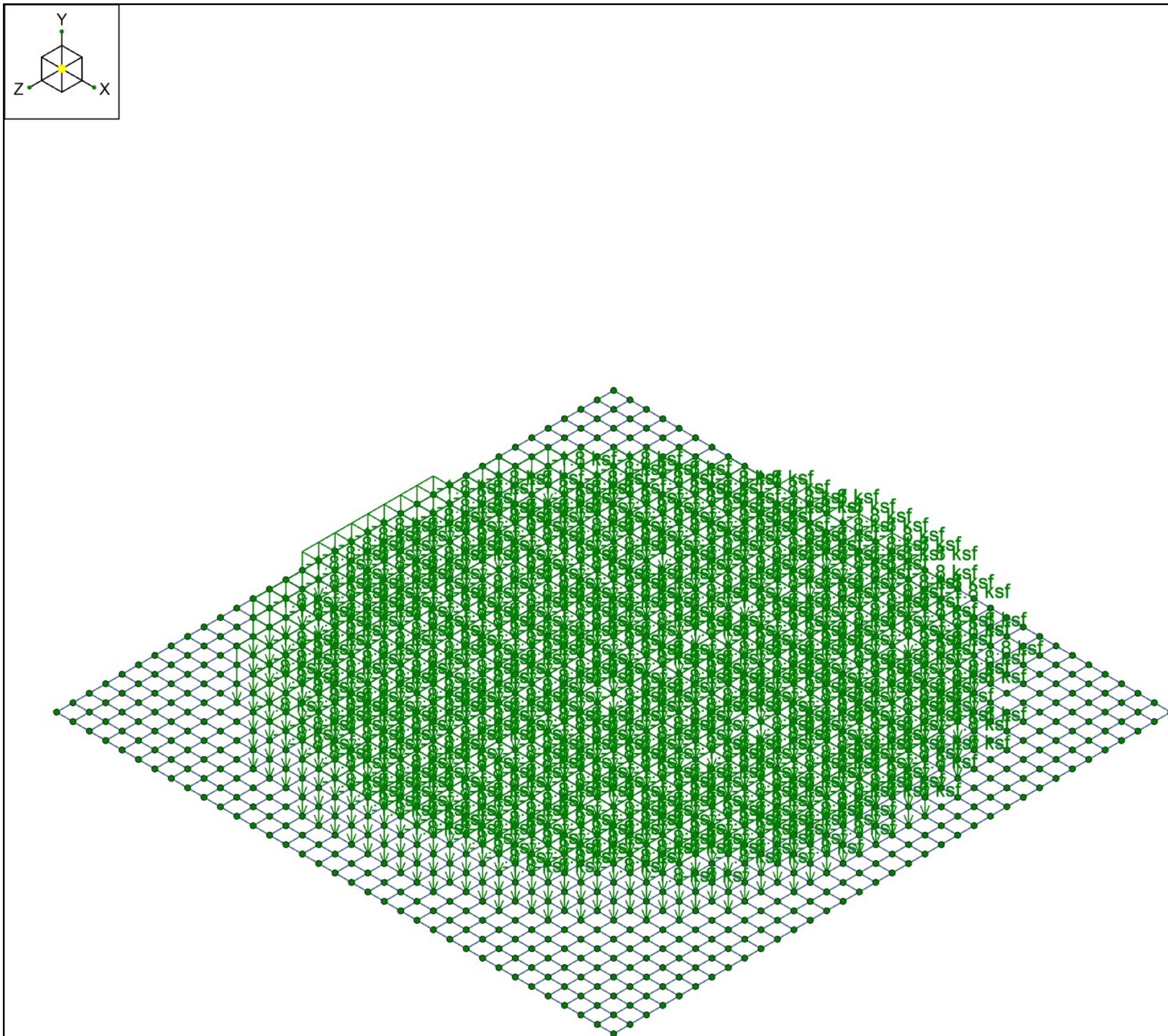
Loads: BLC 5, Live

MME	MME	Bethany Tank 30 Foot Diameter	SK-3
	Bob Riley		Nov 03, 2025 at 02:29 …
	22102		30 foot diameter tank.r3d



Loads: BLC 6, EQ

MME	MME	Bethany Tank 30 Foot Diameter	SK-4
	Bob Riley		Nov 03, 2025 at 02:30 …
	22102		30 foot diameter tank.r3d



Loads: BLC 7, Product

MME	MME	Bethany Tank 30 Foot Diameter	SK-5
	Bob Riley		Nov 03, 2025 at 02:30 …
	22102		30 foot diameter tank.r3d

Company : MME
Designer : Bob Riley
Job Number : 22102
Model Name : Bethany Tank 30 Foot Dia…

11/3/2025
2:33:42 PM
Checked By : ___________

Basic Load Cases

	BLC Description	Category	Nodal	Surface(Plate/Wall)
1	Tank	DL	20	
2	Foundation Net Down	OL1		578
3	Foundation Full uplift	OL2		578
4	Founation Net All	OL3		2180
5	Live	LL	20	
6	EQ	EL	20	
7	Product	DL		727

Load Combinations

	Description	Solve	P-Delta	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor
1	Bearing DL		Y	DL	1	4	1						
2	Bearing DL + LL		Y	DL	1	LL	1	4	1				
3	Bearing DL + EQ	Yes	Y	DL	1	2	1	EL	1	3	1		
4	DL + .75(EQ + LL)	Yes	Y	DL	1	2	1	EL	0.75	LL	0.75	3	1
5	.6DL - EQ		Y	DL	0.6	2	1	EL	1	3	1		

Node Loads and Enforced Displacements (BLC 1 : Tank)

	Node Label	L, D, M	Direction	Magnitude [(k, k-ft), (in, rad), (k*s²/ft, k*s²*ft)]
1	N829	L	Y	-2.1
2	N840	L	Y	-2.1
3	N727	L	Y	-2.1
4	N933	L	Y	-2.1
5	N1128	L	Y	-2.1
6	N670	L	Y	-2.1
7	N674	L	Y	-2.1
8	N76	L	Y	-2.1
9	N66	L	Y	-2.1
10	N326	L	Y	-2.1
11	N332	L	Y	-2.1
12	N2592	L	Y	-2.1
13	N2030	L	Y	-2.1
14	N2020	L	Y	-2.1
15	N2240	L	Y	-2.1
16	N1962	L	Y	-2.1
17	N1967	L	Y	-2.1
18	N1693	L	Y	-2.1
19	N1432	L	Y	-2.1
20	N1481	L	Y	-2.1

Node Loads and Enforced Displacements (BLC 5 : Live)

	Node Label	L, D, M	Direction	Magnitude [(k, k-ft), (in, rad), (k*s²/ft, k*s²*ft)]
1	N829	L	Y	-0.5
2	N840	L	Y	-0.5
3	N727	L	Y	-0.5
4	N933	L	Y	-0.5
5	N1128	L	Y	-0.5
6	N670	L	Y	-0.5
7	N674	L	Y	-0.5
8	N76	L	Y	-0.5
9	N66	L	Y	-0.5
10	N326	L	Y	-0.5
11	N332	L	Y	-0.5
12	N2592	L	Y	-0.5
13	N2030	L	Y	-0.5
14	N2020	L	Y	-0.5
15	N2240	L	Y	-0.5
16	N1962	L	Y	-0.5
17	N1967	L	Y	-0.5
18	N1693	L	Y	-0.5
19	N1432	L	Y	-0.5
20	N1481	L	Y	-0.5

Node Loads and Enforced Displacements (BLC 6 : EQ)

	Node Label	L, D, M	Direction	Magnitude [(k, k-ft), (in, rad), (k*s²/ft, k*s²*ft)]
1	N829	L	Y	77.71
2	N840	L	Y	73.91
3	N727	L	Y	62.87
4	N933	L	Y	45.68
5	N1128	L	Y	24.01
6	N670	L	Y	0
7	N674	L	Y	-24.01
8	N76	L	Y	-45.68
9	N66	L	Y	-62.87
10	N326	L	Y	-73.91
11	N332	L	Y	-77.71
12	N2592	L	Y	-73.91
13	N2030	L	Y	-62.87
14	N2020	L	Y	-45.68
15	N2240	L	Y	-24.01
16	N1962	L	Y	0
17	N1967	L	Y	24.01
18	N1693	L	Y	45.68

Node Loads and Enforced Displacements (BLC 6 : EQ) (Continued)

	Node Label	L, D, M	Direction	Magnitude [(k, k-ft), (in, rad), (k*s²/ft, k*s²*ft)]
19	N1432	L	Y	62.87
20	N1481	L	Y	73.91

46 Foot Diameter Tank Calculations

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Tanks information

Tank Name — **Bethany 46 foot Diameter**

Tank Address

Tank Coordinates

Seismic Design of Water Storage Tanks - (AWWA D100-21)

Welded Steel Ground Supported Flat Bottomed Tank

Steel Material Properties – Steel ASTM A 283 Grade C

Yield Strength	F_y=	**30 ksi**	
Compression Strength	F_{cy}=	**30 ksi**	
Ultimate Tensile Strength	F_U=	**55 ksi**	
Maximum Design Tensile Stress	F_t=	**15 ksi**	Section 3.2 (Tbl 5)
Modulus of Elasticity	E=	**29000 ksi**	
Joint Efficiency	Je=	**0.85**	
Poissons Ratio	n=	**0.3**	
Shear Modulus	Gm =	11154 ksi	
Steel Density	g_s =	**490.0 pcf**	

