Design QA/QC Check Form

Name of Design Package:	Settlement due to groundwater drawdown at Tawariki St Shaft	Originating Firm:	McMillen Jacobs Associates
Date:	1/11/2018	Originator:	Sam Burgess & Victor Lee
Documents in Design Package (attach list if necessary):	• Excel Sheet ConsolidationSettlement.xlsx Inputs are in this folder in needed: *\Box\5222.0 Central Interceptor Detailed Design\07 Working Files\20 Grey Lynn Tunnel\11 Settlement\01 Drawdown analysis\QAQC\Input Doc's for reference*		

	Print Name	**Sign Name**	**Date**
Checker performs CHECK	Michael Coryell		05/11/2018
Originator BACKCHECK & UPDATE	Sam Burgess		06/11/2018
Checker RECHECK	Michael Coryell		06/11/2018
Design Project Manager CHECK	Victor Romero		07/11/2018

Calculation Cover Sheet

<table>
<tr><td colspan="2">Project:
Central Interceptor Extension</td><td>Job No:
5222.0</td><td>Task No:</td><td>Page 1 of: 3
Total Pages
Incl. Attachments</td></tr>
<tr><td colspan="3">Client:
Watercare</td><td colspan="2">Calculation No:
N/A</td></tr>
<tr><td colspan="5">Subject/Title: Settlement due to groundwater drawdown at Tawariki St Shaft</td></tr>
<tr><td>Rev. No.</td><td colspan="2">Design Phase (%)</td><td colspan="2">Comments</td></tr>
<tr><td>0</td><td colspan="2">N/A – consent report input</td><td colspan="2"></td></tr>
<tr><td>1</td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

Objective(s):

To analyse and quantify the settlement due to consolidation at the Tawariki St Shaft, located at the end of the Grey Lynn tunnel on the Central Interceptor Extension. This will be added to other settlement contour plots in CAD and used to assess settlement impact on infrastructure and buildings.

Methodology & Assumptions:

This analysis covers settlement due to ground water drawdown (consolidation), other settlement sources have been accounted for or ignored as follows:

1. Mechanical Excavation Settlement: Occurs but is not covered in this calculation package. It has been modelled by Yiming and will be added together in CAD with other settlement sources to produce final contours.
2. Initial Settlement from loading – not applicable, no permanent loading
3. GW induced Settlement (Consolidation): Occurs and is covered in this Calculation pack.
4. GW induced Settlement (secondary): Secondary settlement has been ignored in this calculation because:
   a. the soil does not have a significant portion of secondary settlement prone soils
   b. the excavation produces drawdown over a construction period of 2 years (maximum) and is then expected to recover. The soil does not have a significant period of time to develop secondary settlement (time dependent)

The consolidation has generally been calculated using Craig's Soil Mechanics 7th edition for settlement calculation: $d = (m_v \times \Delta\sigma' \times H)$. This is a linear calculation, there are more sophisticated equations to choose from, but this one was chosen for its simplicity, available input data, and because it is generally conservative. The drawdown is given from the WWA's drawdown inputs, and the height of compressible layers dictate in the spreadsheet.

References & Inputs:

Inputs:

- The Central Interceptor Geotechnical Interpretive Report (GIR) [PWCIN-DEL-REP-GT-J-100048] for geotechnical inputs.
- The OPUS 1-D compressibility test results for volume compressibility values (mv)
- Drawdown data comes from MJA’s sub-contractor WWA. This drawdown data is for layer 1 which is the perched aquifer at soil depth of the profile.
- Craig's Soil Mechanics 7th edition for settlement calculation: d = (mv x $\Delta\sigma'$ x H). Excerpt is pasted in the spreadsheet.
- Borehole logs for **BH04**, BH05, and BH03 & general geology knowledge of the area from undertaking site investigations.
- Contour data from Auckland council GIS to predict settlement behavior.

Conclusion(s):

Scenario 6 produces slightly higher values than scenario 4. Scenario 6 (most conservative) using the CIE 1-D consolidation (green data- most applicable) has been selected (highlighted in yellow below) for use. The maximum settlement generated from this is 13.5mm.

Drawdown is less than 50mm (settlement of less than 2mm) At a distance of 350m from the shaft in all directions and will be the extent of the contour plots. The settlement profile along each cardinal direction will be used to generate a contour plot in CAD with interpolation between angles. The contours show in the plot will be at multiples of 5mm.

Settlement due to Groundwater Drawdown (Consolidation)

Designed by: Sam Burgess   Checked: M. Coryell   Date: 07/11/2018

Interpreting 1-D consolidation results

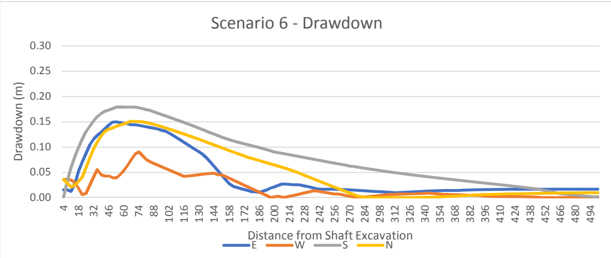
BH	Depth of test, z (m)	Unit	Soil unit weight, γ (from mainline GIR) (kN/m³)	Assumed soil unit weight (from mainline GIR), γ (kN/m3)	Unit weight water, γ_w (from mainline GIR) (kN/m³)	In-Situ total stress, σ (kPa)	Pore water Pressure, U (kPa)	In-Situ effective stress, σ' (kPa)	Max Post-drawdown pore water Pressure, U_p (kPa)	Maximum post-drawdown In-Situ effective stress, σ'_p (kPa)	Change in stress, Δσ (kPa)	Selected pressure range from 1D test data [a]	Volume Compressibility, m_v for pressure range (1/Mpa)
BH03	2.45	Tauranga	13-20 (16)	20	10	49	24.5	24.5	22.7083588	26.2916412	1.7916412	12.5 -25 & 25-50	**0.55**
BH05	4.55	Res. ECBF	18,19	19	10	86.45	45.5	40.95	43.7083588	42.7416412	1.7916412	25 -50 & 50-100	**0.41**
BH05	4.775	Res. ECBF	18,19	19	10	90.725	47.75	42.975	45.9583588	44.7666412	1.7916412	25 -50 & 50-100	**0.094**
BH05	3.05	MG - mostly disturbed TGA	13-20 (16)	20	10	61	30.5	30.5	28.7083588	32.2916412	1.7916412	25 -50 & 50-100	**0.67**
BH05	3.475	MG - mostly disturbed TGA	13-20 (16)	20	10	69.5	34.75	34.75	32.9583588	36.5416412	1.7916412	25 -50 & 50-100	**0.24**

