6.1. GROUND WATER TABLE MEASUREMENT

The groundwater table was reported in the logs at depth ranging from 0.5m – 1.5m from the existing ground surface. The information is presented below for easy reference:

Table 6-1. Groundwater Table Logs

DATE MEASURED	BH-1	BH-2
9/18/15	1.50m (5PM)	-
9/19/15	0.47m (7AM)	-
	0.47m (5PM)	-
9/20/15	1.5m (7AM)	0.97m (5PM)
9/21/15	-	1.2m (7AM)
	-	1.2m (5PM)

6.2. CHEMICAL TESTS

Representative soil samples were also tested for the determination of the chloride, sulphate and organic content. The results of the following tests are shown below:

Table 6-2. Summary of Chemical Test Results

BH NO.	DEPTH (M)	RESULT OF CHEMICAL TESTS		
		CHLORIDE (mg/kg)	SULPHATE (mg/kg)	ORGANIC CONTENT (%)
BH-1	9.0-9.45	34	3500	-
	16.5-16.95	130	68	-
	19.5-19.95	-	-	3.5
BH-2	2.0-2.45	-	-	3.9
	4.5-4.95	80	1500	-
	24.0-24.45	170	73	-

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. General Findings

Based on the results of the investigation, it is concluded that the project site is underlain by relatively thick loose soil sediments, consisting mainly of an uppermost 12.0m of mostly Sand, and very loose to loose in consistency; followed by the soft to stiff clay that extends to about 18.0m depth. The final layer encountered is described as medium dense gravel/sand-sized Limestone fragments with some clay extending down to the bottom of the borehole at 30.45 meters depth.

The following soil parameters may be assumed based on the results of the soil borings.

AVE. DEPTH (meter)	SOIL DESCRIPTION	MEAN N-VALUE	SATURATED UNIT WEIGHT, γ_s, (kN/m^3)	EFFECTIVE COHESION, C' (kPa)	EFFECTIVE PHI ANGLE, ϕ' (degree)
0 – 12.0	Very loose to loose Sand	8	15.5	0	28
12.0 – 18.0	Soft to stiff Clay	12	16.0	10	30
18.0 – 30.0	Medium dense Limestone fragments with some clay	24	17.0	20	36

Table 7-1. Recommended Soil Parameters

From the above findings, it is apparent that the uppermost 12m thick of soil is compressible and has low bearing capacity, as may be inferred from the low SPT N values (Ave=8). This layer is also potentially liquefiable in the event of strong ground motion (major earthquake).

The results of the liquefaction analysis are presented in the next section.

7.2. Liquefaction

The presence of very loose to loose Sand found in the uppermost 12mdepths would indicate that the project site is susceptible to liquefaction phenomenon. Liquefaction refers to the significant loss of strength and/or stiffness due to cyclic pore pressure generation which is generally exhibited by sands and non-plastic silts.

Liquefaction analysis was conducted using the empirical method of Seed and Idriss (1971), and assuming ground acceleration of 0.25g. Cyclic stress ratio (CSR) and cyclic resistance ratio (CRR) were computed followed by the factor of safety against liquefaction, by dividing CRR by CSR.

The results of the liquefaction study are graphically presented in the next page. It shows the liquefaction potential along the depth of the study (CRR and CSR), where the red shaded areas represent potential liquefiable zones. The factor of safety against liquefaction and the degree of settlement are also plotted with respect to the soil depth. The corresponding soil profile is then shown in the next page.

The settlement was estimated to be about 24cm based on the results of BH-1& BH-2 using the procedure developed by Ishihara and Yosemine (1990).

