1MC05

Groundwater Assessment for Construction Tasks – Piling at the Colne Valley Viaduct

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Contents

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1 Scope

1.1.1 This report has been prepared to assess the effects of piling at the Colne Valley viaduct on the groundwater environment, including:

- formulation of a conceptual hydrogeological model for the Colne Valley;
- identification of construction activities that could affect groundwater movement or quality;
- effects of addition of liquids other than water to aquifers as part of construction;
- monitoring requirements; and
- stakeholder consultation completed or underway.

1.1.2 The purpose of the report is not to repeat the information provided in the Environmental Statement, but to build on that and to provide more detailed information regarding design and construction proposals that were not available at the time that the Environmental Statement was being prepared. Where there are no changes from the method / approach outlined in the Environmental Statement, only a cursory assessment is included in this report. This report should be read in conjunction with the Environmental Statement.

2 Client Objectives

2.1.1 The client objectives are to meet the requirements of the HS2 Technical Standards that support the Environmental Minimum Requirements.

3 Technical Standards

3.1.1 The Technical Standards of relevance to this hydrogeological assessment include:

- Technical Standard – groundwater Protection, HS2-HS2-EV-STD-000-000010
- Technical Standard - Water Framework Directive Compliance Process (HS2-HS2-EV-STD-000-000012)
- Technical Standard - Water resources and flood risk consents and approvals, HS2-HS2-EV-STD-000-000015
- Technical Standard - Water Resources Strategy (HS2-HS2-EV-STD-000-000016)
- Technical Standard - Water Resources and Flood Risk Monitoring Strategy HS2-(HS2-EV-STD-000-000029)
- Technical Standard – Civil Engineering Instrumentation and Monitoring, HS2-HS2-CV-STD-000-000004

Although separate documentation has been prepared as part of the Water Framework Directive Compliance Process, some of the requirements are also included in this assessment.

4 Construction activities

4.1 Site location and setting

4.1.1 The Colne Valley Viaduct is a 3.4km long structure that will be constructed to carry HS2 over the water features of the Colne Valley, including Harefield No. 2 Lake, Savay Lake, Korda Lake and Long Pond, the Grand Union Canal, the River Colne and the Newyears Green Bourne. The lakes and ponds were formed following gravel extraction and many of these water features now make up the Mid Colne Valley Site of Special Scientific Interest (SSSI). Topography is relatively flat, with an elevation of approximately 40mAOD.

4.1.2 The viaduct will be orientated south east to north west, beginning at the South Embankment that will be constructed to the west of Harvil Road. At the north west end of the viaduct the North Embankment will be constructed to the west of the A412 North Orbital Road. Figure 1 shows the features of the Colne Valley and is derived from the Environmental Statement[1].

[1] HS2 2013, London-West Midlands Environmental Statement, Volume 5 Technical Appendices, CFA7 Colne Valley, Water resources assessment (WR-002-007)

Figure 1: Map of Colne Valley (HS2, 2013)

4.2 Geology and hydrogeology characteristics

4.2.1 The area is underlain by Cretaceous chalk of the White Chalk Subgroup, made up of the Seaford Chalk and the Newhaven Chalk (Appendix A). At the extreme south eastern tip of the viaduct the Chalk is overlain by the Lambeth Group which is comprised of clay, silt and sand with minor limestone bands (Appendix A and Appendix B). Superficial deposits in the vicinity of the viaduct consist of alluvium; comprised of clay, peat, silt, sand and gravel associated with the River Colne; the Shepperton Gravel Member, underlying the lakes of the Colne valley and the Taplow Gravel Member, present between the River Colne and the A412 North Orbital Road (Appendix A and Appendix B).

4.2.2 At the Northmoor abstraction boreholes, which are to the north east of the north western end of the viaduct some 9m of gravel was identified overlying the Chalk. The rest water levels in the boreholes were approximately 3.3m below datum, which is likely to be around 1 to 2m below ground level.

4.2.3 The Chalk is classified as a Principal aquifer and is extensively used for groundwater abstraction, including a significant quantity of public water supply. The Lambeth Group, the various gravel formations and the alluvium are classified as Secondary A aquifers, but they are not widely used for water supply in this area.

4.2.4 The Chalk aquifer that the piles for the viaduct will be bored into will be within the Water Framework Directive (WFD) Mid Chilterns Chalk water body, which has a total area of 730km^2. The piles for the viaduct will not penetrate the Radlett Tertiaries water body which is to the south of the viaduct. Impacts on groundwater from a WFD water body perspective are summarised in the Section C1 - Updated WFD Compliance Assessment[2] and are not explicitly discussed below to avoid duplication with that report.