Concrete Material Properties

Type of foundation — **Slab or Pile Cap**

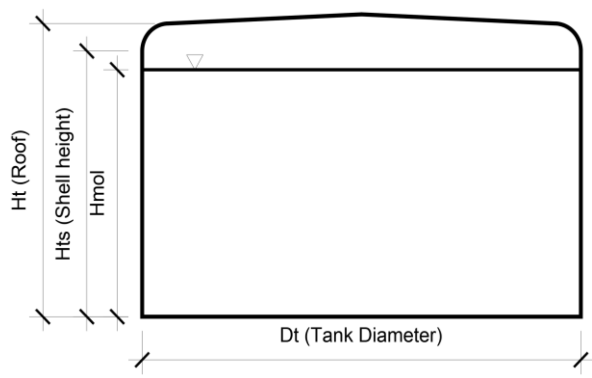
Concrete Compression Strength	f'c =	**3.0 ksi**	
Rebar Yield Strength	F_{yr} =	**60 ksi**	
Concrete unit weight	g_c =	**150.0 pcf**	
Strength reduction factor – Tension	$Ø_T$ =	**0.9**	
Strength reduction factor – Bending	$Ø_B$ =	**0.9**	

Soil Properties

Soil unit weight	g_s =	**120.0 pcf**	
Allowable bearing soil pressure (net)	q_{bra} =	**1.5 ksf**	
Bearing pressure short-term increase	ST =	**1.33**	
Allowable bearing soil pressure (short term)	qbrgST = qbrg * ST =	2.00 ksf	
Coefficient of lateral earth pressure (0 if geotech report values are used)	k =	**0.333**	
Active pressure from calculation	Pac = k *gsoil =	40.0 pcf	
Active pressure per Geotech report (0 if given as a coefficient)	Pag=	**0.0 pcf**	
Active pressure	Use Pa = Pac	40.0 pcf	
Coefficient of friction from calc (ASD)	mc = 0.7*Tan(30°)=	0.404	Section A13.2
Coefficient of friction from Geotech report (0 if using AWWA coefficient)	mg =	**0**	
Coefficient of friction	**m = if(mg >0 , mg, mc)=**	**0.404**	
Passive Pressure per Geotech report	PPg=	**200.0 pcf**	

Tank Properties

Tank Diameter	Dt =	**46.0 ft**
Shell Height	Hts =	**37.0 ft**
Roof Height	Ht =	**40.0 ft**
Torus Height(radius)	Htor =	3.0 ft
Water Height (maximum operating level H)	Hmol =	**32.5 ft**
Tank Radius	Rt= Dt/2 =	23.0 ft



Water Volume

Vw = (π * Dt^2 * Hmol) / 4 = 54012 ft^3

Tank Capacity C = 7.48052 * Vw = 404036.6 gallons

Tank Roof Area Ar = (π * Dt^2) / 4 = 1662 ft^2

Tank Circumference Ct = (π * Dt) = 144.5 ft

Tank Roof Dead Load

Rafter Weight	wrft =	**25.0 #/ft**
Rafter Length	Lrft =	**23.0 ft**
Rafter quantity	Nrft =	**20**

Total weight of rafters

Wrftr = wrft * Lrft * Nrft/1000 = 11.50 kips

Tank Rafter Depth	Rd=	**10.00 in**
Tank roof plate thickness	tplrf =	**0.25 in**
Tank roof plate weight	wplrf = tplrf * gs/12 =	10.21 psf

Plate Area - Roof area - torus projected area

Arpl =(π(Dt-2*Htor)^2)/4 = 1257 ft^2

Weight of roof plate	Wplrf = Arpl * wplrf/1000 =	12.8 kips
Area of torus plate	Ator = π*Htor/2*Ct =	681 ft^2
Weight of torus plate	Wpltor = Ator*wplrf/1000 =	7.0 kips
Tank Roof Weight – Total Dead Load	Wr = Wrftr + Wplrf+Wpltor =	31.3 kips
Tank Roof Load – Total Dead Load	wr = Wr/Arpl =	24.9 psf

Tank Roof Live Load	wLL =	**20.0 psf**
# of Bearing points	Bp=	**2**

1 = Tank shell only, no interior supports
2 = Tank shell and center column
3 = Tank shell, intermediate column line at midpoint, and center column

Plate Distribution Factor to outer shell

plDf= if(Bp<=1,1,if(Bp <= 2 , 0.75 , 0.4375)) = 0.75

Rafter Distribution Factor to outer shell

rftDf= if(Bp<=1,0,if(Bp<=2,0.5,0.25)) = 0.5

Tank Roof Weight – On Shell

WrsDL = rftDf * Wrftr + plDf * Wplrf = 15.37 kips

Tank Roof Live Load – On Shell

WrsLL = plDf * Ar * wLL = 24.93 kips

Water Density gw = **62.4 pcf**

Water Specific Gravity G_w = **1**

Total Water Weight Ww = Vw * gw/1000 = 3370.3 kips

Water Weight per ft2 wp = Hmol * gw/1000 = 2.03 ksf

Water Weight available to resist uplift (For ground supported tanks = 0, Sec 3.8.5.3)

WwUplift= **0.00 kips**

Tank Shell Geometry

# of Rings	Rno =	**4**	
Ring 1 Height (Lowest ring)	R1h =	**9.25 ft**	
Ring 1 Thickness	R1t =	**0.31 in**	
Ring 1 Area	R1a=R1h *R1t/12 =	0.24 ft^2	
Ring 1 y-bar	R1y=R1h *.5=	4.6 ft	
Ring 2 Height	R2h =	**9.25 ft**	
Ring 2 Thickness	R2t =	**0.31 in**	
Ring 2 Area	R2a=R2h *R2t/12=	0.24 ft^2	
Ring 2 y-bar	R2y=R1h+R2h *.5=	13.9 ft	
Ring 3 Height	R3h =	**9.25 ft**	
Ring 3 Thickness	R3t =	**0.31 in**	
Ring 3 Area	R3a=R3h *R3t/12 =	0.24 ft^2	
Ring 3 y-bar	R3y=R1h+R2h+R3h *.5=	23.1 ft	
Ring 4 Height	R4h = 0 ft	**9.25 ft**	37.00 ft
Ring 4 Thickness	R4t = .0 in	**0.31 in**	**OK**
Ring 4 Area	R4a=R4h *R4t =	0.24 ft^2	-
Ring 4 y-bar	R4y=R1h+R2h+R3h+R4h *.5=	32.4 ft	

Average Tank Shell Thickness

tave = (R1a + R2a + R3a+ R4a)/Hts = 0.31 in

Tank Shell Weight

WshlDL = 2*π*R*(R1a + R2a + R3a+ R4a)*gs/1000 = 67.96 kips

Tank Bottom Thickness tbott = **0.25 in**

Tank Bottom Annulus Thickness tanul = **0.25 in**

Tank Bottom Actual Thickness (including corrosion)

ts = **0.25 in**

Tank Bottom Annulus Width

L = .216 * tanul*(Fy/(Hmol *Gw)^.5 = 1.641 ft (Eq 13-34)

Tank Bottom Weight (Section 3.8.5.3)

Wf = Ar * tbott * gs/(12*1000) = 16.97 kips

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Seismic Design Criteria		ASCE 7	
Risk Category		**IV**	(Section 3.1.1)
Seismic Importance Factor	IE =	1.5	(Table 21)
Soil Site Class		**C**	
Mapped Acceleration Parameters:			
	S_{DS} =	**1.886**	
	SD1 =	**0.882**	
	S1 =	**0.944**	
Response Modification Factors:			
Type of Tank: (Table 24 Section 13.2.5)			
Self-Anchored Tank			
Impulsive	R_{isa} =	**2.5**	
Mechanically Anchored Tank			
Impulsive	R_{ima}=	**3**	
Convective	R_c =	**1.5**	
Determine Natural Periods			
Damping Scaling Factor (Section 13.2.6.3.2 – convert from 5% to 0.5%)			
	K =	**1.5**	
Impulsive Natural Period (Section 13.5)			
	Ti =	**0 sec**	
Convective (Sloshing Wave) Period			
	Tc = 2 *π *(Dt/(3.68 *32.2 *tanh(3.68 *Hmol/Dt))) =	3.94 sec	(Eq. 13-18)
Region-Dependent Transition Period			
	T_L =	**12 sec**	(Fig. 19)
	T_S = SD1 / SDS =	0.47 sec	
Determine Design Accelerations – General Procedure (Section 13.2.6)			
Design Spectral Impulsive Acceleration			
	Ti<=TS then Sai = SDS =	1.886	Eq. 13-5
	Ts<Ti<=TL then Sai = SD1/(Ti) =	-	Eq. 13-6
	Ti>TL then Sai = TL*SD1/(Ti)^2) =	-	Eq. 13-7
	Therefore, Sai =	**1.886**	
Design Spectral Convective Acceleration			
	Tc <= TL then Sac = K*SD1/Tc =	0.336	Eq. 13-8
	Tc > TL then Sac = K*TL*SD1/Tc^2 =	1.025	Eq. 13-9
	Therefore, Sac =	**0.336**	
Self-anchored			
Impulsive Accel, max, (ASD)	Ai_maxsa = 0.7*Sai * IE / (Risa) =	0.792	(Eq 13-13)
Impulsive Accel, min,	Ai_minsa = 0.36 *S1 * IE / (Risa) =	0.204	(Eq 13-13)
Impulsive Accel,	**Aisa = max(Ai_maxsa,Ai_minsa) =**	**0.792**	
Mechanically anchored			
Impulsive Accel, max, (ASD)	Ai_maxma =0.7* Sai * IE / (Rima) =	0.660	(Eq 13-13)
Impulsive Accel, min,	Ai_minma = 0.36 *S1 * IE / (Rima) =	0.170	(Eq 13-13)
Impulsive Accel,	**Aima = max(Ai_maxma,Ai_minma) =**	**0.660**	

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Convective Design Acceleration (ASD)