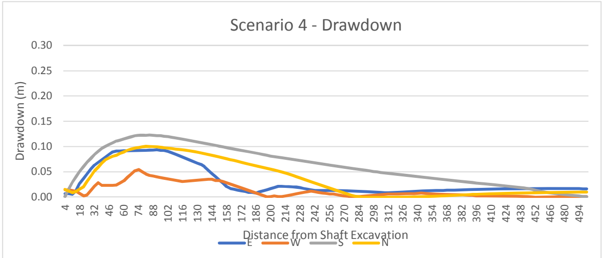
Green is data from previous testing on CI mainline. This is to examine how much different the 1-D consolidation data set is.
Orange is 1D consolidation data from CIE

Volume compressibility values for calculations.

	[1]Coefficient of volume compressibility, $m_{v(avg)}$ (m²/MN)	[2]Thickness of soil layer, H (m)	Void ratio at the end of primary consolidation (kN/m³)
CIE-BH 04 Geology Profile** (MG/TA: values assume TA)	0.6700	4	1.137
CIE-BH 04 Geology Profile** (CIE data Residual ECBF)	0.4100	3.3	0.82
CIE-BH 04 Geology Profile*** CI mainline mv values from GIR (MG/TA: values assume TA)	0.6000	3.5	1.137
CIE-BH 04 Geology Profile*** CI mainline mv values from GIR (Residual ECBF)	0.1400	1.9	0.82

Unit weight of water, γ_w (kN/m³)	10	Thickness of MG/TGA**** (% of total height)	0.55
CIE-BH04 ground level, (m RL)	12.29	Thickness of Res. ECBF**** (% of total height)	0.45
Total height of compressible layers (m)	7.30		

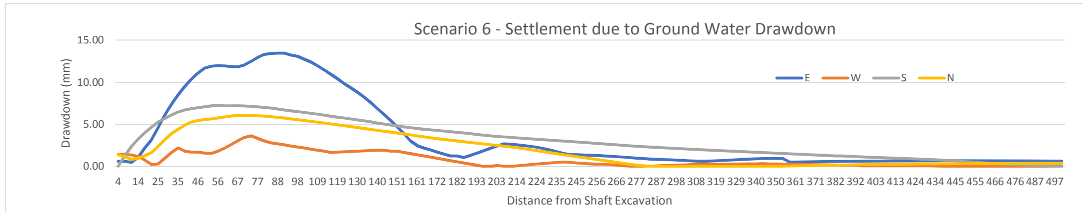




Notes:

[a] : The pressure ranges which include the initial insitu effective stress and the post drawdown insitu effective stress. If 2 are present, the larger value is chosen. This is conservative.
[1] : Coefficient of volume compressibility, $m_{v(avg)}$ is taken as the largest mv values for the layer from lab testing, or the upper bound value for CI mainline data.
[2] : Approximate thickness of soil layer, H, is determined from the respective bore logs
[3] : Surface settlement calculation is adapted from Craig's Soil Mechanics 7th edition and is taken as d = (m_v x Δσ' x H)
* : Δσ' is taken as the difference in pore water pressure before and after dewatering
** : CIE-BH04 borehole does not have m_v test data. Mv data from CIE-BH03 & CIE-BH05 have been used instead, and applied to the corresponding units in BH04.
***: CI mainline compressibility m_v data
****: The geology of each N, E, W, S profile is not known and must be assumed. The mv values to calculate settlement are high compared with typical CI mainline values, so there is inherit conservatism to offset this unknown.
*****: The first line of settlement data at 0.0m was removed because it was mathematically anomalous
WEST Direction: The thickness of compressive layers has been taken as equal to geology at BH04 (7.3m) if the RL decreases from BH04 (i.e., down the valley in the west direction).
EAST Direction: The field shown in plan is know to have been formed with fill on top of original ground. If the RL increases, then the thickness of compressible layers is taken as the increase in the RL, plus 7.30m. This effectively assumes any increase in RL is in compressible material, which is conservative.
SOUTH Direction: The south direction increases in elevation as a natural hill. The thickness of residual rock here will increase and MG/Tauranga will decrease to 0, but the Res ECBF will be much stiffer and have much lower mv values. The thickness of the compressible layers is assumed equal to the thickness of the compressible layers at BH04. This is to simplify the calculation, but will be conservative because the increase in thickness of the residual ECBF will be more than offset my the decrease in compressibility of the residual ECBF.
NORTH Direction: The north direction increases in elevation as a natural hill. The thickness of residual rock here will increase and MG/Tauranga will decrease to 0, but the Res ECBF will be much stiffer and have much lower mv values. The thickness of the compressible layers is assumed equal to the thickness of the compressible layers at BH04. This is to simplify the calculation, but will be conservative because the increase in thickness of the residual ECBF will be more than offset my the decrease in compressibility of the residual ECBF.

Conclusion:
Scenario 6 (most conservative) using the CIE 1-D consolidation (green data- most applicable) has been selected (highlighted in yellow below) for use. The maximum settlement generated from this is 13.5mm. At a distance of 350m from the shaft in all directions, drawdown is less than 50mm (settlement of less than 2mm), and has been ignored for construction of the contour plots. The settlement profile along each cardinal direction will be used to generate a contour plot in CAD with interpolation between angles.



