The Ballina test field

363. Fellenius, B.H., 2016. Embankment settlement prediction. www.Fellenius.net, submitted to the Australian Research Council of Excellence, Geotechnical Science of Engineering, CGSE, Prediction Symposium, Newcastle, September 9-10, 12 p.

# Embankment Settlement Prediction — Preamble

On January 20, 2015, I received the following invitation:

*The Australian Research Council-funded Centre of Excellence for Geotechnical Science and Engineering (CGSE) invites practising engineers and academics to make and submit predictions of the performance of an embankment constructed using prefabricated vertical drains on soft clay ... . All manner of predictions are encouraged and invited.*

*Field observations and the time history of the embankment behaviour, as well as the various predictions of that behaviour will be presented and discussed in a special Prediction Symposium to be held in Newcastle, Australia, on 9 and 10 of September 2016.*

As I find predictions events combine great entertainment with good education on the state-of-practice spicing it with stimulating humiliation, I registered my interest to participate and, on August 5, 2015, I received the link for downloading pertinent information. The information was compiled in a rather unorganized manner and required a good deal of effort to sift out the relevant records, assisted by several questions to the organizers during the next couple of months. I devoted time on and off sorting out the data and on June 13, 2015, I submitted my prediction in the assigned format, as attached.

I had a few additional exchanges of information about release of the actual measurements and was told that the data would be made available to all who had registered their interest. Then, on August 2, I received a message that a payment of $440 was required for the prediction to be included in the conference proceedings! I participated in the prediction event considering it a professional effort and expected, of course, no remuneration for my time. The invitation included no requirement for payment for a prediction submission—had it been, I would not have bothered to produce and submit one, and the extensive correspondence regarding the data and prediction requirements before I submitted my prediction never stated that a payment was required. To require one after having received predictions in response to the invitation is an ambushed hold-up for money. I find the organizers' for-profit approach most unprofessional and unethical. I know of no past prediction event where a charge to predictors was associated with a prediction event. Moreover, I do not give in to blackmail, however petty it is. As I did not pay the charge, my prediction report (attached) was excluded from the conference proceedings.

During the course of my correspondence prior to August 2016, I was told that the actual measurements would be made public at the time of the September Prediction Symposium. However, the records have only been released to some individuals and pubic release is held back for unknown reason. I have seen some on-line results—it is amusing in these days of the Internet that the organizers would believe that information available to a few persons would stay confidential. However, I will await the official release of the records before comparing my prediction to the actual measurements, assuming that the release is imminent. Nevertheless, a few comments are needed: (1) The information provided regarding the site conditions did not include measurements of organic content. Now available information indicates that the organic content of the clay is about 5 % or more. Such organic content will result in a larger secondary compression than usual for inorganic clays. For example, as the results of the Mellösa test fill in Sweden (Chang 1972; 1981) showed that the secondary compression in such organic clay could even be so large that the compression could trigger a "self-induced consolidation" (Chang's term). I worked with Chang in the Mellösa test field and would have made other assumption as to the secondary compression than I did had I known the actual organic content. (2) Moreover, the information disseminated prior to August 2016, did not mention that the site had been flooded during a part of the observation period (July 2013 through June 2015). Of course, flooding reduces the weight of the surcharge and will temporarily slow down the consolidation. This fact has similar weight (pun intended) as the thickness of the fill, which, in contrast, was reported in detail. The flooding effect would simply have been included in the analysis as a temporary unloading and reloading of the site similar to the effect of the soil settling below the groundwater table.

Once the actual records are made public, I intend to add a comparison of my prediction with the actual data along with a discussion.

# EMBANKMENT SETTLEMENT PREDICTION

**Australian Research Council of Excellence, Geotechnical Science of Engineering, CGSE**

**Bengt H. Fellenius, P.Eng., Dr.Tech.**

**2475 Rothesay Avenue, Sidney, BC, Canada, V8L 2B9**
**<Bengt@Fellenius.net>**

**Key words.** Prediction, embankment settlement, soft soil, wick drains, consolidation.

**Abstract**. My prediction addresses immediate compression, consolidation settlement, and secondary compression at the center of the 3.0 m thick embankment placed over the 25 by 95 m area with a 15 m by 80 m crest. Wick drains (PVD) at c/c 1.2 m in a square configuration have been inserted to 14.7 m depth over the 25 by 95 m footprint. The calculations employ the Barron-Kjellman consolidation for radial flow combined with the Asaoka relation for simultaneous vertical flow, as quoted in Fellenius (2016) and correction for gradually reduced stress due to buoyancy. The calculations were performed using the UniSettle4 software (Goudreault and Fellenius 2011) and the results showed that the total settlement of the embankment center after 700 days would amount to 1,200 mm.

## INTRODUCTION

The Australian Research Council of Excellence, CGSE, has invited the geotechnical community to submit predictions of the settlement of an embankment constructed on soft clay through which wick drains, i.e., prefabricated vertical drains (PVD), had been installed in order to accelerate the consolidation process. The following is a summary of the site conditions and my prediction.

## THE SITE

The test site is located to the north of the town of Ballina, New South Wales (NSW) and lies within the Richmond River floodplain (Kelly et al. 2013). It is bounded by two small streams: Emigrant Creek to the north and Fishery Creek to the east. The area was previously used to farm sugar cane. The organizers have provided an extensive amount of soil information to use for the prediction effort from which I have selected the following information as pertinent to my calculations. Figure 1 shows the results of the two CPTU soundings pushed at the site; one 14 m deep and one 38 m deep. As guided by the two CPTU soundings, the soil profile consists of an about 1 m thick silt and sand layer with organic material on about 10 m soft estuarine clay, underlain by a 2.0 m thick transition zone comprised of silt and sand, followed by an about 5 m thick sand layer deposited on about 15 m of soft to firm clay on stiff Pleistocene clay. The groundwater table lies at 0.5 m depth and the pore pressure distribution is hydrostatic.