4.2.5 The Chalk aquifer is a dual permeability aquifer which is characterised by very low flow rates through the rock matrix and much higher rates of flow through fissures. In some areas these fissures are enlarged by solutional weathering which can result in extremely fast flow rates. The Chalk is likely to be heterogeneous with the principal mechanism for groundwater flow to occur through a dendritic network of interconnected fractures and solution enlarged voids rather than expansive voids or karstic features.

4.2.6 Geophysical data available from different boreholes within the Chalk of the Colne Valley indicates the presence of three distinct fissure bands at 14-16m bgl, 26-32m bgl, and 48-52m bgl[3] [4]. The information available does not indicate whether these flow horizons are

[2] Align 2019, Section C1 - Updated Water Framework Directive Compliance Assessment, 2019, Document no.: 1MC05-ALJ-EV-REP-CS01_CL01-100082
[3] Environment Agency, 2005. Groundwater quality review: The Chalk of the Mid-Chilterns and Colne Valley, Thames Region. Report Reference: 6441R4.
[4] Shand, P., Tyler-Whittle R., Bersien T., Peach D.W., Lawrence A.R. and Lewis H.O., 2003. BGS Baseline Report Series: 6. The Chalk of the Colne and Lee River Catchments. Environment Agency Technical Report NC/99/74/6 and BGS commissioned report CR/03/69N.Environment Agency.

present over a wide lateral area, or how connected they are, but they will be acting as principal flow zones where they exist. Additional GI is being conducted in the first half of 2019 and review of this will aid in assessing the degree of fracturing likely to be present in the aquifer in the vicinity of the viaduct.

4.2.7 The majority of groundwater movement is likely to be in the top 50m of the saturated zone of the Chalk aquifer and it is possible that there is layering in the aquifer with some horizons more permeable than others.

4.2.8 Permeability is typically highest in the valleys and lowest in the interfluve areas. Available in-situ permeability estimates obtained from existing GI positions from the Chalfont St Peter area indicate a range of values between 4.75×10^{-5} m/d and 0.95 m/d. The permeability in the Colne Valley is likely to be higher.

4.2.9 Data collected by the British Geological Survey (BGS)[5] indicates that transmissivity in the major valleys (Thames and the Colne) in the Chalk in the Chilterns is high, typically in the range 1500 to 3000m^2/d. The BGS also cite leakage into the Chalk from rivers and overlying sands and gravels as being part of the reason for the high transmissivity values, but also that in some areas the presence of putty chalk can locally reduce permeability.

4.2.10 Once further ground investigation data are available from HS2 investigations more specific permeability data will be available for the Colne Valley.

4.2.11 Groundwater levels beneath the viaduct are very shallow at or just below ground level at about 40mAOD, although the level will vary depending upon proximity to Affinity Water abstraction boreholes and the rate of pumping from these boreholes. The area is known to be subject to groundwater flooding during periods of extreme rainfall. Groundwater movement is generally in a north-west to south-east direction, albeit that the direction is locally changed in the vicinity of the abstractions.

4.2.12 The gravels that overlie the Chalk in the Colne Valley often become silty towards their base, and the upper weathered chalk can often be a clay like "putty chalk". Groundwater is therefore only in partial hydraulic continuity with surface water in the lakes that occupy the majority of the Colne Valley. The annual fluctuation in groundwater level is not known but is likely to be limited to 1 to 5m at distance from the abstraction boreholes, but could be up to 20m in close proximity to the abstraction boreholes, depending upon the pumping regime.

4.2.13 The only known area of significant groundwater contamination along the route of the viaduct is associated with an historical spill of chlorinated solvents at Denham laboratories which is currently being remediated with a pump and treat system.

[5] British Geological Survey, 1997, The physical properties of major aquifers in England and Wales, Hydrogeology Group Technical Report WD/97/34, Environment Agency R&D Publication 8.

4.3 Groundwater abstractions

Affinity Water PWS

4.3.1 Affinity Water is licenced to take 88Ml/d from the Chalk aquifer as part of the Blackford Group licence which includes 9 abstraction boreholes in this area, although not all are operational. The two boreholes immediately adjacent to the viaduct, Blackford and Northmoor abstract up to 37Ml/d. If the abstraction boreholes have to be shut down currently there are very limited options for alternative water supply.

Figure 2: Geology and Groundwater Source Protection Zones in the vicinity of the Colne Valley (HS2, 2013)

4.3.2 All of the large public water supply groundwater abstractions have groundwater source protection zones (SPZ) defined for them (Figure 2). These comprise three zones:

- inner zone (zone 1) - defined as the 50 day travel time from any point below the water table to the source;
- outer zone - defined by a 400 day travel time from a point below the water table; and
- total catchment area - defined as the area around a source within which all groundwater recharge is presumed to be discharged at the source.