Consolidation settlement: one-dimensional method 235

7.3 CONSOLIDATION SETTLEMENT: ONE-DIMENSIONAL METHOD

In order to estimate consolidation settlement, the value of either the coefficient of volume compressibility or the compression index is required. Consider a layer of saturated clay of thickness H. Due to construction the total vertical stress in an elemental layer of thickness dz at depth z is increased by $\Delta\sigma$ (Figure 7.7). It is assumed that the condition of zero lateral strain applies within the clay layer. After the completion of consolidation, an equal increase $\Delta\sigma'$ in effective vertical stress will have taken place corresponding to a stress increase from σ'_0 to σ'_1 and a reduction in void ratio from e_0 to e_1 on the e–σ' curve. The reduction in volume per unit volume of clay can be written in terms of void ratio:

$$\frac{\Delta V}{V_0} = \frac{e_0 - e_1}{1 + e_0}$$

Since the lateral strain is zero, the reduction in volume per unit volume is equal to the reduction in thickness per unit thickness, i.e. the settlement per unit depth. Therefore, by proportion, the settlement of the layer of thickness dz will be given by

$$\begin{aligned} ds_c &= \frac{e_0 - e_1}{1 + e_0}dz \\ &= \left(\frac{e_0 - e_1}{\sigma'_1 - \sigma'_0}\right)\left(\frac{\sigma'_1 - \sigma'_0}{1 + e_0}\right)dz \\ &= m_v \Delta\sigma' dz \end{aligned}$$

where s_c = consolidation settlement.
The settlement of the layer of thickness H is given by

$$s_c = \int_0^H m_v \Delta\sigma' dz$$

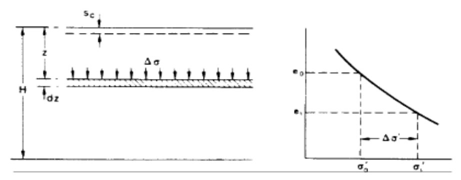


Figure 7.7 Consolidation settlement.

236 Consolidation theory

If m_v and $\Delta\sigma'$ are assumed constant with depth, then

$$s_c = m_v \Delta\sigma' H \quad (7.6)$$

or

$$s_c = \frac{e_0 - e_1}{1 + e_0} H \quad (7.7)$$

or, in the case of a normally consolidated clay,

$$s_c = \frac{C_c \log(\sigma'_1/\sigma'_0)}{1 + e_0} H \quad (7.8)$$

In order to take into account the variation of m_v and/or $\Delta\sigma'$ with depth, the graphical procedure shown in Figure 7.8 can be used to determine s_c.
The variations of initial effective vertical stress (σ'_0) and effective vertical stress increment ($\Delta\sigma'$) over the depth of the layer are represented in Figure 7.8(a); the variation of m_v is represented in Figure 7.8(b). The curve in Figure 7.8(c) represents the variation with depth of the dimensionless product $m_v\Delta\sigma'$ and the area under this curve is the settlement of the layer. Alternatively the layer can be divided into a suitable number of sublayers and the product $m_v\Delta\sigma'$ evaluated at the centre of each sublayer: each product $m_v\Delta\sigma'$ is then multiplied by the appropriate sublayer thickness to give the sublayer settlement. The settlement of the whole layer is equal to the sum of the sublayer settlements.