The laboratory measurements of consistency limits, grain size distribution, and total density are shown in Figure 2 diagrams. As a qualitative reference, the $q_t$-distribution of the 14-m CPTU sounding is added to each diagram. The soft clay is silty, indeed, for most of the depth, the sieve analyses showed the silt content to exceed 30 % indicating silt and clay rather than silty clay. Below 3 m depth, the water content of the soft clay exceeds 100 % and is close to the liquid limit, which is indicative of a highly compressible soil. No information was provided on the soil details from below 12 m depth (other than the 38-m CPT sounding). Presumably, because the prediction effort is directed to the upper 15 m depth.

Results of five compressometer tests were provided from samples recovered from 1.9, 2.3, 2.5, 5.5, and 9.8 m depths. Figure 3 shows the strain-stress diagrams from the tests. The results allow a cursorily evaluation of the tests that indicates virgin condition compressibilities of the soft silty clay: the Janbu modulus number range from 8 at 1.9 m and 2.3 m depths to 7 at 2.5 m. At 5.5 m and 9.8 m depths, the modulus numbers are 5 and 4. These numbers indicate highly

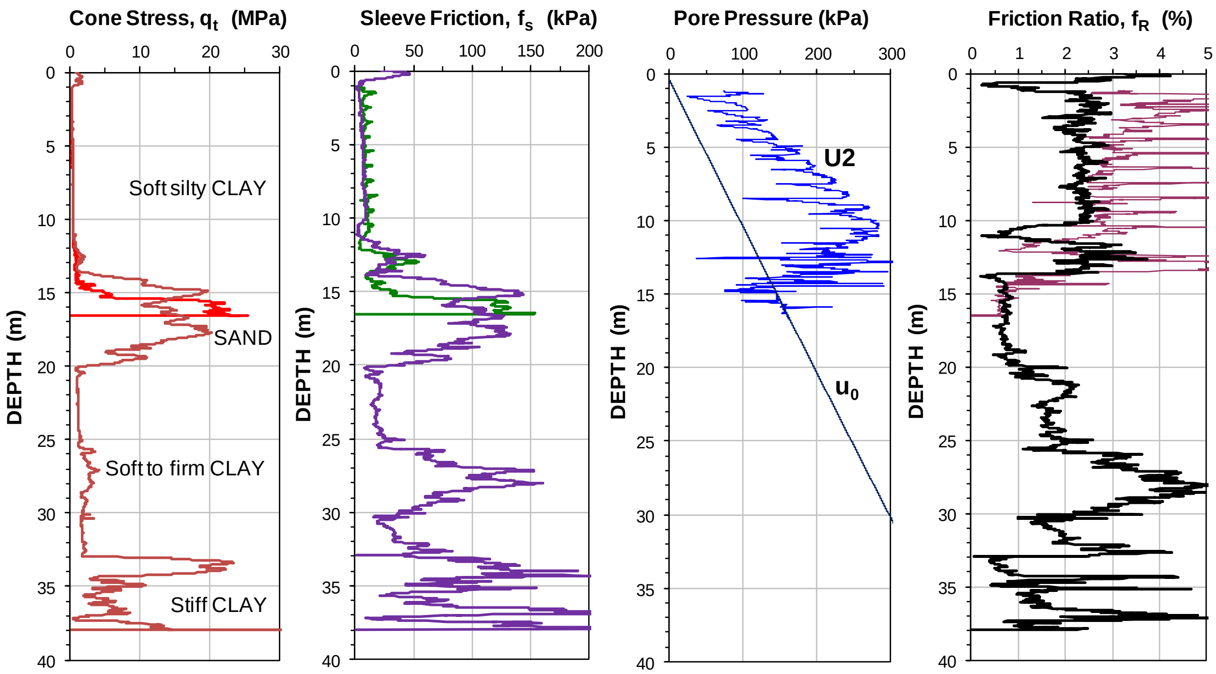


Fig. 1 Two CPT and CPTU diagrams (the spikes in the record occurring at regular depths are considered due to the cone rods slipping during adding of the next rod)

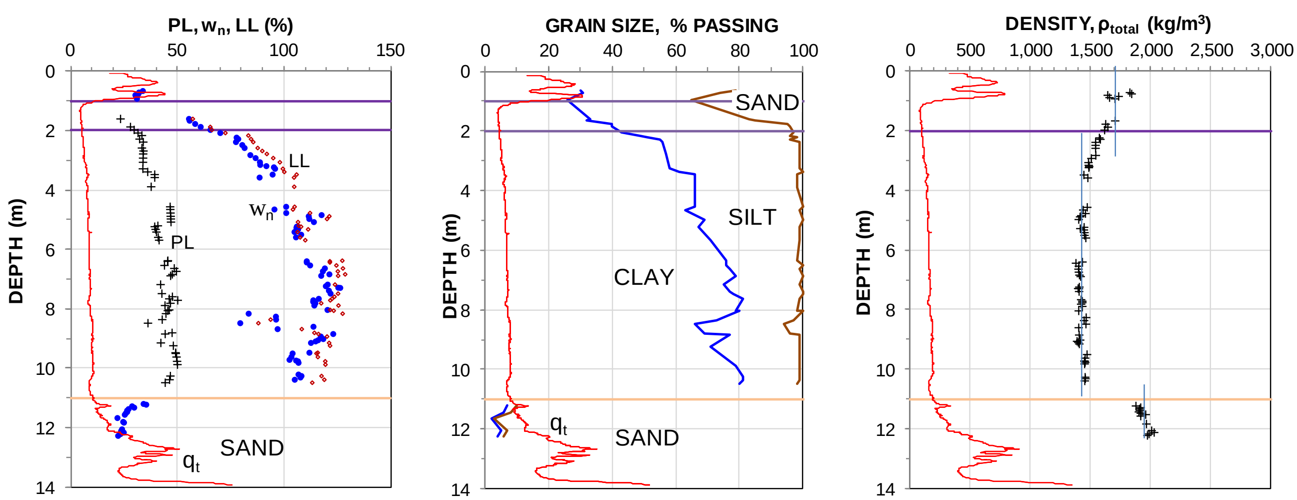


Fig. 2 Results of laboratory tests for Consistency Limits, Grain Size Distributions, and Total Density (Note, the $q_t$-diagram is for qualitative reference, only)