Ac = 0.70 *Sac *1 sec *(IE / (Rc)) = 0.235 (Eq 13-14)

Vertical Design Acceleration (Section 13.5.4.3)

Responses limited by buckling (STR) **Av1 = 0.48 * SDS = 0.905**

Responses not limited by buckling (STR) **Av2 = 0.19 * SDS = 0.358**

<u>Impulsive and Convective Weights</u> (Section 13.5.2)

Wi - effective impulsive weight - tank contents that moves in unison with the tank shell

Dt/Hmol >= 1.333, Wi (1) =
tanh(0.866 *Dt/Hmol) *Ww/(0.866 *Dt/Hmol)= 2313.4 kips (Eq 13-20)

Dt/Hmol < 1.333, Wi (2)= (1 – 0.218 *Dt/Hmol)) *Ww = 2330.4 kips (Eq 13-21)

Dt/Hmol >= 1.33, therefore use Eq 13-20, Wi = Wi(1) = 2313.4 kips

Wc - Effective Convective Weight - the first mode sloshing contents of the tank
Wc =(0.23 *Dt/Hmol) *tanh(3.67 *Hmol/Dt) *Ww = 1085.0 kips (Eq 13-22)

Determine Moment Arms from Bottom of Tank:
Height to Tank Shell C.G.
Xs = (R1a *R1y+R2a *R2y+R3a *R3y+R4a *R4y)/(R1a+R2a+R3a+R4a)
Xs = 18.5 ft

Height to Roof and Torus **Xr = Ht = 40.0 ft**

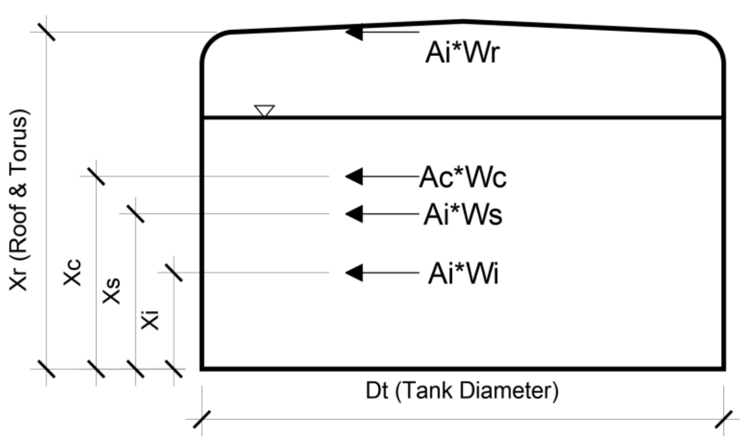
<u>Impulsive and Convective Centroids</u>

Tank Aspect Ratio: Dt/Hmol = 1.415

Ring Foundations

Height to Centroid of Impulsive Weight
Dt/Hmol >= 1.333 Xi (1) = 0.375 * Hmol = 12.2 ft
Dt/Hmol < 1.333 Xi (2) = (.5-0.094*Dt/Hmol)Hmol = 11.9 ft
Therefore, Xi = 12.2 ft

Height to Centroid of Convective Weight (Eq 13-26)
Xc = (1 – ((cosh(3.67 *Hmol/Dt))-1)/((3.67 *Hmol/Dt) *sinh(3.67 *Hmol/Dt))) *Hmol
Xc = 21.7 ft



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Slab or Pile Cap Foundations

Height to Centroid of Impulsive Weight

Dt/Hmol >= 1.333

Ximf(1) = 0.375 (1+1.333(0.866(Dt/Hmol)/(tanh(0.866(Dt/Hmol)-1) * Hmol = 19.6 ft

19.0 ft

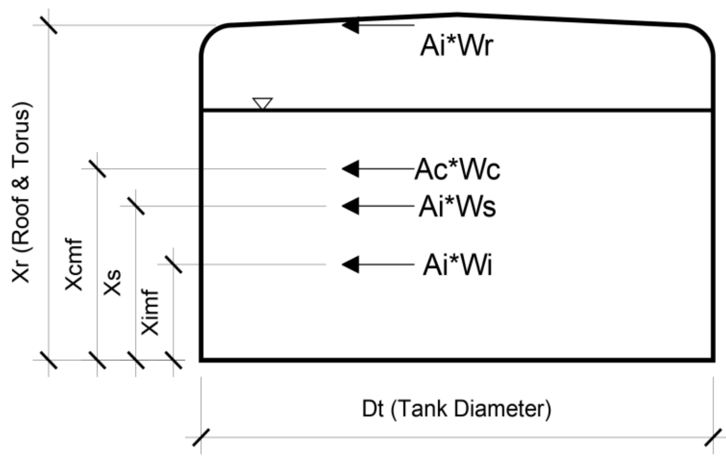
Dt/Hmol < 1.333 Ximf (2) = (.5+0.06*Dt/Hmol)Hmol = N/A Dt/Hmol >= 1.33

Therefore, Ximf = 19.6 ft

Height to Centroid of Convective Weight (Eq 13-26)

Xc = (1 – ((cosh(3.67 *Hmol/Dt))-1.937)/((3.67 *Hmol/Dt) *sinh(3.67 *Hmol/Dt))) *Hmol

Xcmf = 23.48 ft



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Overturning Moment

Design OT Moment @ Bott of Tank Shell: Sec 13.5.2

Self-anchored

Ring Foundation

Ms sa(1) =((Aisa *(Ws *Xs+Wr *Xr+Wi *Xi))2 + (Ac *Wc *Xc)2)^0.5 = (Eq 13-19)

Ms_sa = 24942 Kip-ft

Slab or Pile cap

Mmf sa(2) =((Aisa *(Ws *Xs+Wr *Xr+Wi *Ximf))2 + (Ac *Wc *Xcmf)2)^0.5 = (Eq 13-28)

Mmf_sa= 38391 Kip-ft

Mechanically anchored

Ring Foundation

Ms ma =((Aima *(Ws*Xs+Wr*Xr+Wi*Xi))^2 + (Ac*Wc*Xc)^2)^0.5 = (Eq 13-19)

Ms_ma = 21009 Kip-ft

Slab or Pile cap

Mmf ma =((Aima *(Ws*Xs+Wr*Xr+Wi*Ximf))^2 + (Ac*Wc*Xcmf)^2)^0.5 = (Eq 13-19)

Mmf_ma = 32163 Kip-ft

Resistance to overturning: (Sec 13.5.4.1.1)

Tank shell and roof portion

Total **Wt =(WshDL+WrsDL) = 83.3 kips**

per foot of circumference **wt =(Wt)/Ct = 0.58 kip/ft** (Eq 13-37)

Tank bottom or annulus

Use the lesser of tanul or R1t, tb = 0.25 in

Contents Minimum of WL (1) or WL (2) (Eq 13-33)

WL (1) = 7.9tb(FyHG)^0.5 = 1.95 kip/ft

WL (2) = 1.28HDG = 1.91 kip/ft

Use wL = 1.91 kip/ft

Overturning ratio "J"

Calculation for determinging J uses the overturning moment for a self-anchored tank and Av2 for responses not limited by buckling.

Overturning Ratio

J = Ms_sa*1000/(Dt^2 *(((1-0.4 *Av2) *wt)+WL))= 4.896 (Eq 13-32)

J<0.785	No uplift
0.785 <= J <= 1.54	Uplift, but stable- anchors are not required
J > 1.54	Anchors are required

J = 4.9 > 1.54, Uplift occurs and Anchors are required

Tank anchored for tension loading? **Yes** -

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Freeboard Section 13.6

Convective Design Acceleration

Risk Cat II & III

Tc<=4	Af(2.1) = K * SD1Ie/Tc =	NA	(Eq 13-50)
Tc>4	Af(2.2) = 4K * SD1Ie/Tc^2 =	NA	(Eq 13-51)

Risk Cat = IV

Tc<=TL	Af(4.1) = K * SD1/Tc =	0.34	(Eq 13-52)
Tc>TL	Af(4.2)= K * SD1TL/Tc^2 =	NA	(Eq 13-53)
	Therefore, Af =	**0.34**	

Sloshing Wave Height	d = 0.42 * Dt * Af * 1 sec =	6.5 ft	(Eq 13-49)
Rafter Depth	Rd =	10.00 in	
Freeboard Provided	d prov=Ht-Hmol-Rd=	6.7 ft	-
Maximum Operating Level permitted			
	Hmol(max) = Ht-Rd– d =	32.7 ft	

Hmol = 32.5 ft <= Hmol(max) **OK, adequate freeboard is provided**

Tension Anchorage Section 3.8

Bolt diameter	d =	**1.00 in**	-
Bolt diameter - min	dmin =	1.00 in	
Anchor bolt eccentricity	e =	**5.50 in**	-
Coeff of thermal expansion	Et =	**0.0000065**	
Difference in temperature	T =	**50 Deg F**	
Anchor bolt eccentricity minimum	emin = 2.125 +d/2 + 6(Et)(Dt)T =	5.46 in	
Number of Anchors	N =	**15**	-
Maximum spacing of Anchors	Sanchmax =	10.0 ft	Section 3.8.1.2.1#2
Minimum number of Anchors	Nmin =	6	Section 3.8.1.3
Anchor circle diameter	Dac = Dt + 2*e/12 =	46.9 ft	
Anchor Spacing	S_anch = π * Dac/N =	9.8 ft	-
Anchor circle circumference	Cac = Dac *π	147.4 ft	

Anchor design loads

Anchor Tension – Strength Load Combo Ps = 0.9 DL – Ev + Eh Section 3.8.8.1

Use Av2 - response not limited by buckling

Anchor Tension Load

Ps = 1/N((4*Ms_ma/(Dac) -Wt(0.9-0.4Av))= 115.2 kips (Eq 3-40)