Layer Thickness					Scenario 6															
Distance from shaft (m)	Thickness of compressible layers (m)				Distance from shaft (m)	Measured Groundwater Drawdown***** (m)				[3]Calc. Surface Settlement from CIE-BH04, $\delta_{BH4\text{-}CIE}$ (mm)				[3]Calc. Surface Settlement from CIE-BH04, $\delta_{BH4\text{-}CI}$ (mm)				Max Calc. Surface Settlement, δ_{max} (mm)			
	E	W	S	N		E	W	S	N	E	W	S	N	E	W	S	N	E	W	S	N
3.50	7.30	7.30	7.30	7.30	3.50	0.02	0.04	0.00	0.04	0.62	1.44	0.07	1.43	0.44	1.02	0.05	1.02	0.62	1.44	0.07	1.43
7.00	7.30	7.30	7.30	7.30	7.00	0.02	0.04	0.03	0.03	0.62	1.47	1.31	1.15	0.44	1.04	0.93	0.82	0.62	1.47	1.31	1.15
10.51	7.30	7.30	7.30	7.30	10.51	0.01	0.03	0.06	0.02	0.49	1.40	2.42	0.85	0.35	0.99	1.71	0.60	0.49	1.40	2.42	0.85
14.01	7.38	7.30	7.30	7.30	14.01	0.03	0.03	0.08	0.02	1.12	1.18	3.28	0.99	0.79	0.84	2.33	0.70	1.12	1.18	3.28	0.99
17.51	7.58	7.30	7.30	7.30	17.51	0.05	0.02	0.10	0.03	2.25	0.72	4.04	1.31	1.60	0.51	2.87	0.93	2.25	0.72	4.04	1.31
21.01	8.12	7.30	7.30	7.30	21.01	0.07	0.01	0.12	0.04	3.18	0.24	4.66	1.63	2.26	0.17	3.31	1.16	3.18	0.24	4.66	1.63
24.51	9.48	7.30	7.30	7.30	24.51	0.09	0.01	0.13	0.06	4.61	0.34	5.27	2.42	3.27	0.24	3.74	1.72	4.61	0.34	5.27	2.42
28.01	10.59	7.30	7.30	7.30	28.01	0.10	0.02	0.14	0.08	6.12	1.01	5.70	3.20	4.34	0.72	4.04	2.27	6.12	1.01	5.70	3.20
31.52	11.58	7.30	7.30	7.30	31.52	0.12	0.04	0.15	0.10	7.42	1.68	6.13	3.92	5.26	1.19	4.35	2.78	7.42	1.68	6.13	3.92
35.02	12.46	7.30	7.30	7.30	35.02	0.12	0.06	0.16	0.11	8.46	2.22	6.46	4.42	6.01	1.58	4.58	3.13	8.46	2.22	6.46	4.42
38.52	13.24	7.30	7.30	7.30	38.52	0.13	0.05	0.17	0.12	9.50	1.83	6.72	4.91	6.74	1.30	4.77	3.48	9.50	1.83	6.72	4.91
42.02	13.73	7.30	7.30	7.30	42.02	0.14	0.04	0.17	0.13	10.37	1.71	6.88	5.28	7.36	1.22	4.89	3.74	10.37	1.71	6.88	5.28
45.52	13.99	7.30	7.30	7.30	45.52	0.14	0.04	0.17	0.14	11.10	1.71	6.99	5.46	7.88	1.22	4.96	3.87	11.10	1.71	6.99	5.46
49.03	14.16	7.30	7.30	7.30	49.03	0.15	0.04	0.18	0.14	11.67	1.60	7.10	5.57	8.28	1.13	5.04	3.95	11.67	1.60	7.10	5.57
52.53	14.38	7.30	7.30	7.30	52.53	0.15	0.04	0.18	0.14	11.91	1.56	7.21	5.68	8.45	1.11	5.11	4.03	11.91	1.56	7.21	5.68
56.03	14.58	7.30	7.30	7.30	56.03	0.15	0.05	0.18	0.14	11.97	1.84	7.23	5.78	8.50	1.30	5.13	4.10	11.97	1.84	7.23	5.78
59.53	14.71	7.30	7.30	7.30	59.53	0.15	0.05	0.18	0.15	11.96	2.17	7.22	5.89	8.49	1.54	5.13	4.18	11.96	2.17	7.22	5.89
63.03	14.73	7.30	7.30	7.30	63.03	0.15	0.06	0.18	0.15	11.86	2.60	7.22	6.00	8.42	1.84	5.12	4.26	11.86	2.60	7.22	6.00
66.53	14.85	7.30	7.30	7.30	66.53	0.14	0.08	0.18	0.15	11.84	3.03	7.22	6.09	8.40	2.15	5.12	4.32	11.84	3.03	7.22	6.09
70.04	15.13	7.30	7.30	7.30	70.04	0.14	0.09	0.18	0.15	12.06	3.46	7.21	6.07	8.56	2.46	5.12	4.31	12.06	3.46	7.21	6.07
73.54	15.81	7.30	7.30	7.30	73.54	0.14	0.09	0.18	0.15	12.49	3.64	7.15	6.06	8.86	2.58	5.08	4.30	12.49	3.64	7.15	6.06
77.04	16.53	7.30	7.30	7.30	77.04	0.14	0.08	0.18	0.15	12.92	3.34	7.09	6.04	9.17	2.37	5.03	4.29	12.92	3.34	7.09	6.04
80.54	17.21	7.30	7.30	7.30	80.54	0.14	0.08	0.17	0.15	13.32	3.04	7.02	6.00	9.45	2.16	4.98	4.26	13.32	3.04	7.02	6.00
84.04	17.52	7.30	7.30	7.30	84.04	0.14	0.07	0.17	0.15	13.42	2.84	6.95	5.92	9.52	2.01	4.93	4.20	13.42	2.84	6.95	5.92
87.55	17.75	7.30	7.30	7.30	87.55	0.14	0.07	0.17	0.15	13.46	2.71	6.84	5.85	9.55	1.92	4.85	4.15	13.46	2.71	6.84	5.85
91.05	17.93	7.30	7.30	7.30	91.05	0.14	0.06	0.17	0.14	13.45	2.59	6.73	5.76	9.55	1.83	4.78	4.09	13.45	2.59	6.73	5.76
94.55	18.04	7.30	7.30	7.30	94.55	0.13	0.06	0.16	0.14	13.26	2.46	6.62	5.67	9.41	1.75	4.70	4.02	13.26	2.46	6.62	5.67
98.05	18.05	7.30	7.30	7.30	98.05	0.13	0.06	0.16	0.14	13.10	2.33	6.52	5.57	9.30	1.66	4.63	3.95	13.10	2.33	6.52	5.57