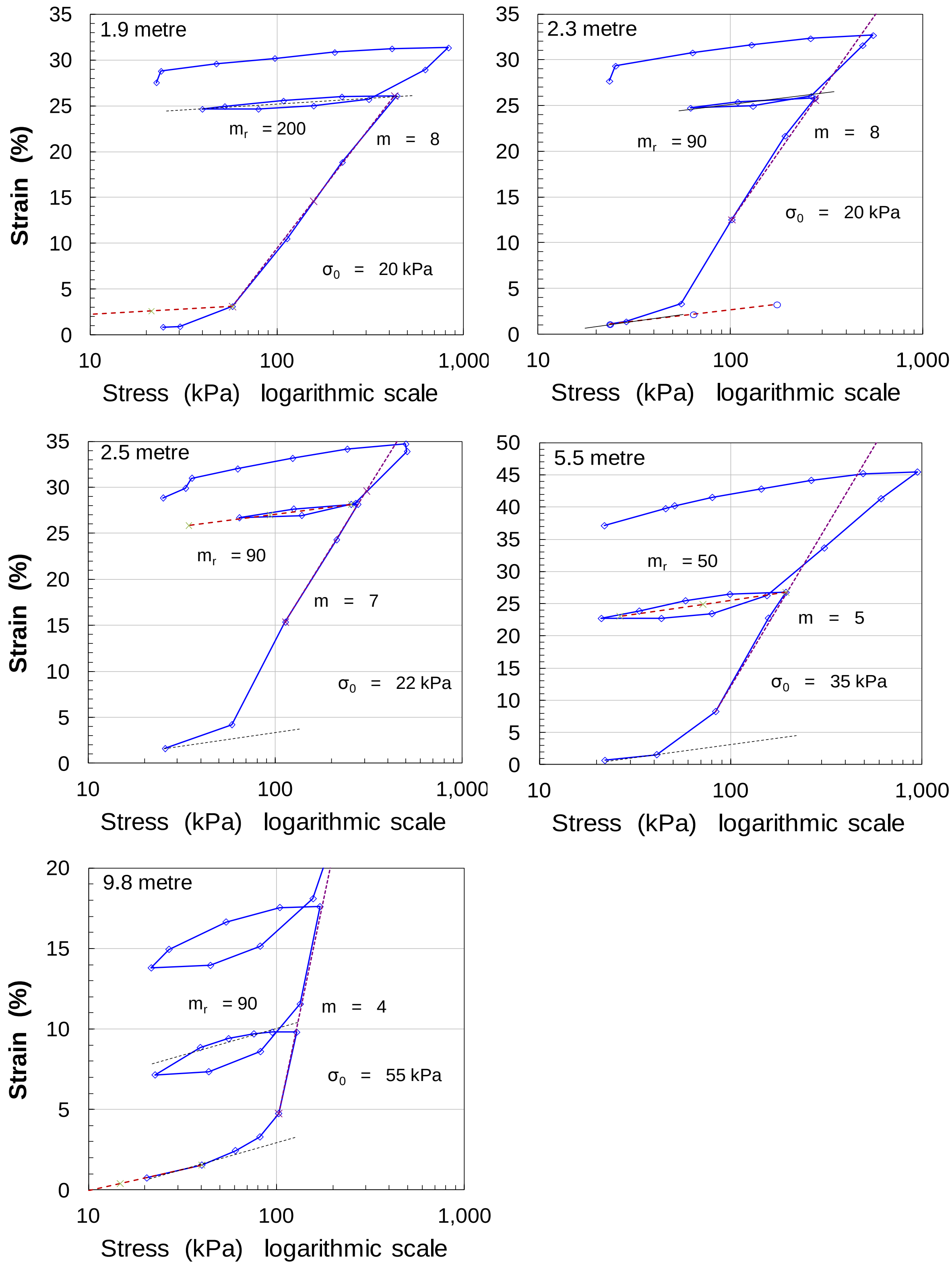


Fig. 3 Strain-stress diagrams from compressometer tests

compressible condition. The recompression modulus number, $m_r$, appears to be 200 at 1.9 m depth, which value I consider to be unrealistic. At the other test depths, the recompression modulus numbers range from 30 through 90, which are more realistic values, considering that the reloading compressibility is usually about ten times the virgin compressibility. The range between upper and lower values of coefficient of consolidation, $c_v$, reported for the tests differ by one to two orders of magnitude!

The site was prepared by removing about 0.3 m of the silt and sand surface layer and placing a 0.6 m thick working platform of sand over an approximately 25 by 95 m area. The test embankment's height above the working platform was 2.4 m and the crest was 15 m by 80 m. The sides sloped 1(V):1.5(H) making the embankment 22 by 92 m. Prior to placing the embankment, vertical drains were installed to 15.0 m depth in a square grid at a center-to-center spacing of 1.2 m. The drains were placed over three equal part areas, the part under the embankment center contained conventional PVD wick drains with a 100 m width and 3 mm thickness.

The site was instrumented to measure settlement (eight depths) and pore pressure distributions (eighteen piezometers) underneath the center of the embankment. Four inclinometers were installed to measure horizontal movements at the bottom of the embankment slope and four settlement plates were placed at the bottom of the working platform to measure fill height and settlement.

Figure 4 shows the cross section of the embankment and settlement anchor depths. The line at 0-m depth denotes the original ground surface before removing the 0.3-m top soil layer.