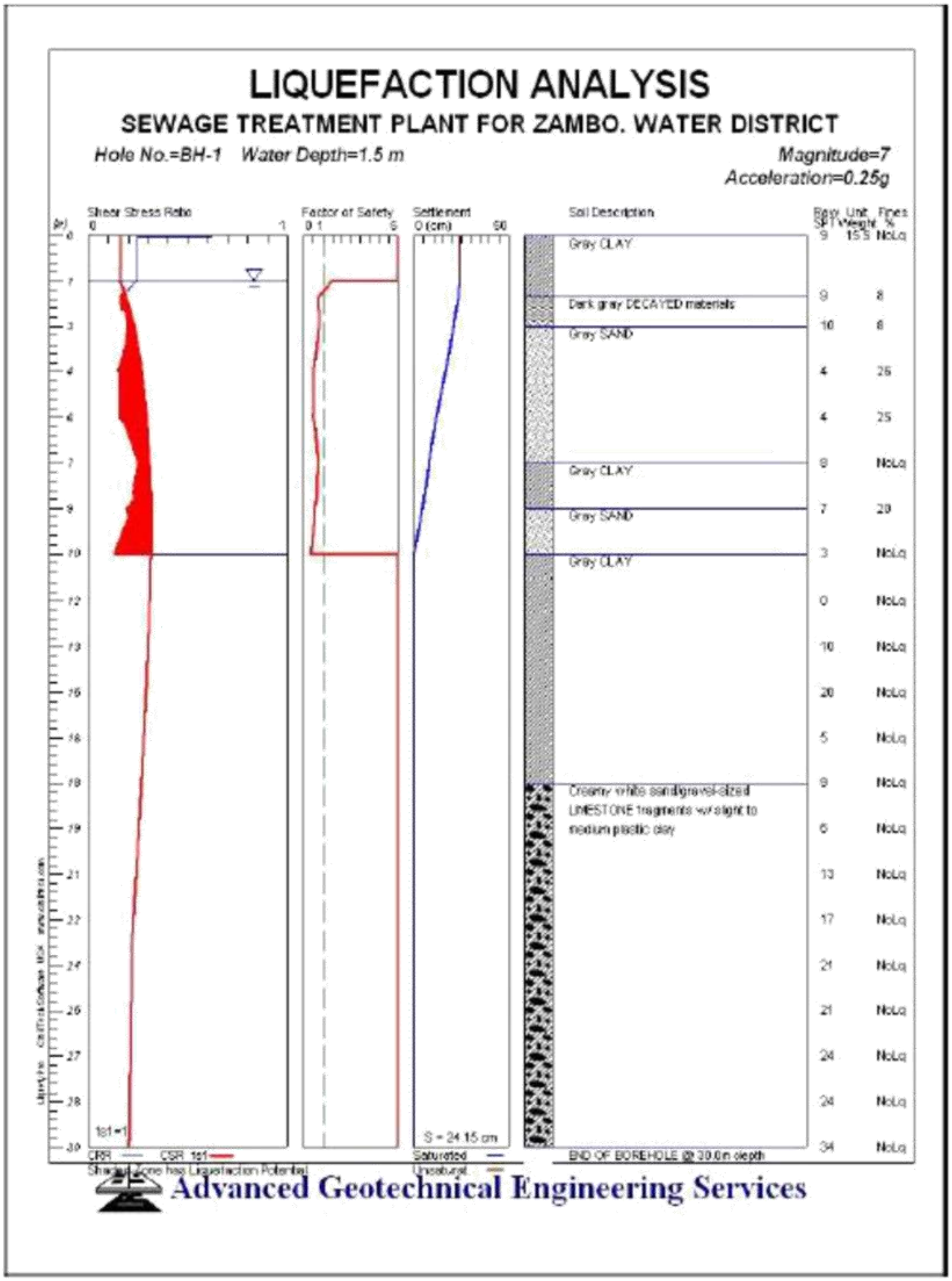

Figure 7-1. Liquefaction Analysis of BH-1

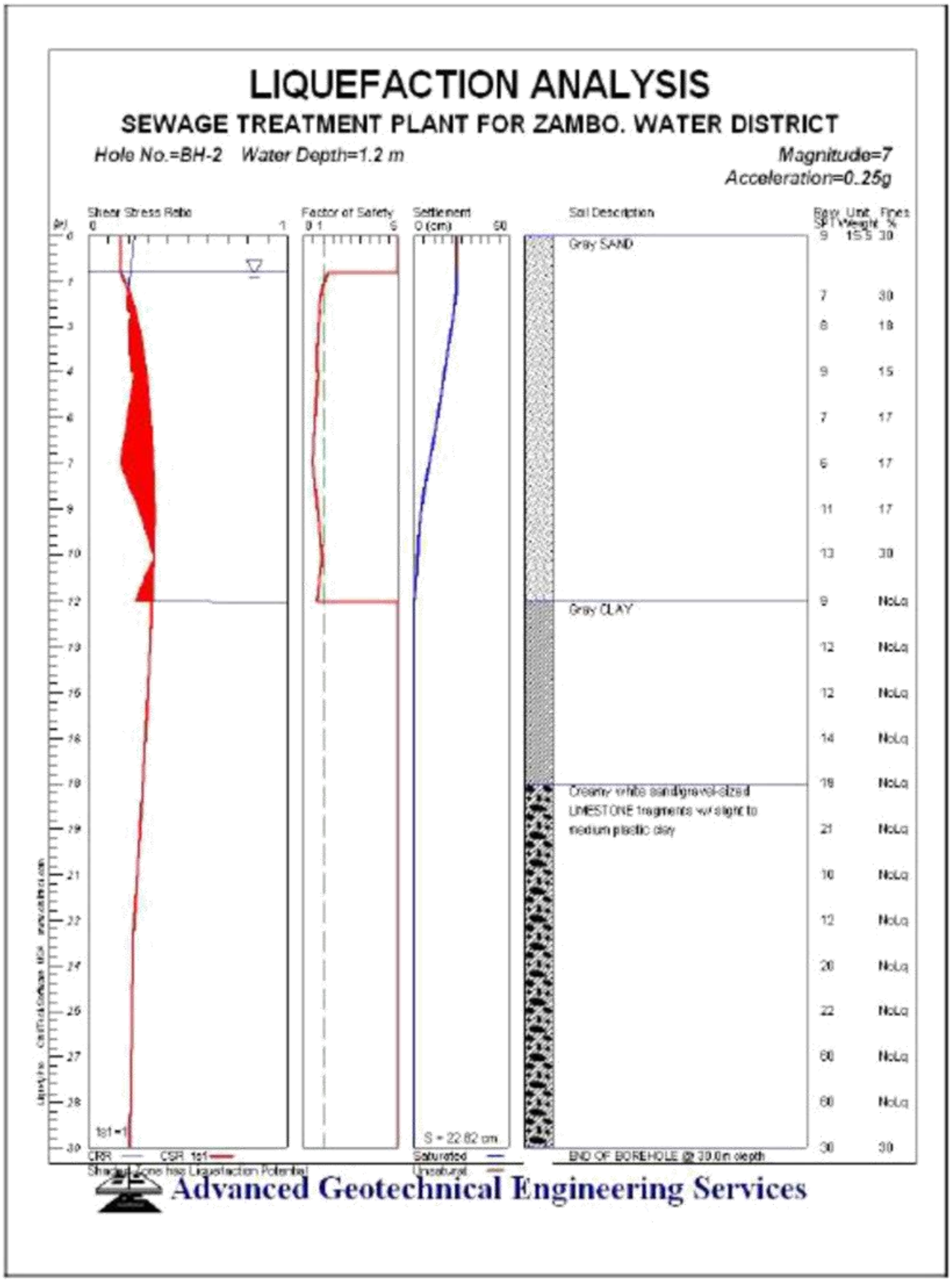

Figure 7-2. Liquefaction Analysis of BH-2

7.3. Lateral Spreading

Lateral spreading is described as the lateral movement of the soil on a gentle sloping ground due to soil liquefaction. Based on the liquefiable potential of the upper soil layer of the project site and nearby shoreline, lateral spreading may occur in an event of a strong earthquake. Documented events are likely on mild slopes of 0.3 to 5%. Horizontal displacement and vertical displacement (settlement and heaving) due to lateral spreading has caused considerable damage to infrastructures and especially underground / utility lines.

In-situ ground solidification technique, such as the deep cement mixing (DCM), is known for mitigation of earthquake-induced lateral spreading. DCM is installed by inserting columns of soil-concrete mixture in the project site. The installation creates a grid of soil-cement columns that produces a stiffer strength to support in-situ soil to reduce lateral spreading. The popularity of this method is indisputable in Japan, followed by the United States and Scandinavia.