101.55	18.10	7.30	7.30	7.30	101.55	0.13	0.05	0.16	0.14	12.76	2.21	6.42	5.47	9.06	1.57	4.56	3.88	12.76	2.21	6.42	5.47
105.05	18.22	7.30	7.30	7.30	105.05	0.12	0.05	0.16	0.13	12.41	2.08	6.33	5.37	8.81	1.48	4.49	3.81	12.41	2.08	6.33	5.37
108.56	18.24	7.30	7.30	7.30	108.56	0.12	0.05	0.15	0.13	11.95	1.96	6.22	5.27	8.48	1.39	4.41	3.74	11.95	1.96	6.22	5.27
112.06	18.20	7.30	7.30	7.30	112.06	0.11	0.05	0.15	0.13	11.44	1.83	6.10	5.17	8.12	1.30	4.33	3.67	11.44	1.83	6.10	5.17
115.56	18.11	7.30	7.30	7.30	115.56	0.11	0.04	0.15	0.13	10.91	1.70	5.98	5.07	7.74	1.21	4.25	3.60	10.91	1.70	5.98	5.07
119.06	18.05	7.30	7.30	7.30	119.06	0.10	0.04	0.15	0.12	10.40	1.72	5.87	4.97	7.38	1.22	4.16	3.53	10.40	1.72	5.87	4.97
122.56	17.94	7.30	7.30	7.30	122.56	0.10	0.04	0.14	0.12	9.87	1.76	5.77	4.88	7.00	1.25	4.10	3.46	9.87	1.76	5.77	4.88
126.07	17.82	7.30	7.30	7.30	126.07	0.09	0.04	0.14	0.12	9.33	1.79	5.66	4.77	6.62	1.27	4.01	3.38	9.33	1.79	5.66	4.77
129.57	17.70	7.30	7.30	7.30	129.57	0.09	0.05	0.14	0.12	8.80	1.83	5.54	4.65	6.25	1.30	3.93	3.30	8.80	1.83	5.54	4.65
133.07	17.53	7.30	7.30	7.30	133.07	0.09	0.05	0.13	0.11	8.26	1.87	5.42	4.54	5.86	1.32	3.85	3.22	8.26	1.87	5.42	4.54
136.57	17.53	7.30	7.30	7.30	136.57	0.08	0.05	0.13	0.11	7.63	1.90	5.30	4.43	5.41	1.35	3.76	3.14	7.63	1.90	5.30	4.43
140.07	17.76	7.30	7.30	7.30	140.07	0.07	0.05	0.13	0.11	6.89	1.94	5.19	4.32	4.89	1.38	3.68	3.06	6.89	1.94	5.19	4.32
143.57	18.15	7.30	7.30	7.30	143.57	0.06	0.05	0.13	0.10	6.18	1.97	5.07	4.20	4.39	1.39	3.60	2.98	6.18	1.97	5.07	4.20
147.08	18.65	7.30	7.30	7.30	147.08	0.05	0.05	0.12	0.10	5.47	1.83	4.95	4.09	3.88	1.30	3.51	2.90	5.47	1.83	4.95	4.09
150.58	19.21	7.30	7.30	7.30	150.58	0.04	0.05	0.12	0.10	4.73	1.83	4.84	3.98	3.36	1.30	3.43	2.82	4.73	1.83	4.84	3.98
154.08	19.71	7.30	7.30	7.30	154.08	0.04	0.04	0.12	0.10	3.92	1.69	4.73	3.87	2.78	1.20	3.36	2.74	3.92	1.69	4.73	3.87
157.58	19.89	7.30	7.30	7.30	157.58	0.03	0.04	0.11	0.09	3.02	1.55	4.63	3.76	2.14	1.10	3.29	2.67	3.02	1.55	4.63	3.76
161.08	19.90	7.30	7.30	7.30	161.08	0.02	0.03	0.11	0.09	2.48	1.41	4.52	3.65	1.76	1.00	3.21	2.59	2.48	1.41	4.52	3.65
164.59	19.77	7.30	7.30	7.30	164.59	0.02	0.03	0.11	0.09	2.23	1.27	4.43	3.54	1.58	0.90	3.14	2.51	2.23	1.27	4.43	3.54
168.09	19.61	7.30	7.30	7.30	168.09	0.02	0.03	0.11	0.09	1.98	1.13	4.36	3.43	1.41	0.80	3.09	2.44	1.98	1.13	4.36	3.43
171.59	19.45	7.30	7.30	7.30	171.59	0.02	0.02	0.11	0.08	1.74	0.99	4.29	3.33	1.23	0.71	3.05	2.36	1.74	0.99	4.29	3.33
175.09	19.27	7.30	7.30	7.30	175.09	0.01	0.02	0.10	0.08	1.50	0.86	4.22	3.22	1.06	0.61	3.00	2.28	1.50	0.86	4.22	3.22
178.59	19.19	7.30	7.30	7.30	178.59	0.01	0.02	0.10	0.08	1.26	0.72	4.15	3.13	0.90	0.51	2.95	2.22	1.26	0.72	4.15	3.13
182.09	19.07	7.30	7.30	7.30	182.09	0.01	0.01	0.10	0.08	1.26	0.58	4.09	3.04	0.89	0.41	2.90	2.16	1.26	0.58	4.09	3.04
185.60	18.92	7.30	7.30	7.30	185.60	0.01	0.01	0.10	0.07	1.07	0.44	4.00	2.96	0.76	0.31	2.84	2.10	1.07	0.44	4.00	2.96
189.10	18.81	7.30	7.30	7.30	189.10	0.01	0.01	0.10	0.07	1.35	0.30	3.91	2.87	0.96	0.21	2.78	2.04	1.35	0.30	3.91	2.87
192.60	18.50	7.30	7.30	7.30	192.60	0.02	0.00	0.09	0.07	1.61	0.16	3.83	2.78	1.15	0.11	2.71	1.97	1.61	0.16	3.83	2.78
196.10	18.28	7.30	7.30	7.30	196.10	0.02	0.00	0.09	0.07	1.88	0.02	3.74	2.70	1.33	0.02	2.65	1.91	1.88	0.02	3.74	2.70
199.60	18.37	7.30	7.30	7.30	199.60	0.02	0.00	0.09	0.06	2.17	0.06	3.65	2.61	1.54	0.04	2.59	1.85	2.17	0.06	3.65	2.61
203.11	18.30	7.30	7.30	7.30	203.11	0.02	0.00	0.09	0.06	2.44	0.12	3.59	2.52	1.73	0.09	2.55	1.79	2.44	0.12	3.59	2.52
206.61	18.17	7.30	7.30	7.30	206.61	0.03	0.00	0.09	0.06	2.71	0.04	3.54	2.43	1.92	0.03	2.51	1.72	2.71	0.04	3.54	2.43