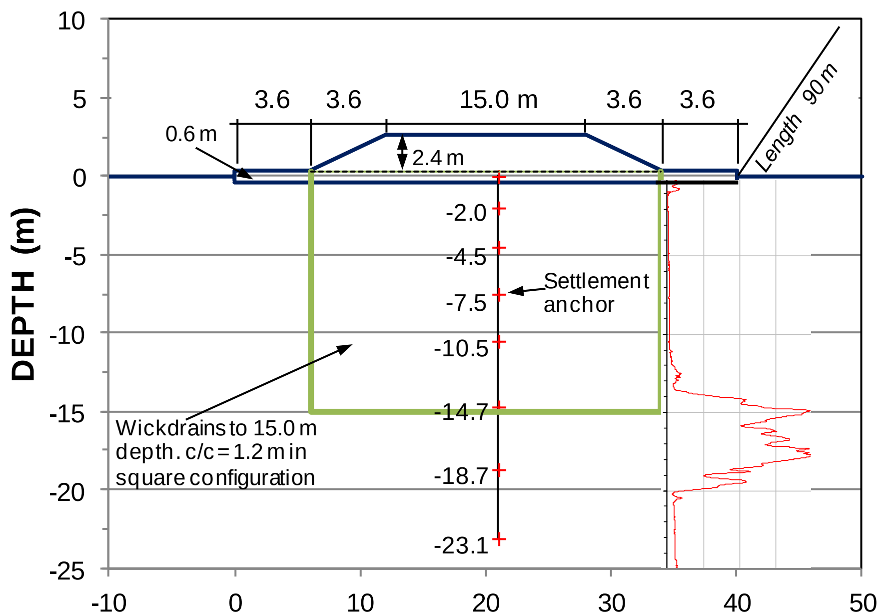


Fig. 4 Cross section

Figure 5, shows the fill height (sequence of construction of the platform and embankment) as height over the ground surface after the initial 0.3-m excavation. The placing of the fill started on July 24, 2013 and frequent observations continued until June 15, 2015, 690 days later. Assuming that Day 0 is June 15, 2013, construction of the 0.6-m working platform started on Day 10 and was completed on Day 15. Placing the first 0.6 m of embankment started on Day 25 and was completed on Day 31. Placing the remaining 1.8 m started on Day 58 and the full 3.0-m height was in place on Day 66.

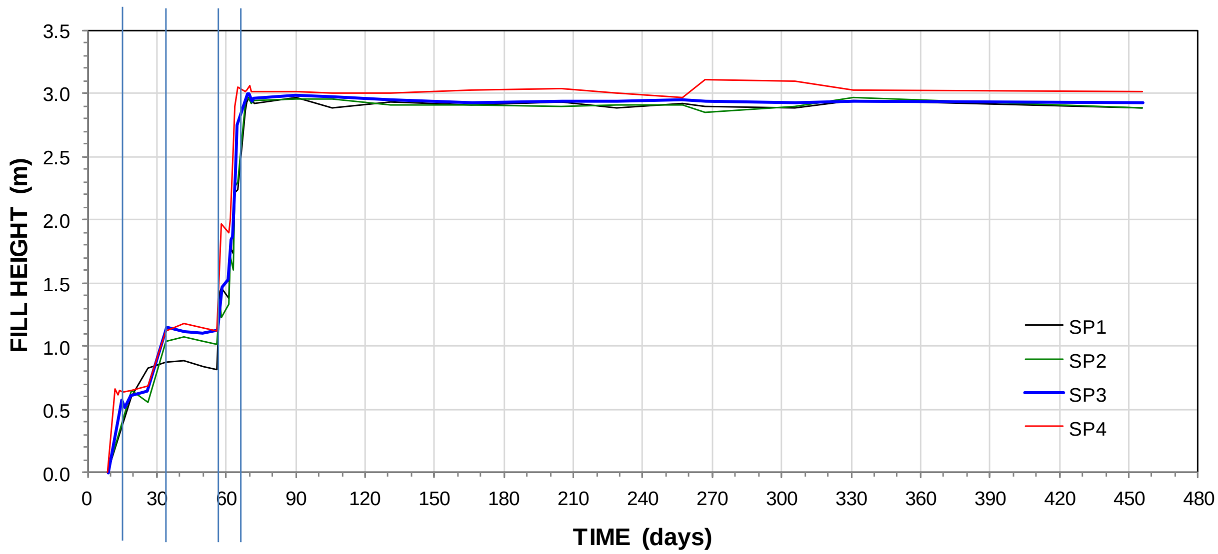


Fig. 5 Fill height versus time

The primary objective of my prediction effort is to calculate the settlement over time for the first 700 days of the 3.0-m embankment (at the ground surface and at the depths indicated in Figure 4 coinciding with the observation dates ("time-settlement curves") including upper and lower bounds of estimates. I have also made an estimate of the distribution of horizontal movement at the embankment slope location (as also desired for the prediction effort). It is simple to also calculate the settlement of the embankment along its sides. However, without having reference to actual observations of settlement along an embankment side that were correlated to horizontal movements in a similar geology, the numbers would be rather uninteresting. I have therefore refrained from presenting such results.

## INPUT TO CALCULATIONS

The site information is approximated to the parameters shown in Table 1. The times (days) of consolidation (90 %) listed refer to only vertical consolidation or only horizontal consolidation. The consolidation modulus numbers input for all layers, but the soft silty clay layer, are input just to smoothen the calculation results and avoid too sudden deformation to appear as kinks of the curves. A secondary compression index, $c_\alpha$, equal to 0.03 and a 6 months consolidation time is chosen so as to obtain 50 mm secondary compression in two years after Day 0.

The only parameters directly provided from the organizers of the prediction effort used for the prediction calculations are the soil densities and the virgin modulus numbers of the soft silty clay (as interpreted from the lab data illustrated in Figure 3) along with the dates of placing the embankment fill (Figure 5). All other input is from judgment or plain guessing. The calculations are performed using conventional settlement and consolidation theory as summarized in my text book (Fellenius 2016).

The net 0.3 m, 0.6-m and 1.8-m lifts are estimated to result in 6, 11, and 33 kPa stress to the ground, respectively, to a 50-kPa total applied stress. The lifts are assumed applied at Days 20, 30, and 70. Because the soil is unloaded due to buoyancy when it settles below the groundwater table, the applied stress was reduced by 6.0, 2.5, and 3.5 kPa at Days 75, 105, and 120, respectively.