Shear anchorage

Allowable Lateral Shear

Vallow = m *(Ws+Wr+Wi+Wc) *(1-0.4 *Av2) = 1210.9 kips

Design shear @ top of foundation

Self - Anchored (ASD)

Vf_sa =0.7*((Ai_sa *(Ws+Wr +Wi))^2 + (Ac *Wc)^2)^.5 = NA

-

Mechanically anchored

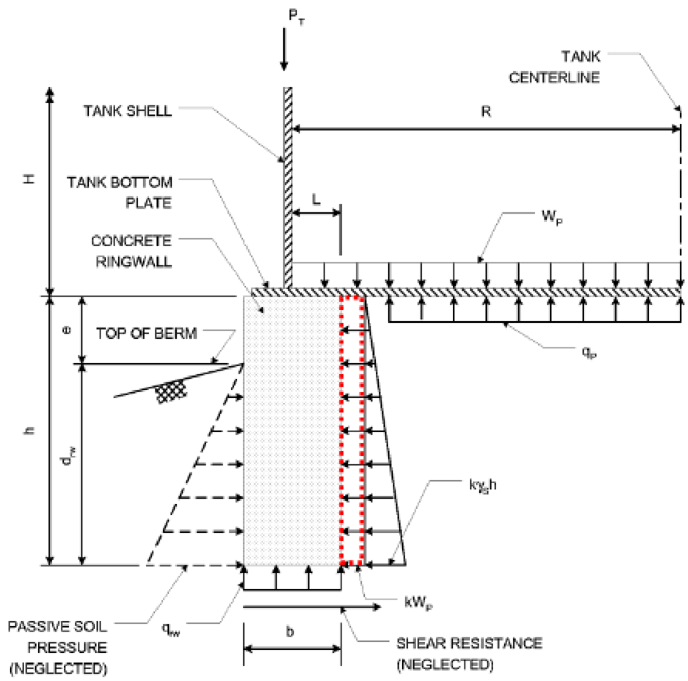
Vf_ma = 0.7*((Ai_ma *(Ws+Wr +Wi))^2 + (Ac *Wc)^2)^.5 = 1129.0 kips

Mechanical shear anchors are not reqd

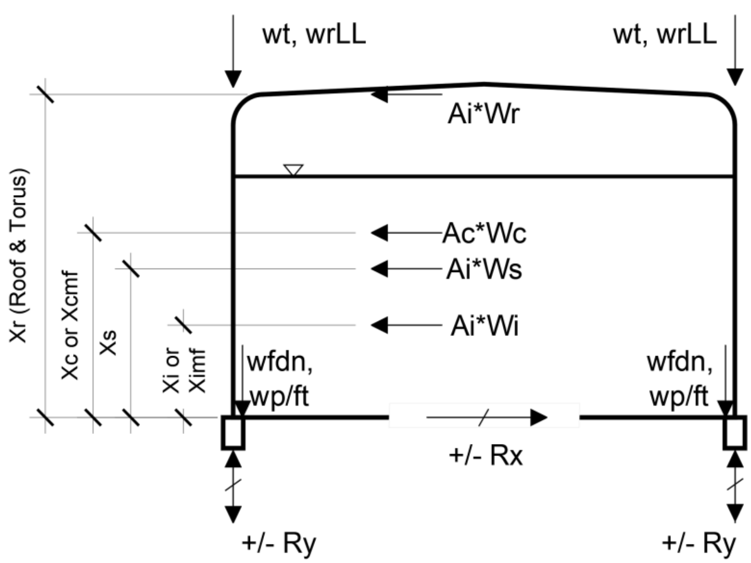
Tank anchored for Shear? **No** -

Foundation -

The foundation analysis and design is based upon the Process Industry Practices (PIP) "Guidelines for Tank Foundation Designs, PIP STE3021



Ringwall Loading for Unanchored Tank



For bearing pressure calcs for the weight of the foundation below grade, use:

Net Unit Weight = gn = gc - gs = 30.0 pcf

For resistance to uplift calcs use: **Full Unit Weight = gc =** 150.0 pcf

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		w	P total = w*Ct
Basic Load Cases			
Dead Load (bearing) (DL_brg)			
Ring or Pile cap Foundation (bearing)	wfd_brg =	0.60 kip/ft	86.7 kips
Piers/Spier (bearing)	Wpier_brg/spier =	0.15 kip/ft	21.9 kips
Tank (wt)	wt =	0.58 kip/ft	83.3 kips
Product (wp) (bearing w/EQ LC)	wp =	5.58 kip/ft	806.0 kips
Dead Load (Uplift Resistance on Foundation)			
Ring or Pile cap Foundation (uplift)	wfdn =	1.80 kip/ft	260.1 kips
Piers/Spier (uplift)	Wpie/spier =	0.76 kip/ft	109.7 kips
Tank (wt)	wt =	0.58 kip/ft	83.3 kips
Product (wp) (uplift)	wL =	1.91 kip/ft	276.5 kips
Roof Live (RLL)	wRLL = WrsLL/Ct =	0.17 kip/ft	24.9 kips
	Mot =		
Seismic (bearing) (EL)			
Vertical Load from Mot	EL1= (Mot/Sf)=	0.00 kip/ft	0.0 kips
Vertical Load (wt)	EL2 = 0.7 * 0.4 * Av * wt =	0.06 kip/ft	8.4 kips
Vertical Load (wp)(bearing)	EL3 = 0.7 * 0.4 * Av * wp =	0.56 kip/ft	80.9 kips
Seismic (uplift) (EL)			
Vertical Load from Mot	EL1= (Mot/Sf)=	0.00 kip/ft	0.0 kips
Vertical Load (wt)	EL2 = 0.7 * 0.4 * Av * wt =	-0.06 kip/ft	-8.4 kips
Vertical Load (wp)(uplift)	EL3 = 0.7 * 0.4 * Av * wL =	-0.19 kip/ft	-27.7 kips

Slab Foundations - Anchored Load Combinations

ASD Load Combinations

Tank Circumference	Ct = 144.5133 ft		
Total number of points (Max 20)	pts = 20	OK	-
Distance between points	Spts 7.2257 ft		

Slab Foundation Parameters

Slab depth	ds = 2.0 ft
Slab Plan Dimensions - width	ws = 50.0 ft
Slab Plan Dimensions - length	ls = 50.0 ft
Foundation height above grade	es = 0.5 ft
Inside of tank shell to edge of fdn	L = 1.0 ft

Slab weight	Wfdn_slab = ds*ws*ls*gc =	750.0 kips
Foundation weight above grade	Wfdn_slab_a = e*ws*ls*gc/1000 =	187.5 kips
Foundation weight net below grade	Wfdn_slab_n = (ds-es)*ws*ls*(gn)/1000 =	112.5 kips

For Slab Foundations use Mot = Mmf_ma = **32163 Kip-ft**

Overturning Stability Ratio 0.5D(WT +Wfd + Wg)/Mot > 2.0

WT = Ws + Wr + Wp+ Wf

Shell	Ws = 68.0 kips
Roof	Wr = 31.3 kips
Product	Wp = 3370.3 kips
Floor	Wf = 17.0 kips
Foundation	wfdn_slab = 750.0 kips
Soil	Wg = 0.0 kips
	4236.5 kips

0.5D(WT +Wfd + Wg)/Mot = 3.0 OK >2

Gravity Loads

		w	P = w*Spts
Foundation Above Grade	wfd_a =	0.30 kip/ft	2.168 kips
Tank (wt)	wt =	0.58 kip/ft	4.166 kips
Product (wp)	wp =	2.0 ksf	
Live Load	wRLL = WrsLL/Ct =	0.17 kip/ft	1.2 kips

Seismic Load Combinations — Use Av2 - response not limited by buckling

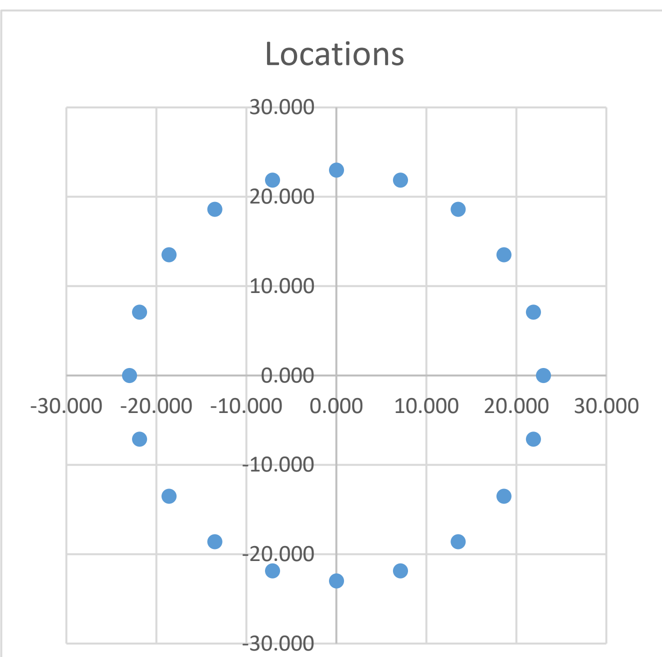
Reference API 650 Annex E Section E6.2.3 Foundations — Sf = π*(Dt^2)/4 = D^2/1.273 = 1661.9