210.11	17.99	7.30	7.30	7.30	210.11	0.03	0.00	0.09	0.06	2.66	0.04	3.48	2.33	1.89	0.03	2.47	1.66	2.66	0.04	3.48	2.33
213.61	17.74	7.30	7.30	7.30	213.61	0.03	0.00	0.08	0.06	2.58	0.10	3.42	2.25	1.83	0.07	2.43	1.59	2.58	0.10	3.42	2.25
217.11	17.44	7.30	7.30	7.30	217.11	0.03	0.00	0.08	0.05	2.50	0.17	3.37	2.14	1.77	0.12	2.39	1.52	2.50	0.17	3.37	2.14
220.61	17.12	7.30	7.30	7.30	220.61	0.03	0.01	0.08	0.05	2.41	0.24	3.31	2.02	1.71	0.17	2.35	1.43	2.41	0.24	3.31	2.02
224.12	16.82	7.30	7.30	7.30	224.12	0.02	0.01	0.08	0.05	2.32	0.31	3.26	1.90	1.65	0.22	2.31	1.35	2.32	0.31	3.26	1.90
227.62	16.60	7.30	7.30	7.30	227.62	0.02	0.01	0.08	0.04	2.13	0.38	3.20	1.78	1.51	0.27	2.27	1.26	2.13	0.38	3.20	1.78
231.12	16.38	7.30	7.30	7.30	231.12	0.02	0.01	0.08	0.04	1.95	0.44	3.14	1.66	1.38	0.32	2.23	1.18	1.95	0.44	3.14	1.66
234.62	16.12	7.30	7.30	7.30	234.62	0.02	0.01	0.08	0.04	1.77	0.51	3.09	1.54	1.25	0.36	2.19	1.09	1.77	0.51	3.09	1.54
238.12	15.87	7.30	7.30	7.30	238.12	0.02	0.01	0.08	0.04	1.59	0.55	3.03	1.42	1.13	0.39	2.15	1.01	1.59	0.55	3.03	1.42
241.63	15.60	7.30	7.30	7.30	241.63	0.02	0.01	0.07	0.03	1.44	0.50	2.98	1.30	1.02	0.35	2.11	0.92	1.44	0.50	2.98	1.30
245.13	15.31	7.30	7.30	7.30	245.13	0.02	0.01	0.07	0.03	1.41	0.45	2.92	1.18	1.00	0.32	2.07	0.84	1.41	0.45	2.92	1.18
248.63	15.03	7.30	7.30	7.30	248.63	0.02	0.01	0.07	0.03	1.38	0.39	2.86	1.07	0.98	0.28	2.03	0.76	1.38	0.39	2.86	1.07
252.13	14.73	7.30	7.30	7.30	252.13	0.02	0.01	0.07	0.02	1.35	0.34	2.81	0.95	0.96	0.24	1.99	0.68	1.35	0.34	2.81	0.95
255.63	14.43	7.30	7.30	7.30	255.63	0.02	0.01	0.07	0.02	1.32	0.28	2.75	0.84	0.93	0.20	1.95	0.59	1.32	0.28	2.75	0.84
259.13	14.13	7.30	7.30	7.30	259.13	0.02	0.01	0.07	0.02	1.29	0.28	2.70	0.72	0.91	0.20	1.91	0.51	1.29	0.28	2.70	0.72
262.64	13.81	7.30	7.30	7.30	262.64	0.02	0.01	0.07	0.02	1.25	0.23	2.64	0.61	0.89	0.16	1.87	0.43	1.25	0.23	2.64	0.61
266.14	13.49	7.30	7.30	7.30	266.14	0.02	0.00	0.06	0.01	1.19	0.18	2.58	0.49	0.84	0.12	1.83	0.35	1.19	0.18	2.58	0.49
269.64	13.21	7.30	7.30	7.30	269.64	0.02	0.00	0.06	0.01	1.13	0.12	2.52	0.38	0.80	0.09	1.79	0.27	1.13	0.12	2.52	0.38
273.14	12.87	7.30	7.30	7.30	273.14	0.02	0.00	0.06	0.01	1.07	0.07	2.48	0.27	0.76	0.05	1.76	0.19	1.07	0.07	2.48	0.27
276.64	12.54	7.30	7.30	7.30	276.64	0.01	0.00	0.06	0.00	1.01	0.01	2.44	0.15	0.72	0.01	1.73	0.11	1.01	0.01	2.44	0.15
280.14	12.24	7.30	7.30	7.30	280.14	0.01	0.00	0.06	0.00	0.95	0.02	2.39	0.09	0.68	0.02	1.70	0.06	0.95	0.02	2.39	0.09
283.65	12.00	7.30	7.30	7.30	283.65	0.01	0.00	0.06	0.00	0.90	0.05	2.34	0.04	0.64	0.04	1.66	0.03	0.90	0.05	2.34	0.04
287.15	11.81	7.30	7.30	7.30	287.15	0.01	0.00	0.06	0.00	0.85	0.08	2.30	0.00	0.61	0.06	1.63	0.00	0.85	0.08	2.30	0.00
290.65	11.65	7.30	7.30	7.30	290.65	0.01	0.00	0.06	0.00	0.84	0.11	2.25	0.00	0.60	0.08	1.60	0.00	0.84	0.11	2.25	0.00
294.15	11.54	7.30	7.30	7.30	294.15	0.01	0.00	0.05	0.00	0.80	0.15	2.20	0.00	0.57	0.10	1.56	0.00	0.80	0.15	2.20	0.00
297.65	11.52	7.30	7.30	7.30	297.65	0.01	0.00	0.05	0.00	0.76	0.18	2.15	0.00	0.54	0.12	1.53	0.00	0.76	0.18	2.15	0.00
301.16	11.55	7.30	7.30	7.30	301.16	0.01	0.01	0.05	0.00	0.73	0.21	2.11	0.00	0.52	0.15	1.50	0.00	0.73	0.21	2.11	0.00
304.66	11.60	7.30	7.30	7.30	304.66	0.01	0.01	0.05	0.00	0.69	0.24	2.06	0.00	0.49	0.17	1.46	0.00	0.69	0.24	2.06	0.00
308.16	11.70	7.30	7.30	7.30	308.16	0.01	0.01	0.05	0.00	0.66	0.27	2.02	0.00	0.47	0.19	1.44	0.00	0.66	0.27	2.02	0.00
311.66	11.86	7.30	7.30	7.30	311.66	0.01	0.01	0.05	0.00	0.64	0.28	1.99	0.00	0.45	0.20	1.41	0.00	0.64	0.28	1.99	0.00
315.16	12.07	7.30	7.30	7.30	315.16	0.01	0.01	0.05	0.00	0.65	0.28	1.95	0.00	0.46	0.20	1.39	0.00	0.65	0.28	1.95	0.00