**TABLE 1 Input Parameters**

| Soil Type | Depth (m) | Density, $\rho_t$ (kg/m$^3$) | $m_i$ (--) | $m_{ir}$ (--) | $\Delta\sigma_c$ (kPa) | m (--) | $m_r$ (--) | Time (d) required for consolidation Vertical | Hor. |
|---|---|---|---|---|---|---|---|---|---|
| Clay, Silt, Sand | 0 - 1.5 | 1,800 | 400 | 400 | 30 | 200 | 400 | 5d. | 5d. |
| Sandy Clay Silt | 1.5 - 3.0 | 1,500 | 200 | 400 | 20 | 50 | 200 | 30d. | 5d. |
| **Soft silty Clay** | **3 - 7.5** | **1,400** | **50** | **100** | **10** | **6** | **50** | **50 yr.** | **100d.** |
| **Soft silty Clay** | **7.5 - 15** | **1,400** | **50** | **100** | **10** | **5** | **50** | **50 yr.** | **100d.** |
| Dense Sand | 15 - 20 | 2,000 | 400 | 400 | 20 | 200 | 200 | 1d. | 1d. |
| Soft to firm Clay | 30 - 33 | 1,900 | 300 | 800 | 50 | 100 | 600 | 4 yr. | - - |
| Stiff Clay | 33 - 40 | 2,100 | 400 | 900 | 500 | 400 | 900 | 4 yr. | - - |

$m_i$ = modulus number for virgin immediate compression
$m_{ir}$ = modulus number for immediate re-compression
m = modulus number for virgin consolidation settlement
$m_{ir}$ = modulus number for settlement for re-loading consolidation settlement
$\Delta\sigma_c$ = preconsoldation margin

## RESULTS

The calculations are carried out using the UniSettle software (Goudreault and Fellenius, 2011) with the above mentioned input. Figure 6 shows the calculated settlements: Immediate Compression, Consolidation Settlement, Secondary Compression, and Total Settlement. Figure 7 shows the total settlement versus time for the depths of the anchor points. Figure 8 shows the distribution of settlement versus depth at Day 700. The results pertain primarily to the location of Sp2.

As estimated by judgment, only, I expect the horizontal movement curve measured in the inclinometer tubes to be about 50 to 100 mm at the ground surface increasing to about 300 mm at 3 m depth and reducing from there to about 200 mm at 6 m depth to insignificant movement at 12 m depth. Figure 9 shows the estimated distribution of horizontal movement along a vertical at the edge of the embankment.

## REFERENCES

Fellenius, B.H., 2016. Basics of foundation design. Updated Electronic Edition, https://www.Fellenius.net, 451 p.

Goudreault, P.A. and Fellenius, B.H., 2011. UniSettle Version 4 tutorial with background and analysis examples. UniSoft Ltd., Ottawa. [https://www.UniSoftLtd.com]. 85 p.

Kelly R., O'Loughlin, C.D., Bates, L. Gourvenec, S.M. Colreavy, C., White, D.J. Gaone, F.M., Doherty, J.P., and Randolph, M.F., 2014. In-situ testing at the national soft soil field testing facility, Ballina, New South Wales. Australian Geomechanics 49(4) 15-28.

## ANNEX

Tables (Table 2 through 4) containing the data plotted in Figures 6 through 8 are attached.