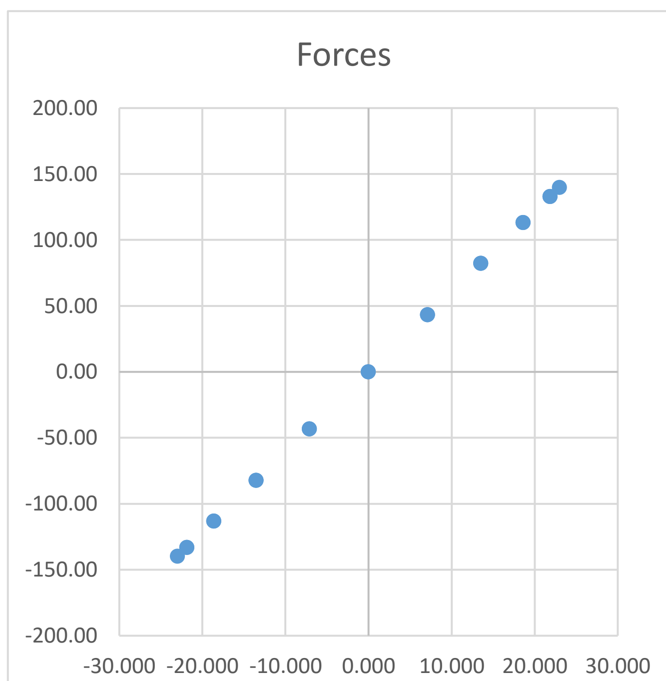
LC2 = wfdn_brg + wt(1+ 0.7*0.4Av)+1.273*Mmf_ma/D^2

LC3 = 0.6*wfd + wt(0.6-0.7*).4Av - 1.273*Mmf_ma/D^2

46 Foot Diamter Tank

	Θ Angle (rad)	Nodes	D_tank*COS(Θ)/2 X = C	D_tank*sin(Θ)/2 y	Ev (ASD) = Spts*Mot*(C/I)	Ev (STR) = EV(ASD)/0.7
0	0.000	P1	23.000	0.000	139.84	199.8 kips
1	0.314	P2	21.874	7.107	133.00	190.0 kips
2	0.628	P3	18.607	13.519	113.13	161.6 kips
3	0.942	P4	13.519	18.607	82.20	117.4 kips
4	1.257	P5	7.107	21.874	43.21	61.7 kips
5	1.571	P6	0.000	23.000	0.00	0.0 kips
6	1.885	P7	-7.107	21.874	-43.21	-61.7 kips
7	2.199	P8	-13.519	18.607	-82.20	-117.4 kips
8	2.513	P9	-18.607	13.519	-113.13	-161.6 kips
9	2.827	P10	-21.874	7.107	-133.00	-190.0 kips
10	3.142	P11	-23.000	0.000	-139.84	-199.8 kips
11	3.456	P12	-21.874	-7.107	-133.00	-190.0 kips
12	3.770	P13	-18.607	-13.519	-113.13	-161.6 kips
13	4.084	P14	-13.519	-18.607	-82.20	-117.4 kips
14	4.398	P15	-7.107	-21.874	-43.21	-61.7 kips
15	4.712	P16	0.000	-23.000	0.00	0.0 kips
16	5.027	P17	7.107	-21.874	43.21	61.7 kips
17	5.341	P18	13.519	-18.607	82.20	117.4 kips
18	5.655	P19	18.607	-13.519	113.13	161.6 kips
19	5.969	P20	21.874	-7.107	133.00	190.0 kips
					0.00	0.0 kips





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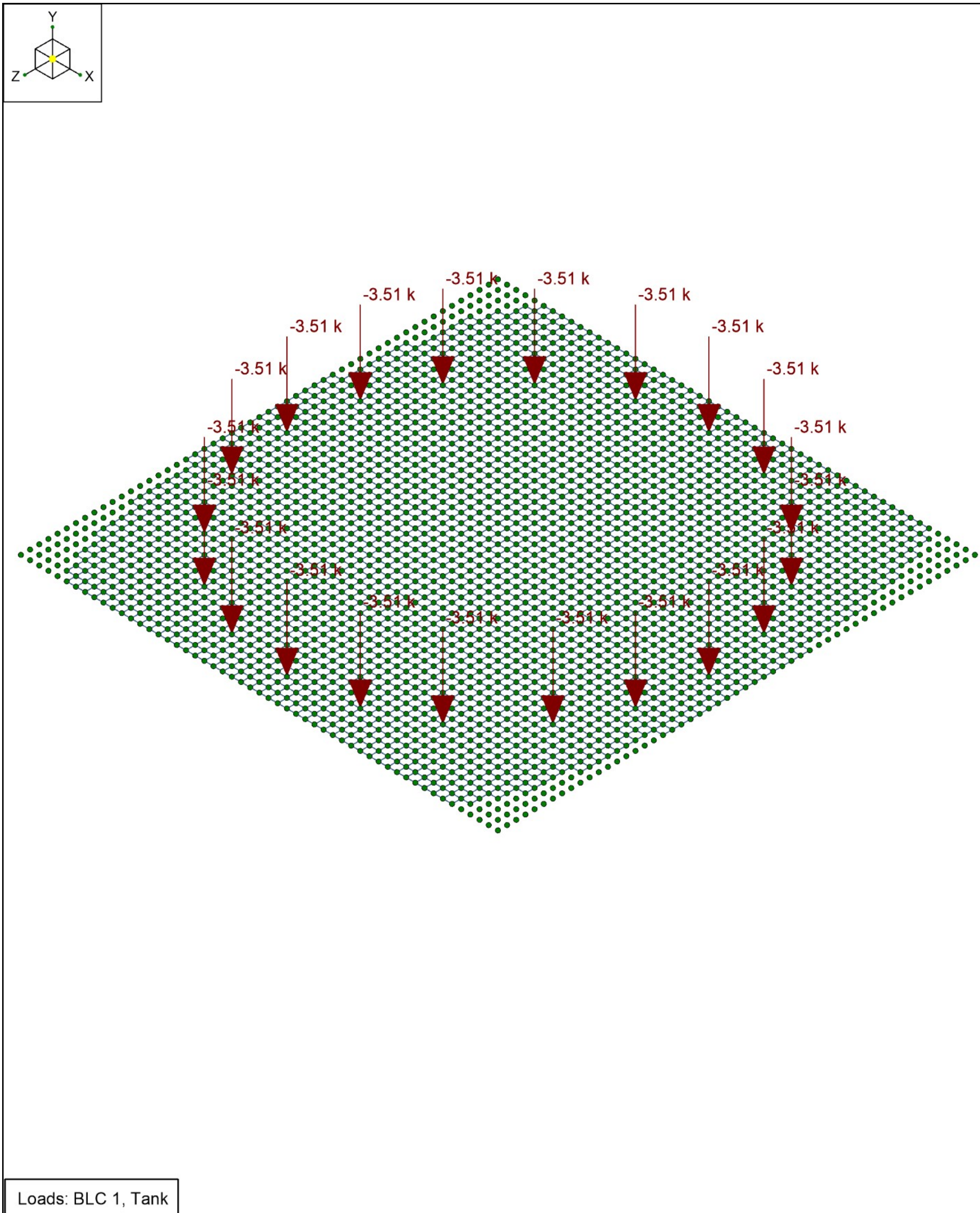
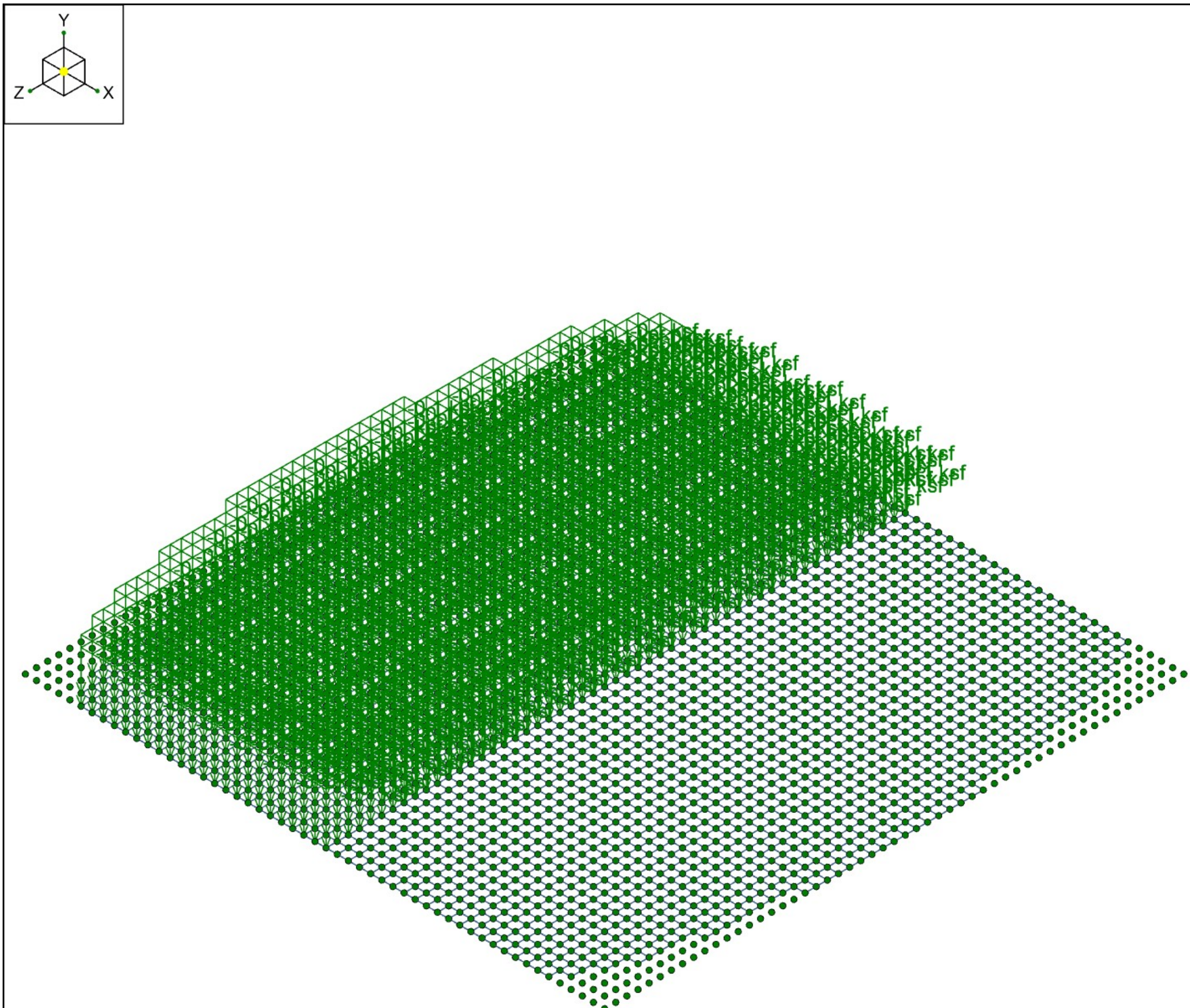
Check of applied forces