Scenario 4																
Distance from shaft (m)	Measured Groundwater Drawdown ***** (m)				[3]Calc. Surface Settlement from CIE-BH04, $\delta_{BH4\text{-}CIE}$ (mm)				[3]Calc. Surface Settlement from CIE-BH04, $\delta_{BH4\text{-}CI}$ (mm)				Max Calc. Surface Settlement, δ_{max} (mm)			
	E	W	S	N	E	W	S	N	E	W	S	N	E	W	S	N
3.5	0.01	0.01	0.00	0.02	0.28	0.59	0.03	0.61	0.20	0.42	0.02	0.43	0.28	0.59	0.03	0.61
7.0	0.01	0.01	0.02	0.01	0.27	0.57	0.63	0.47	0.19	0.41	0.44	0.33	0.27	0.57	0.63	0.47
10.5	0.01	0.01	0.03	0.01	0.22	0.53	1.18	0.34	0.16	0.38	0.83	0.24	0.22	0.53	1.18	0.34
14.0	0.01	0.01	0.04	0.01	0.54	0.44	1.63	0.44	0.38	0.31	1.16	0.31	0.54	0.44	1.63	0.44
17.5	0.03	0.01	0.05	0.02	1.13	0.27	2.05	0.63	0.80	0.19	1.46	0.45	1.13	0.27	2.05	0.63
21.0	0.04	0.00	0.06	0.02	1.64	0.09	2.42	0.82	1.17	0.06	1.72	0.58	1.64	0.09	2.42	0.82
24.5	0.05	0.00	0.07	0.03	2.42	0.17	2.79	1.25	1.72	0.12	1.98	0.89	2.42	0.17	2.79	1.25
28.0	0.06	0.01	0.08	0.04	3.27	0.52	3.09	1.68	2.32	0.37	2.19	1.19	3.27	0.52	3.09	1.68
31.5	0.06	0.02	0.08	0.05	4.05	0.86	3.39	2.08	2.87	0.61	2.41	1.48	4.05	0.86	3.39	2.08
35.0	0.07	0.03	0.09	0.06	4.72	1.14	3.64	2.39	3.35	0.81	2.59	1.70	4.72	1.14	3.64	2.39
38.5	0.07	0.02	0.10	0.07	5.40	0.94	3.87	2.70	3.84	0.67	2.74	1.91	5.40	0.94	3.87	2.70
42.0	0.08	0.02	0.10	0.07	6.00	0.93	4.04	2.95	4.26	0.66	2.87	2.09	6.00	0.93	4.04	2.95
45.5	0.08	0.02	0.10	0.08	6.53	0.93	4.18	3.11	4.63	0.66	2.97	2.20	6.53	0.93	4.18	3.11
49.0	0.09	0.02	0.11	0.08	6.96	0.92	4.32	3.23	4.94	0.66	3.07	2.29	6.96	0.92	4.32	3.23
52.5	0.09	0.02	0.11	0.08	7.22	0.95	4.46	3.35	5.13	0.68	3.16	2.38	7.22	0.95	4.46	3.35
56.0	0.09	0.03	0.11	0.09	7.35	1.11	4.55	3.48	5.21	0.79	3.23	2.47	7.35	1.11	4.55	3.48
59.5	0.09	0.03	0.12	0.09	7.43	1.30	4.64	3.60	5.28	0.93	3.29	2.55	7.43	1.30	4.64	3.60
63.0	0.09	0.04	0.12	0.09	7.46	1.57	4.73	3.72	5.30	1.11	3.35	2.64	7.46	1.57	4.73	3.72
66.5	0.09	0.05	0.12	0.10	7.54	1.83	4.81	3.84	5.35	1.30	3.41	2.72	7.54	1.83	4.81	3.84
70.0	0.09	0.05	0.12	0.10	7.68	2.09	4.90	3.89	5.45	1.48	3.48	2.76	7.68	2.09	4.90	3.89
73.5	0.09	0.05	0.12	0.10	8.05	2.19	4.92	3.95	5.71	1.56	3.49	2.80	8.05	2.19	4.92	3.95
77.0	0.09	0.05	0.12	0.10	8.44	2.01	4.93	4.01	5.99	1.43	3.50	2.84	8.44	2.01	4.93	4.01
80.5	0.09	0.05	0.12	0.10	8.81	1.83	4.94	4.04	6.25	1.30	3.51	2.87	8.81	1.83	4.94	4.04
84.0	0.09	0.04	0.12	0.10	8.99	1.72	4.95	4.03	6.38	1.22	3.51	2.86	8.99	1.72	4.95	4.03
87.6	0.09	0.04	0.12	0.10	9.13	1.67	4.93	4.02	6.48	1.18	3.50	2.85	9.13	1.67	4.93	4.02
91.1	0.09	0.04	0.12	0.10	9.25	1.61	4.91	4.00	6.56	1.15	3.48	2.84	9.25	1.61	4.91	4.00
94.6	0.09	0.04	0.12	0.10	9.20	1.56	4.89	3.97	6.53	1.11	3.47	2.82	9.20	1.56	4.89	3.97
98.1	0.09	0.04	0.12	0.10	9.21	1.51	4.86	3.94	6.54	1.07	3.45	2.79	9.21	1.51	4.86	3.94
101.6	0.09	0.04	0.12	0.10	9.06	1.45	4.82	3.90	6.43	1.03	3.42	2.77	9.06	1.45	4.82	3.90
105.1	0.09	0.03	0.12	0.10	8.83	1.40	4.78	3.87	6.27	0.99	3.40	2.75	8.83	1.40	4.78	3.87
108.6	0.08	0.03	0.12	0.10	8.55	1.35	4.73	3.84	6.07	0.96	3.36	2.72	8.55	1.35	4.73	3.84
112.1	0.08	0.03	0.12	0.09	8.23	1.29	4.68	3.80	5.84	0.92	3.32	2.70	8.23	1.29	4.68	3.80
115.6	0.08	0.03	0.11	0.09	7.90	1.24	4.62	3.77	5.61	0.88	3.28	2.68	7.90	1.24	4.62	3.77
119.1	0.08	0.03	0.11	0.09	7.58	1.26	4.57	3.74	5.38	0.89	3.24	2.65	7.58	1.26	4.57	3.74
122.6	0.07	0.03	0.11	0.09	7.25	1.28	4.52	3.70	5.14	0.91	3.21	2.63	7.25	1.28	4.52	3.70
126.1	0.07	0.03	0.11	0.09	6.91	1.31	4.46	3.65	4.90	0.93	3.17	2.59	6.91	1.31	4.46	3.65
129.6	0.07	0.03	0.11	0.09	6.58	1.33	4.41	3.59	4.67	0.95	3.13	2.54	6.58	1.33	4.41	3.59
133.1	0.06	0.03	0.11	0.09	6.23	1.36	4.35	3.52	4.42	0.97	3.09	2.50	6.23	1.36	4.35	3.52
136.6	0.06	0.03	0.11	0.09	5.79	1.39	4.29	3.46	4.11	0.98	3.05	2.45	5.79	1.39	4.29	3.46
140.1	0.05	0.04	0.11	0.08	5.23	1.41	4.24	3.39	3.71	1.00	3.01	2.41	5.23	1.41	4.24	3.39
143.6	0.05	0.04	0.10	0.08	4.69	1.43	4.18	3.33	3.33	1.02	2.97	2.36	4.69	1.43	4.18	3.33
147.1	0.04	0.03	0.10	0.08	4.15	1.33	4.12	3.27	2.95	0.95	2.93	2.32	4.15	1.33	4.12	3.27
150.6	0.03	0.03	0.10	0.08	3.59	1.33	4.07	3.20	2.55	0.95	2.89	2.27	3.59	1.33	4.07	3.20