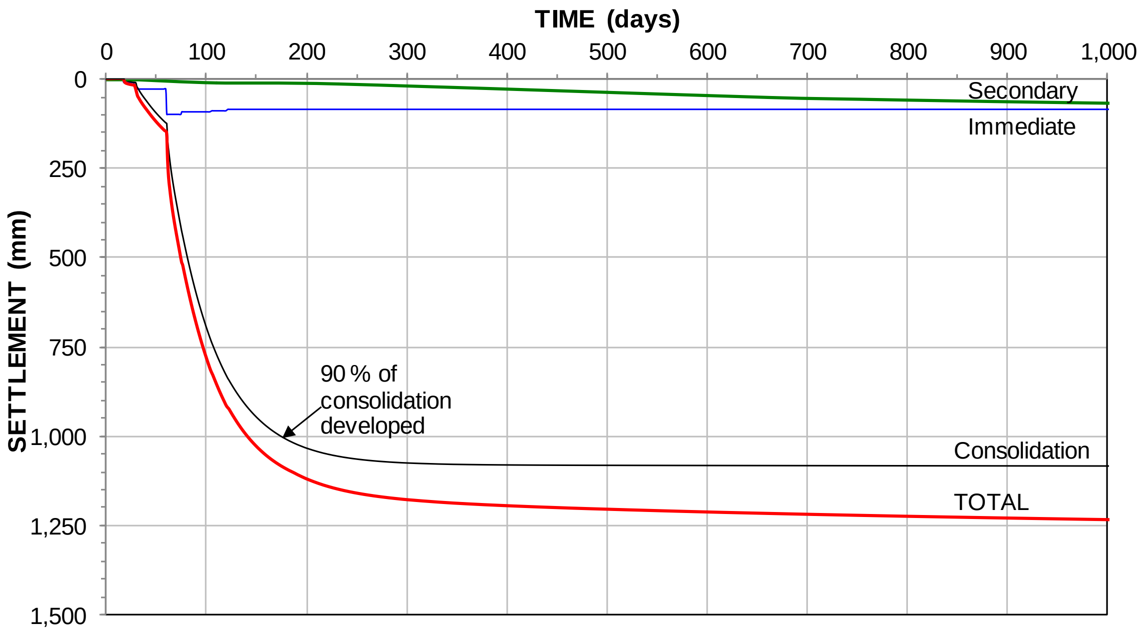


Fig. 6 Calculated ground surface settlement versus time

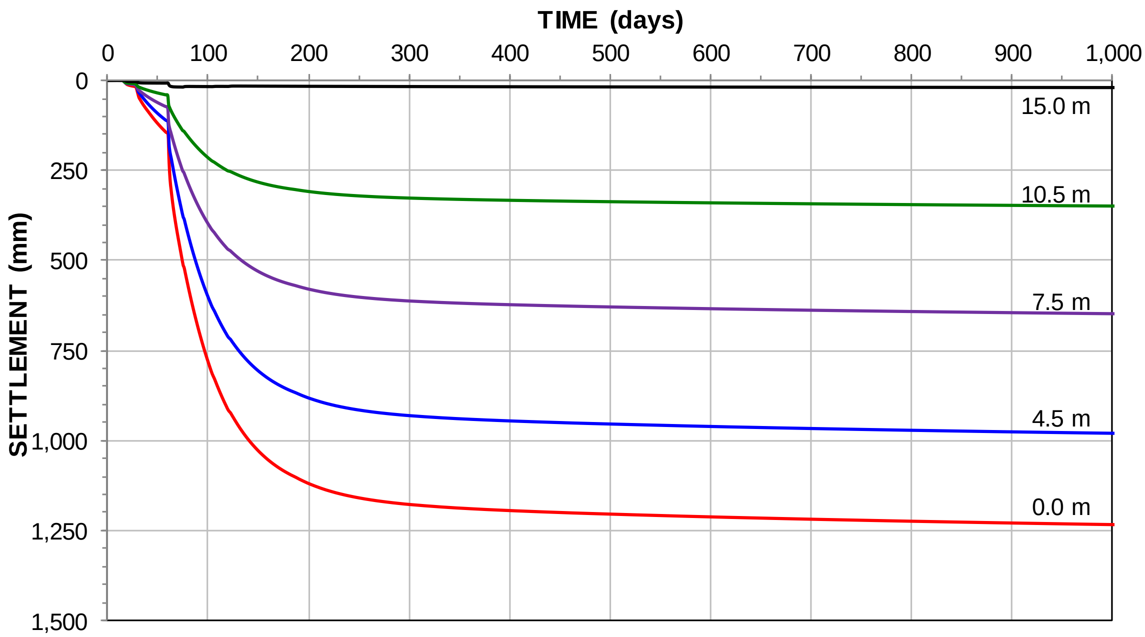


Fig. 7 Calculated settlement versus time at depths of anchor points

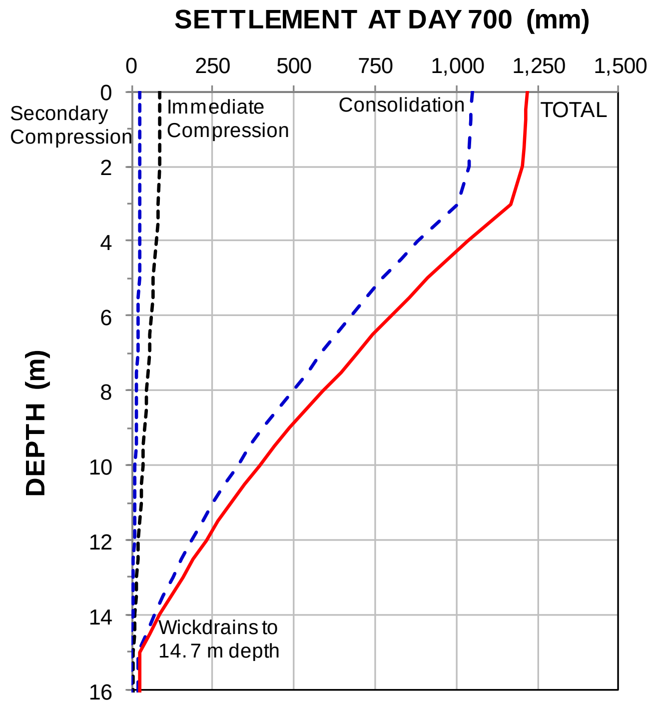


Fig. 8 Calculated settlement versus depth at Day 700

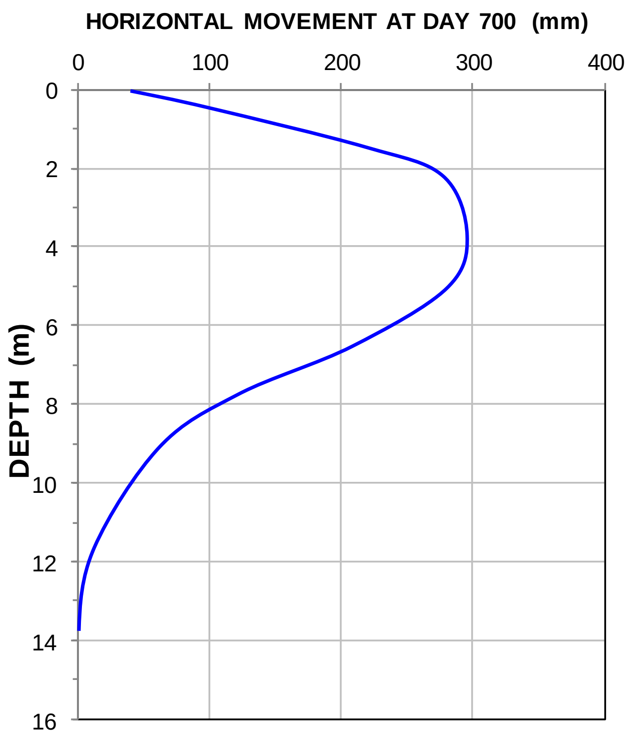


Fig. 9 Estimated horizontal movement versus depth at Day 700

**TABLE 2. Data used to plot Figure 6**

| Figure 6 | | | | | | |
|---|---|---|---|---|---|---|
| Boussinesq Distribution - All Layers at SP2 (0.00, -25.00) | | | | | | |
| Actual dates & days | | | Compression | | | |
| Date | Time (days) | Uavg (%) | Immediate (mm) | Consolidation (mm) | Secondary (mm) | Total (mm) |
| 13-07-24 | 0 | 0.0 | 0 | 0 | 0 | 0 |
| 13-09-08 | 16 | 0.0 | 0 | 0 | 0 | 0 |
| 13-12-08 | 19 | 0.3 | 9 | 3 | 0 | 12 |
| 13-08-19 | 26 | 0.8 | 9 | 8 | 1 | 17 |
| 13-08-28 | 35 | 3.5 | 28 | 39 | | 67 |
| 13-04-09 | 42 | 5.9 | 28 | 66 | | 94 |
| 13-12-09 | 50 | 8.4 | 28 | 94 | 2 | 122 |
| 13-09-18 | 56 | 10.0 | 28 | 112 | | 140 |
| 13-09-20 | 58 | 10.4 | 28 | 117 | | 145 |
| 13-09-23 | 61 | 11.1 | 101 | 125 | | 226 |
| 13-09-24 | 62 | 15.6 | 101 | 175 | | 276 |
| 13-09-25 | 63 | 18.0 | 101 | 203 | | 304 |
| 13-09-26 | 64 | 20.2 | 101 | 227 | | 328 |
| 13-09-27 | 65 | 22.1 | 101 | 249 | 3 | 350 |
| 13-09-30 | 68 | 27.1 | 101 | 305 | | 406 |
| 13-01-10 | 69 | 28.5 | 101 | 321 | | 422 |
| 13-02-10 | 70 | 30.0 | 101 | 337 | | 438 |
| 13-03-10 | 71 | 31.3 | 101 | 352 | | 453 |
| 13-10-22 | 90 | 53.0 | 94 | 596 | | 690 |
| 13-07-11 | 106 | 65.7 | 91 | 738 | | 829 |
| 13-02-12 | 131 | 78.1 | 87 | 878 | 7 | 965 |
| 14-06-01 | 166 | 87.6 | 87 | 985 | | 1,071 |
| 14-02-14 | 205 | 92.0 | 87 | 1,034 | | 1,124 |
| 14-10-03 | 229 | 93.9 | 87 | 1,055 | 12 | 1,150 |
| 14-07-04 | 257 | 94.9 | 87 | 1,067 | | 1,167 |
| 14-04-17 | 267 | 95.3 | 87 | 1,071 | | 1,174 |
| 14-05-26 | 306 | 95.5 | 87 | 1,074 | | 1,180 |
| 14-06-20 | 331 | 95.8 | 87 | 1,077 | | 1,186 |
| 14-08-26 | 398 | 96.0 | 87 | 1,079 | | 1,195 |
| 14-10-23 | 456 | 96.1 | 87 | 1,080 | | 1,202 |
| 14-12-16 | 510 | 96.1 | 87 | 1,081 | | 1,205 |
| 15-06-15 | 691 | 96.2 | 87 | 1,081 | 50 | 1,218 |
| | 1,022 | 96.3 | 87 | 1,083 | 67 | 1,236 |

# TABLE 3. Data used to plot Figure 7

| Figure 7 | Figure 7 | | | | | Figure 7 | | | | | Figure 7 | | | | | Figure 7 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth 4.5 m | | | | | Depth 7.5 m | | | | | Depth 10.5 m | | | | | Depth 15 m | | | | |
| | Uavg | Compression | | | | Uavg | Compression | | | | Uavg | Compression | | | | Uavg | Compression | | | |
| Time | | Immediate | Consolidation | Secondary | Total | | Immediate | Consolidation | Secondary | Total | | Immediate | Consolidation | Secondary | Total | | Immediate | Consolidation | Secondary | Total |
| (days) | (%) | (mm) | (mm) | (mm) | (mm) | (%) | (mm) | (mm) | (mm) | (mm) | (%) | (mm) | (mm) | (mm) | (mm) | (%) | (mm) | (mm) | (mm) | (mm) |
| 0 | 0.0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0 |
| 16 | 0.0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0 |
| 19 | 0.2 | 8 | 1 | 0 | 9 | 0.2 | 6 | 1 | 0 | 7 | 0.3 | 4 | 1 | 0 | 5 | 3.2 | 2 | 1 | 0 | 2 |
| 26 | 0.6 | 8 | 5 | 0 | 13 | 0.6 | 6 | 4 | 0 | 10 | 0.9 | 4 | 3 | 0 | 7 | 6.1 | 2 | 1 | 0 | 3 |