Nodes		X = C	Ev (ASD) = Spts*Mot*(C/I)	M (ASD)	
0	P1	23.00	139.8 kips	3216 Kip-ft	
1	P2	21.87	133.0 kips	2909 Kip-ft	
2	P3	18.61	113.1 kips	2105 Kip-ft	
3	P4	13.52	82.2 kips	1111 Kip-ft	
4	P5	7.11	43.2 kips	307 Kip-ft	
5	P6	0.00	0.0 kips	0 Kip-ft	
6	P7	-7.11	-43.2 kips	307 Kip-ft	
7	P8	-13.52	-82.2 kips	1111 Kip-ft	
8	P9	-18.61	-113.1 kips	2105 Kip-ft	
9	P10	-21.87	-133.0 kips	2909 Kip-ft	
10	P11	-23.00	-139.8 kips	3216 Kip-ft	
11	P12	-21.87	-133.0 kips	2909 Kip-ft	
12	P13	-18.61	-113.1 kips	2105 Kip-ft	
13	P14	-13.52	-82.2 kips	1111 Kip-ft	
14	P15	-7.11	-43.2 kips	307 Kip-ft	
15	P16	0.00	0.0 kips	0 Kip-ft	
16	P17	7.11	43.2 kips	307 Kip-ft	
17	P18	13.52	82.2 kips	1111 Kip-ft	
18	P19	18.61	113.1 kips	2105 Kip-ft	
19	P20	21.87	133.0 kips	2909 Kip-ft	
				32163 Kip-ft	OK

X_

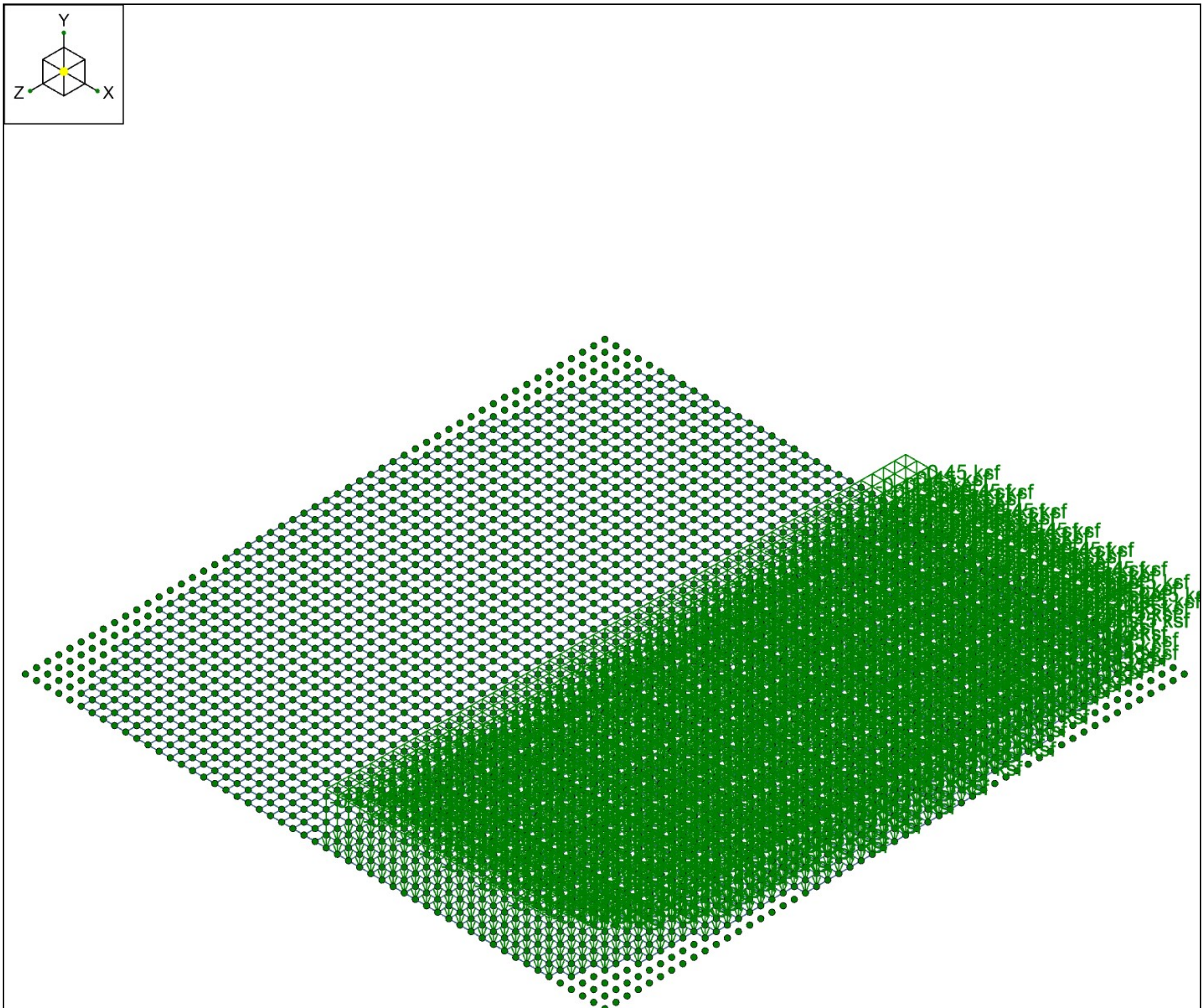


MME	MME	Bethany Tank 46 Foot Diameter	SK-10
	Bob Riley		Nov 03, 2025 at 02:5…
	22102		46 foot diameter tank.…



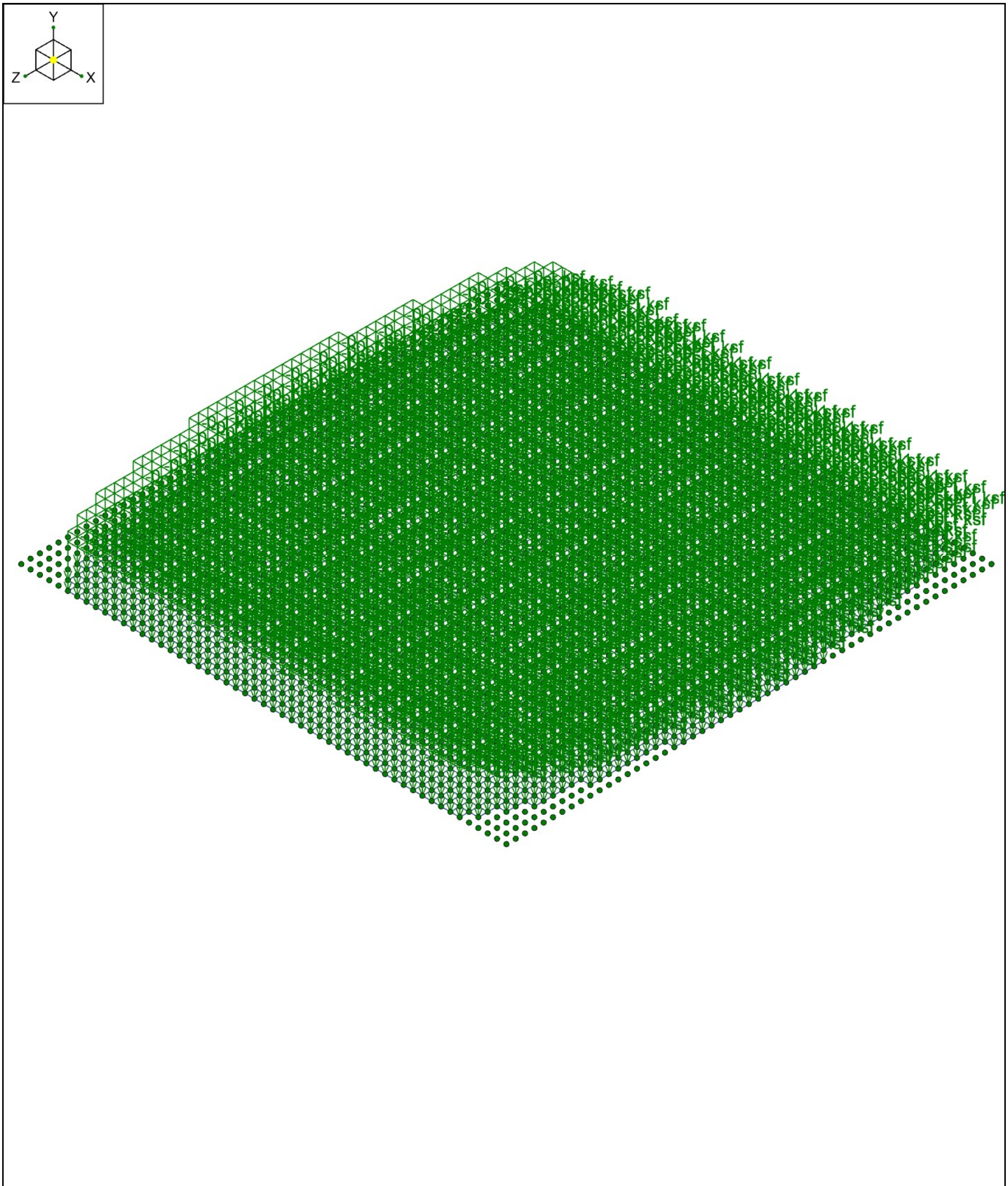
Loads: BLC 2, Foundation Net Down

MME	Bob Riley	Bethany Tank 46 Foot Diameter	SK-11
			Nov 03, 2025 at 02:5…
	22102		46 foot diameter tank.…