154.1	0.03	0.03	0.10	0.08	2.98	1.23	4.00	3.14	2.11	0.87	2.84	2.23	2.98	1.23	4.00	3.14
157.6	0.02	0.03	0.10	0.08	2.29	1.13	3.94	3.06	1.63	0.80	2.80	2.17	2.29	1.13	3.94	3.06
161.1	0.02	0.03	0.10	0.07	1.88	1.03	3.88	2.99	1.34	0.73	2.75	2.12	1.88	1.03	3.88	2.99
164.6	0.02	0.02	0.09	0.07	1.70	0.93	3.82	2.92	1.21	0.66	2.71	2.07	1.70	0.93	3.82	2.92
168.1	0.01	0.02	0.09	0.07	1.52	0.83	3.77	2.85	1.08	0.59	2.68	2.02	1.52	0.83	3.77	2.85
171.6	0.01	0.02	0.09	0.07	1.33	0.73	3.72	2.78	0.95	0.51	2.64	1.97	1.33	0.73	3.72	2.78
175.1	0.01	0.02	0.09	0.07	1.16	0.62	3.68	2.70	0.82	0.44	2.61	1.92	1.16	0.62	3.68	2.70
178.6	0.01	0.01	0.09	0.07	0.98	0.52	3.63	2.63	0.70	0.37	2.58	1.87	0.98	0.52	3.63	2.63
182.1	0.01	0.01	0.09	0.06	0.98	0.42	3.58	2.57	0.69	0.30	2.54	1.82	0.98	0.42	3.58	2.57
185.6	0.01	0.01	0.09	0.06	0.84	0.32	3.52	2.50	0.60	0.23	2.50	1.77	0.84	0.32	3.52	2.50
189.1	0.01	0.01	0.09	0.06	1.06	0.22	3.46	2.43	0.75	0.16	2.46	1.72	1.06	0.22	3.46	2.43
192.6	0.01	0.00	0.08	0.06	1.27	0.12	3.40	2.36	0.90	0.08	2.41	1.68	1.27	0.12	3.40	2.36
196.1	0.01	0.00	0.08	0.06	1.47	0.02	3.34	2.29	1.05	0.01	2.37	1.63	1.47	0.02	3.34	2.29
199.6	0.02	0.00	0.08	0.06	1.70	0.04	3.27	2.22	1.21	0.03	2.32	1.58	1.70	0.04	3.27	2.22
203.1	0.02	0.00	0.08	0.05	1.92	0.10	3.23	2.16	1.36	0.07	2.29	1.53	1.92	0.10	3.23	2.16
206.6	0.02	0.00	0.08	0.05	2.12	0.03	3.19	2.08	1.51	0.02	2.26	1.48	2.12	0.03	3.19	2.08
210.1	0.02	0.00	0.08	0.05	2.09	0.03	3.14	2.01	1.48	0.02	2.23	1.43	2.09	0.03	3.14	2.01
213.6	0.02	0.00	0.08	0.05	2.03	0.09	3.10	1.93	1.44	0.06	2.20	1.37	2.03	0.09	3.10	1.93
217.1	0.02	0.00	0.08	0.05	1.97	0.15	3.05	1.84	1.40	0.10	2.17	1.31	1.97	0.15	3.05	1.84
220.6	0.02	0.01	0.07	0.04	1.90	0.20	3.01	1.74	1.35	0.14	2.13	1.23	1.90	0.20	3.01	1.74
224.1	0.02	0.01	0.07	0.04	1.84	0.26	2.96	1.64	1.31	0.18	2.10	1.16	1.84	0.26	2.96	1.64
227.6	0.02	0.01	0.07	0.04	1.69	0.32	2.92	1.53	1.20	0.23	2.07	1.09	1.69	0.32	2.92	1.53
231.1	0.02	0.01	0.07	0.04	1.55	0.38	2.87	1.43	1.10	0.27	2.04	1.01	1.55	0.38	2.87	1.43
234.6	0.02	0.01	0.07	0.03	1.41	0.43	2.83	1.33	1.00	0.31	2.01	0.94	1.41	0.43	2.83	1.33
238.1	0.01	0.01	0.07	0.03	1.27	0.47	2.78	1.22	0.90	0.33	1.97	0.87	1.27	0.47	2.78	1.22
241.6	0.01	0.01	0.07	0.03	1.15	0.42	2.74	1.12	0.82	0.30	1.94	0.80	1.15	0.42	2.74	1.12
245.1	0.01	0.01	0.07	0.03	1.13	0.38	2.69	1.02	0.80	0.27	1.91	0.72	1.13	0.38	2.69	1.02
248.6	0.01	0.01	0.07	0.02	1.10	0.33	2.65	0.92	0.78	0.23	1.88	0.65	1.10	0.33	2.65	0.92
252.1	0.01	0.01	0.06	0.02	1.08	0.29	2.60	0.82	0.77	0.20	1.85	0.58	1.08	0.29	2.60	0.82
255.6	0.01	0.01	0.06	0.02	1.06	0.24	2.56	0.72	0.75	0.17	1.82	0.51	1.06	0.24	2.56	0.72
259.1	0.01	0.01	0.06	0.02	1.03	0.24	2.51	0.62	0.73	0.17	1.78	0.44	1.03	0.24	2.51	0.62
262.6	0.01	0.00	0.06	0.01	1.01	0.19	2.47	0.52	0.72	0.14	1.75	0.37	1.01	0.19	2.47	0.52
266.1	0.01	0.00	0.06	0.01	0.96	0.15	2.42	0.43	0.68	0.11	1.72	0.30	0.96	0.15	2.42	0.43
269.6	0.01	0.00	0.06	0.01	0.92	0.10	2.37	0.33	0.65	0.07	1.68	0.23	0.92	0.10	2.37	0.33
273.1	0.01	0.00	0.06	0.01	0.87	0.06	2.33	0.23	0.62	0.04	1.66	0.16	0.87	0.06	2.33	0.23
276.6	0.01	0.00	0.06	0.00	0.83	0.01	2.29	0.13	0.59	0.01	1.63	0.09	0.83	0.01	2.29	0.13
280.1	0.01	0.00	0.06	0.00	0.79	0.02	2.25	0.08	0.56	0.01	1.60	0.05	0.79	0.02	2.25	0.08
283.7	0.01	0.00	0.05	0.00	0.75	0.05	2.21	0.03	0.53	0.03	1.57	0.02	0.75	0.05	2.21	0.03
287.2	0.01	0.00	0.05	0.00	0.71	0.07	2.17	0.00	0.51	0.05	1.54	0.00	0.71	0.07	2.17	0.00
290.7	0.01	0.00	0.05	0.00	0.70	0.10	2.13	0.00	0.50	0.07	1.51	0.00	0.70	0.10	2.13	0.00
294.2	0.01	0.00	0.05	0.00	0.67	0.13	2.09	0.00	0.48	0.09	1.48	0.00	0.67	0.13	2.09	0.00
297.7	0.01	0.00	0.05	0.00	0.64	0.15	2.04	0.00	0.46	0.11	1.45	0.00	0.64	0.15	2.04	0.00
301.2	0.01	0.00	0.05	0.00	0.62	0.18	2.00	0.00	0.44	0.13	1.42	0.00	0.62	0.18	2.00	0.00
304.7	0.01	0.01	0.05	0.00	0.59	0.20	1.96	0.00	0.42	0.14	1.39	0.00	0.59	0.20	1.96	0.00
308.2	0.01	0.01	0.05	0.00	0.57	0.23	1.93	0.00	0.41	0.16	1.37	0.00	0.57	0.23	1.93	0.00
311.7	0.01	0.01	0.05	0.00	0.55	0.24	1.90	0.00	0.39	0.17	1.34	0.00	0.55	0.24	1.90	0.00
315.2	0.01	0.01	0.05	0.00	0.57	0.25	1.86	0.00	0.41	0.17	1.32	0.00	0.57	0.25	1.86	0.00