| 35 | 3.0 | 23 | 26 | 0 | 50 | 2.9 | 17 | 17 | 0 | 34 | 3.2 | 11 | 10 | 0 | 21 | 13.3 | 3 | 3 | 0 | 7 |
| 42 | 5.5 | 23 | 49 | 0 | 72 | 5.2 | 17 | 30 | 0 | 47 | 5.2 | 11 | 16 | 0 | 27 | 14.1 | 3 | 3 | 0 | 7 |
| 50 | 8.0 | 23 | 71 | 0 | 94 | 7.4 | 17 | 43 | 0 | 60 | 7.1 | 11 | 22 | 0 | 33 | 14.5 | 3 | 4 | 0 | 7 |
| 56 | 9.6 | 23 | 85 | 0 | 108 | 8.9 | 17 | 52 | 0 | 68 | 8.4 | 11 | 26 | 0 | 37 | 14.8 | 3 | 4 | 0 | 7 |
| 58 | 10.0 | 23 | 89 | 0 | 112 | 9.3 | 17 | 54 | 0 | 71 | 8.8 | 11 | 27 | 0 | 38 | 14.9 | 3 | 4 | 0 | 7 |
| 61 | 10.7 | 83 | 95 | 0 | 179 | 9.9 | 59 | 58 | 0 | 117 | 9.3 | 37 | 29 | 0 | 66 | 15.0 | 9 | 4 | 0 | 13 |
| 62 | 13.3 | 83 | 118 | 0 | 202 | 12.6 | 59 | 73 | 0 | 132 | 12.0 | 37 | 37 | 0 | 74 | 26.1 | 9 | 6 | 0 | 15 |
| 63 | 14.9 | 83 | 132 | 0 | 215 | 14.2 | 59 | 83 | 0 | 142 | 14.0 | 37 | 44 | 0 | 80 | 30.3 | 9 | 7 | 0 | 16 |
| 64 | 16.5 | 83 | 147 | 0 | 230 | 16.0 | 59 | 93 | 0 | 152 | 15.9 | 37 | 49 | 0 | 86 | 32.7 | 9 | 8 | 0 | 17 |
| 65 | 18.3 | 83 | 162 | 0 | 245 | 17.7 | 59 | 103 | 0 | 162 | 17.6 | 37 | 55 | 0 | 91 | 34.2 | 9 | 8 | 0 | 17 |
| 68 | 23.2 | 83 | 206 | 0 | 289 | 22.6 | 59 | 132 | 0 | 191 | 22.5 | 37 | 70 | 0 | 107 | 36.1 | 9 | 9 | 0 | 18 |
| 69 | 24.8 | 83 | 220 | 0 | 303 | 24.2 | 59 | 141 | 0 | 200 | 24.0 | 37 | 75 | 0 | 111 | 36.4 | 9 | 9 | 0 | 18 |
| 70 | 26.3 | 83 | 233 | 0 | 317 | 25.7 | 59 | 150 | 0 | 209 | 25.5 | 37 | 79 | 0 | 116 | 36.6 | 9 | 9 | 0 | 18 |
| 71 | 27.8 | 83 | 247 | 0 | 330 | 27.2 | 59 | 159 | 0 | 217 | 26.9 | 37 | 84 | 0 | 120 | 36.8 | 9 | 9 | 0 | 18 |
| 90 | 30.7 | 83 | 272 | 0 | 356 | 30.1 | 59 | 176 | 0 | 234 | 29.8 | 37 | 93 | 0 | 129 | 37.1 | 9 | 9 | 0 | 18 |
| 106 | 50.6 | 77 | 449 | 0 | 526 | 49.9 | 54 | 291 | 0 | 345 | 48.9 | 34 | 152 | 0 | 186 | 35.3 | 8 | 9 | 0 | 17 |
| 131 | 63.8 | 75 | 567 | 0 | 641 | 63.1 | 53 | 368 | 0 | 421 | 61.8 | 33 | 192 | 0 | 225 | 36.5 | 8 | 9 | 0 | 17 |
| 166 | 76.9 | 71 | 683 | 0 | 754 | 76.1 | 50 | 444 | 0 | 494 | 74.3 | 31 | 231 | 0 | 262 | 34.4 | 7 | 8 | 0 | 15 |
| 205 | 86.9 | 71 | 771 | 0 | 842 | 86.1 | 50 | 502 | 0 | 552 | 84.0 | 31 | 261 | 0 | 292 | 35.9 | 7 | 9 | 0 | 16 |
| 229 | 91.4 | 71 | 812 | 3 | 886 | 90.6 | 50 | 529 | 2 | 581 | 88.5 | 31 | 275 | 1 | 307 | 37.1 | 7 | 9 | 0 | 16 |
| 257 | 93.4 | 71 | 829 | 8 | 908 | 92.6 | 50 | 541 | 5 | 596 | 90.4 | 31 | 281 | 3 | 316 | 38.0 | 7 | 9 | 0 | 16 |
| 267 | 94.5 | 71 | 839 | 12 | 922 | 93.7 | 50 | 547 | 8 | 605 | 91.5 | 31 | 285 | 5 | 321 | 38.8 | 7 | 9 | 0 | 16 |
| 306 | 94.7 | 71 | 841 | 13 | 925 | 94.0 | 50 | 548 | 9 | 608 | 91.8 | 31 | 286 | 6 | 322 | 39.1 | 7 | 10 | 0 | 17 |
| 331 | 95.2 | 71 | 845 | 17 | 933 | 94.4 | 50 | 551 | 12 | 613 | 92.3 | 31 | 287 | 7 | 325 | 39.8 | 7 | 10 | 0 | 17 |
| 398 | 95.5 | 71 | 847 | 20 | 939 | 94.7 | 50 | 553 | 14 | 617 | 92.6 | 31 | 288 | 9 | 328 | 40.6 | 7 | 10 | 0 | 17 |
| 456 | 95.8 | 71 | 850 | 31 | 952 | 95.1 | 50 | 555 | 22 | 627 | 93.0 | 31 | 289 | 13 | 333 | 43.1 | 7 | 11 | 0 | 18 |
| 510 | 95.8 | 71 | 850 | 33 | 955 | 95.1 | 50 | 555 | 23 | 628 | 93.0 | 31 | 290 | 14 | 335 | 43.6 | 7 | 11 | 0 | 18 |
| 691 | 95.9 | 71 | 851 | 44 | 966 | 95.2 | 50 | 556 | 31 | 637 | 93.3 | 31 | 290 | 19 | 340 | 46.7 | 7 | 11 | 0 | 18 |
| 1,022 | 96.0 | 71 | 852 | 59 | 983 | 95.5 | 50 | 557 | 42 | 649 | 93.7 | 31 | 292 | 25 | 348 | 51.6 | 7 | 13 | 0 | 20 |