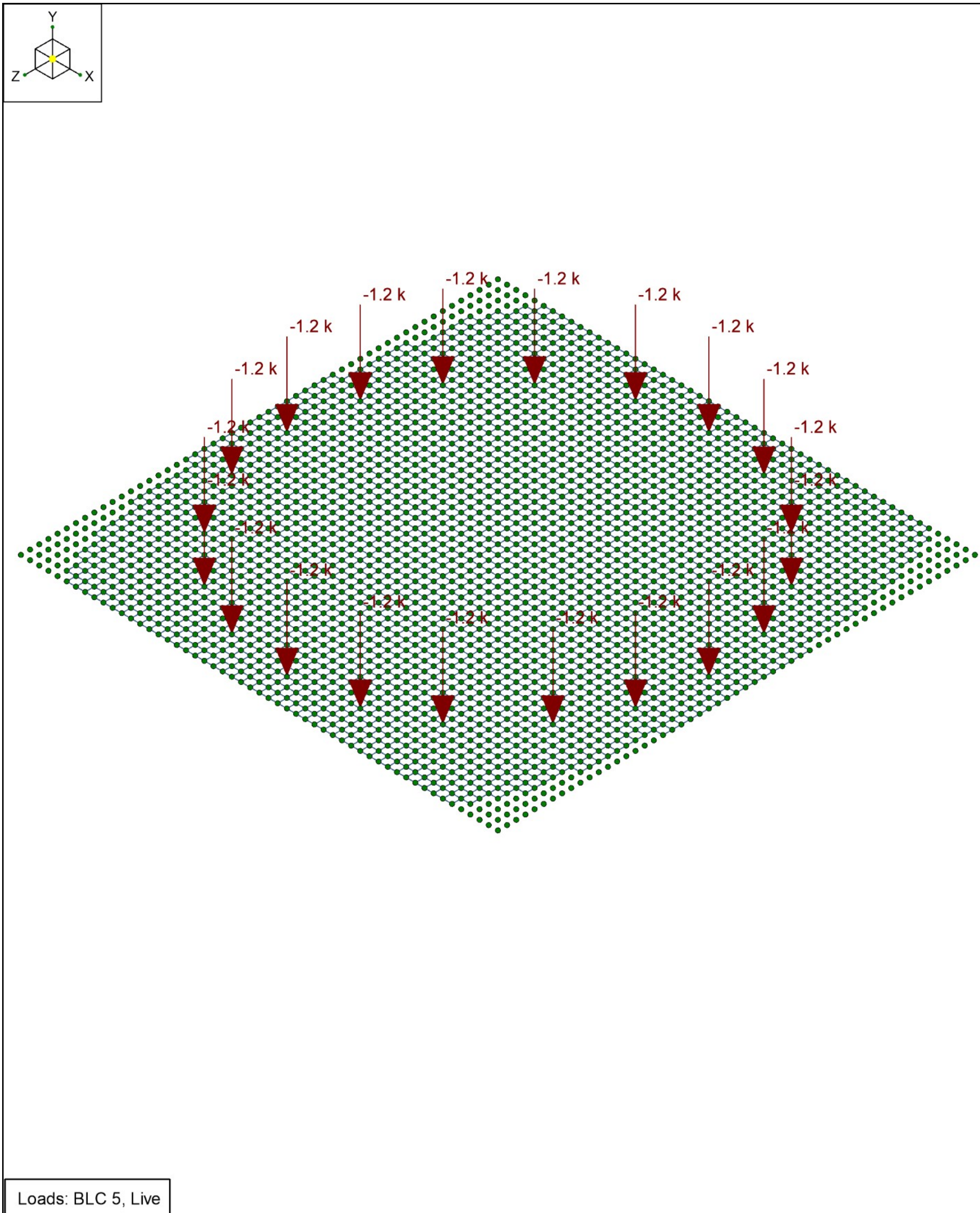
Loads: BLC 3, Foundation Full uplift

MME	MME	Bethany Tank 46 Foot Diameter	SK-12
	Bob Riley		Nov 03, 2025 at 02:5…
	22102		46 foot diameter tank.…

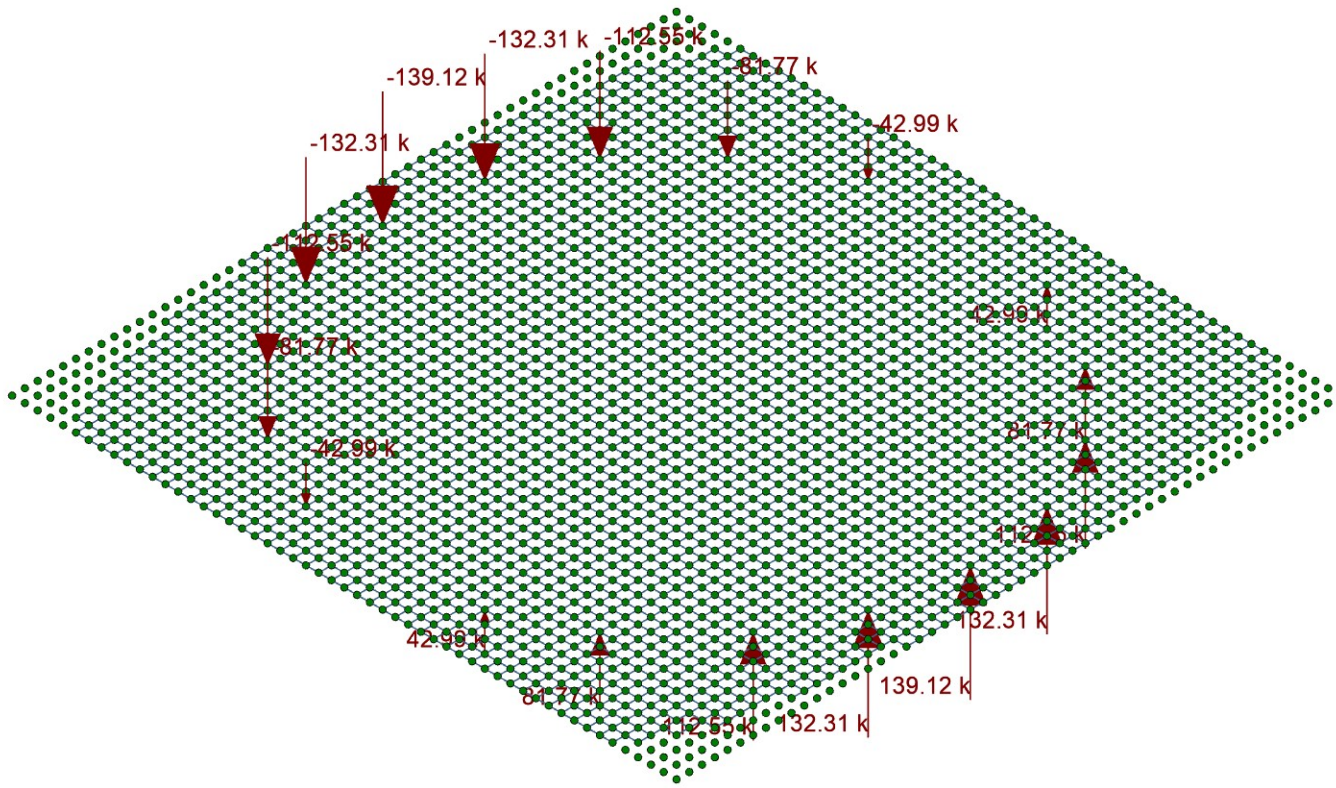


Loads: BLC 4, Foundation Net All

MME	MME	Bethany Tank 46 Foot Diameter	SK-13
	Bob Riley		Nov 03, 2025 at 02:5…
	22102		46 foot diameter tank.…