**TABLE 4. Data used to plot Figure 8**

| **Figure 8** | | | | | | |
|---|---|---|---|---|---|---|
| Boussinesq Distribution at SP2 (0.00, -25.00) | | | | | | |
| | Effective Stresses | | Settlement | | | |
| Depth | Initial | Final | Immediate | Consolidation | Secondary | TOTAL |
| (m) | (kPa) | (kPa) | (mm) | (mm) | (mm) | (mm) |
| | | | | | | |
| Layer 1: 0.0 - 1.5m Clayey silty Sand (Janbu j = 0) | | | | | | |
| 0.0 | 0.0 | 38.0 | 87 | 1,048 | 27 | 1,218 |
| 0.5 | 9.0 | 47.0 | 86 | 1,045 | 27 | 1,214 |
| 1.5 | 17.0 | 54.9 | 85 | 1,041 | 27 | 1,209 |
| 2.0 | 19.5 | 57.4 | 84 | 1,038 | 27 | 1,205 |
| 3.0 | 24.5 | 62.0 | 83 | 1,002 | 27 | 1,167 |
| 3.5 | 26.5 | 63.8 | 79 | 941 | 26 | 1,099 |
| 4.0 | 28.5 | 65.5 | 75 | 883 | 25 | 1,034 |
| 5.0 | 32.5 | 68.8 | 68 | 774 | 22 | 910 |
| 6.0 | 36.5 | 71.9 | 60 | 675 | 20 | 797 |
| 7.0 | 40.5 | 74.8 | 53 | 585 | 18 | 693 |
| 8.0 | 44.5 | 77.7 | 46 | 495 | 16 | 590 |
| 9.0 | 48.5 | 80.5 | 40 | 406 | 13 | 488 |
| 10.0 | 52.5 | 83.3 | 34 | 326 | 11 | 394 |
| 11.0 | 56.5 | 86.1 | 28 | 252 | 9 | 308 |
| 12.0 | 60.5 | 88.9 | 22 | 186 | 7 | 228 |
| 13.0 | 64.5 | 91.8 | 17 | 125 | 5 | 156 |
| 14.0 | 68.5 | 94.8 | 11 | 70 | 2 | 88 |
| 15.0 | 72.5 | 97.7 | 7 | 20 | 0 | 26 |
| 16.0 | 82.5 | 106.8 | 6 | 19 | 0 | 25 |