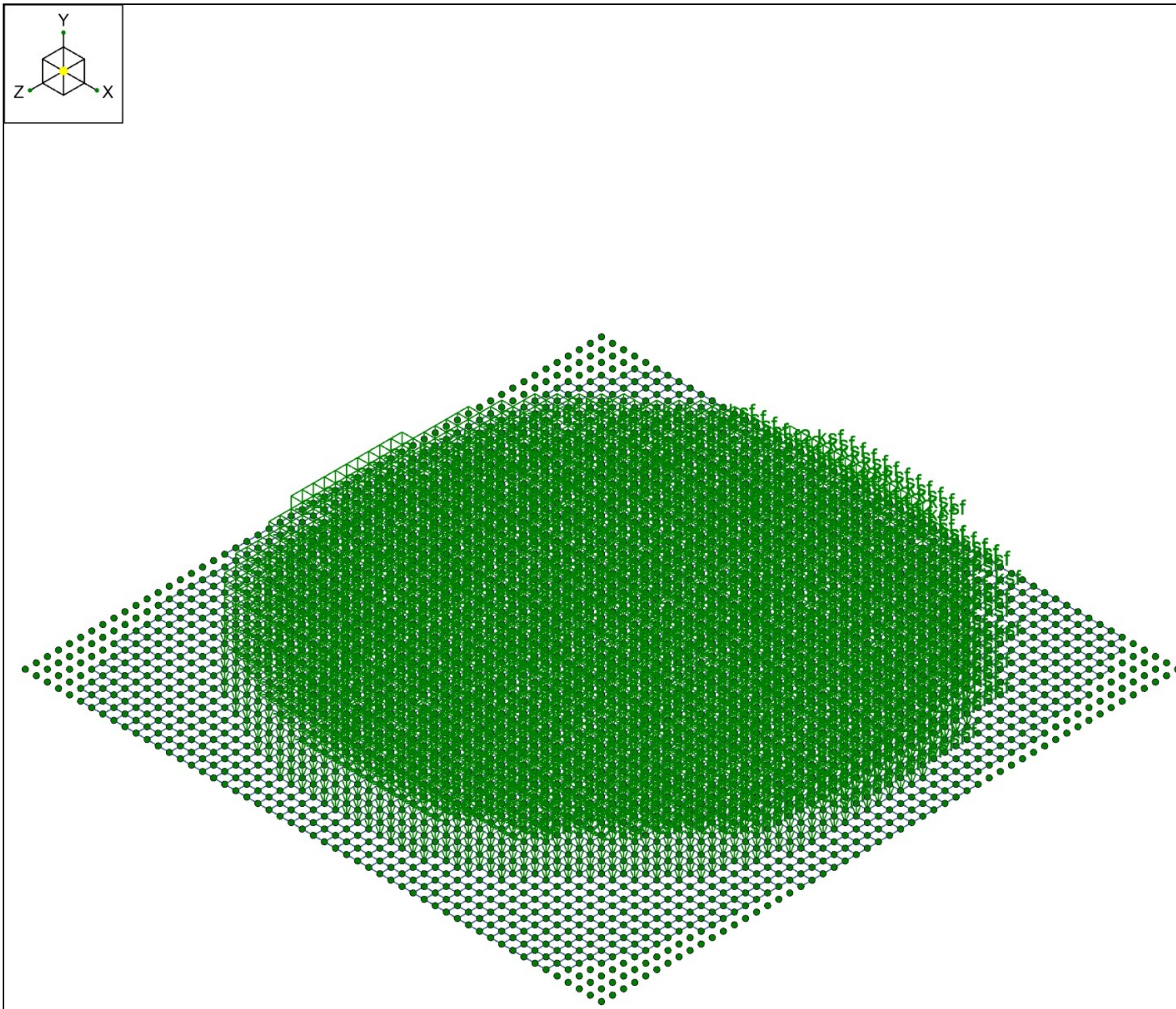


MME	MME	Bethany Tank 46 Foot Diameter	SK-14
	Bob Riley		Nov 03, 2025 at 02:5…
	22102		46 foot diameter tank.…



Loads: BLC 6, EQ

MME	MME	Bethany Tank 46 Foot Diameter	SK-15
	Bob Riley		Nov 03, 2025 at 02:5…
	22102		46 foot diameter tank.…



Loads: BLC 7, Product

MME	MME	Bethany Tank 46 Foot Diameter	SK-16
	Bob Riley		Nov 03, 2025 at 02:5…
	22102		46 foot diameter tank.…

Basic Load Cases

	BLC Description	Category	Nodal	Surface(Plate/Wall)
1	Tank	DL	20	
2	Foundation Net Down	OL1		1327
3	Foundation Full uplift	OL2		1224
4	Foundation Net All	OL3		2551
5	Live	LL	20	
6	EQ	EL	20	
7	Product	DL		1716

Load Combinations

	Description	Solve	P-Delta	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor
1	Bearing DL		Y	DL	1	4	1								
2	Bearing DL + LL		Y	DL	1	LL	1	4	1						
3	Bearing DL + EQ		Y	DL	1	2	1	EL	1	3	1				
4	Bearing DL + .75(LL + EQ)		Y	DL	1	2	1	EL	0.75	LL	0.75	LLS	0.75	3	1
5	Bearing DL - EQ	Yes	Y	DL	0.6	2	1	EL	1	3	1				

Node Loads and Enforced Displacements (BLC 1 : Tank)

	Node Label	L, D, M	Direction	Magnitude [(k, k-ft), (in, rad), (k*s²/ft, k*s²*ft)]
1	N862	L	Y	-3.51
2	N756	L	Y	-3.51
3	N744	L	Y	-3.51
4	N1105	L	Y	-3.51
5	N1045	L	Y	-3.51
6	N640	L	Y	-3.51
7	N583	L	Y	-3.51
8	N429	L	Y	-3.51
9	N468	L	Y	-3.51
10	N226	L	Y	-3.51
11	N361	L	Y	-3.51
12	N2509	L	Y	-3.51
13	N2355	L	Y	-3.51
14	N2394	L	Y	-3.51
15	N2157	L	Y	-3.51
16	N1932	L	Y	-3.51
17	N1876	L	Y	-3.51
18	N1607	L	Y	-3.51
19	N1392	L	Y	-3.51
20	N1352	L	Y	-3.51

Company : MME
Designer : Bob Riley
Job Number : 22102
Model Name : Bethany Tank 46 Foot Dia…

11/3/2025
2:58:41 PM
Checked By : ___________

Node Loads and Enforced Displacements (BLC 5 : Live)

	Node Label	L, D, M	Direction	Magnitude [(k, k-ft), (in, rad), (k*s²/ft, k*s²*ft)]
1	N862	L	Y	-1.2
2	N756	L	Y	-1.2
3	N744	L	Y	-1.2
4	N1105	L	Y	-1.2
5	N1045	L	Y	-1.2
6	N640	L	Y	-1.2
7	N583	L	Y	-1.2
8	N429	L	Y	-1.2
9	N468	L	Y	-1.2
10	N226	L	Y	-1.2
11	N361	L	Y	-1.2
12	N2509	L	Y	-1.2
13	N2355	L	Y	-1.2
14	N2394	L	Y	-1.2
15	N2157	L	Y	-1.2
16	N1932	L	Y	-1.2
17	N1876	L	Y	-1.2
18	N1607	L	Y	-1.2
19	N1392	L	Y	-1.2
20	N1352	L	Y	-1.2

Node Loads and Enforced Displacements (BLC 6 : EQ)

	Node Label	L, D, M	Direction	Magnitude [(k, k-ft), (in, rad), (k*s²/ft, k*s²*ft)]
1	N862	L	Y	139.12
2	N756	L	Y	132.31
3	N744	L	Y	112.55
4	N1105	L	Y	81.77
5	N1045	L	Y	42.99
6	N640	L	Y	0
7	N583	L	Y	-42.99
8	N429	L	Y	-81.77
9	N468	L	Y	-112.55
10	N226	L	Y	-132.31
11	N361	L	Y	-139.12
12	N2509	L	Y	-132.31
13	N2355	L	Y	-112.55
14	N2394	L	Y	-81.77
15	N2157	L	Y	-42.99
16	N1932	L	Y	0
17	N1876	L	Y	42.99
18	N1607	L	Y	81.77

Node Loads and Enforced Displacements (BLC 6 : EQ) (Continued)

	Node Label	L, D, M	Direction	Magnitude [(k, k-ft), (in, rad), (k*s²/ft, k*s²*ft)]
19	N1392	L	Y	112.55
20	N1352	L	Y	132.31

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JOB 22102 BETHANY
SHEET NO. ______ OF ______
CALCULATED BY BR DATE 11/3/25
CHECKED BY ______ DATE ______
SCALE ______

SPRING CONSTANT

$K_1 = 800\ \#/in^3$ GEOTECH REPORT

$K_0 = K_1 \left[\frac{B+1}{2B}\right]^2 = 800\ \#/in^3 \left[\frac{52+1}{2(52)}\right]^2 = 208\ \#/in^3$

$B = 52$

FOR RISA SUBGRADE MODULUS

$K_0 = 208\ \#/in^3 \left(\frac{12''}{1}\right)^3 \frac{1}{1000} = 359\ k/ft^3$

FOR SOIL PRESSURE CHECKS USE NET LOAD ON COMPRESSION SIDE

FOR 3' THICK

PORTION BELOW GRADE $2.5'\left(\frac{150-110}{150}\right) = 0.67'$

PORTION ABOVE GRADE 0.5 $= 0.5'$

$\overline{1.2'}$

$\therefore$ USE MULTIPLIER $\frac{1.2}{3.0} = 0.4$

OR $W_{DL_N} = 2.5'(1')(0.04) = 0.1\ k/ft^2$

FOR UPLIFT SIDE USE FULL DEADLOAD

$W_{DL_G} = 3'(1'^2)(0.15) = 0.45\ k/ft^2$

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JOB 22102 BETHANY
SHEET NO. OF
CALCULATED BY BR DATE 11/3/25
CHECKED BY DATE
SCALE

46 foot Ø BEARING RESULTS

DL + LL max f_{brg} = 2.35 k/ft² Δ = −0.08"

DL + EQ + LL f_{brg} = 3.15 k/ft² Δ = −0.11"
DL + (0.75(EQ+LL))

0.6 DL − EQ f_{brg} = 2.7 k/ft² Δ = −0.06"

30 FOOT Ø BEARING RESULTS

DL + LL f_{brg} = 1.8 k/ft² Δ = −0.06"

DL + EQ
DL + 0.75(EQ+LL) f_{brg} = 3.26 k/ft² Δ = −0.113"

0.6 DL + EQ f_{brg} = 3.0 k/ft² Δ = −0.11