4.3.3 The SPZs are defined by modelling and are based on best available data and licensed (rather than actual) abstraction rates. These zones are best estimates and in heterogeneous aquifers such as the Chalk should be taken as indicative rather than definitive. The inner and outer zones could be greater in extent and may be a slightly different shape where there are preferential flow zones. All modelling is dependent upon the available data and where this is limited there is quite a bit of interpolation. Furthermore, the model used is a single layer model and so takes no account of any vertical variations in permeability. SPZs should therefore be used with a degree of caution. Given the heterogeneous nature of the aquifer and the available hydrogeological data further groundwater modelling would be unlikely to increase the certainty of the hydrogeological environment and in particular groundwater flowpaths from proposed structures. Additional modelling has therefore not been undertaken.

4.3.4 The viaduct is located within SPZ1 and SPZ2 for either the Northmoor or Blackford abstractions (primarily SPZ1). The abstracted water is generally of good quality, although manganese is slightly elevated (see below). The only water treatment employed by Affinity Water prior to distribution is application of UV. The viaduct is approximately 40m from the Blackford abstraction and approximately 360m away from the Northmoor abstraction.

4.3.5 There is a further abstraction located to the south-east of the viaduct at Ickenham, and the viaduct lies within SPZ1 and SPZ2 for that source. However, the source is currently not utilised due to contamination from an historical landfill and so potential effects on this source are not considered further.

4.3.6 The Northmoor abstraction comprises three boreholes drilled to about 90m depth with two connected by a blasted heading. The boreholes penetrated about 8.6m of gravel before encountering the Chalk. The abstraction has high turbidity on occasions and the boreholes encountered blocky and broken chalk and due to collapse in the past have casing installed. A small cavity was encountered in one of the boreholes. Rest water level is about 1 to 2m below ground level.

4.3.7 The Blackford abstraction comprises three boreholes drilled to about 90m depth with rest water level at about 2m below ground level. The boreholes penetrated about 10-11m thickness of gravel. Affinity Water report that the abstraction water has elevated manganese concentrations due to infiltration of water from lakes and the overlying sand and gravel down into the Chalk. The boreholes have suffered collapse in the past and a cavity has been identified at 35m depth.

4.3.8 The past turbidity issues at Northmoor, coupled with the collapse of aquifer material at the abstraction boreholes indicates that the Chalk in the Colne Valley is well fractured and highly permeable, something that is not unusual in valley locations.

4.3.9 Construction activities that take place beneath the water table within the peak demand period (between May and September inclusive) are likely to be of most concern to Affinity Water as this is when demand is highest and the resilience in the supply system is lowest. Timing is therefore important in planning the construction works and considering the potential effects on public water supplies.

Private licensed and unlicensed abstractions (1km radius)

4.3.10 Six licensed private abstractions and one unlicensed private abstraction have been identified within a 1km radius of the viaduct (as shown on Figure 3). The licensed abstractions are predominantly used for non-potable activities such as mineral washing at quarries and for irrigation at golf courses. The unlicensed private supply is registered to a sailing club, so these may be impacted by any turbidity affects caused by construction activities.

4.3.11 Two of the licensed abstractions are used for process water at a laboratory and this is understood to be used as part of a pump and treat system implemented to remediate historical chlorinated solvent contamination which occurred during the operation of Denham film studios, upon which the laboratory now stands.

4.3.12 There is the potential for further unlicensed supplies to exist, as a license is not required for abstraction volumes less than 20m^3 per day. An information request has been sent to the local authorities through which the viaduct passes to gain an update on the number and locations of unlicensed supplies, and replies have been received from all except the London Borough of Hillingdon. No additional abstractions were reported.

Figure 3: Private groundwater abstractions along the Colne Valley Viaduct

4.4 Surface water interactions

4.4.1 Much of the floor of the Colne Valley in the area surrounding the viaduct has been subject to sand and gravel extraction with post extraction restoration as a series of lakes. The depth of removal and the thickness of material remaining is very variable, partly being dependent upon the amount of silt in the deposit. As noted above, there is thought to be some continuity between water in these lakes and that in the Chalk, but the degree of continuity depends upon the amount of silt in the lower sand and gravel horizons and the extent to which the upper layers of the Chalk are clay-like "putty" chalk.

4.4.2 The Viaduct crosses the Newyears Green Bourne west of Harvil Road and also crosses the River Colne between the lakes of the Colne valley and the A412 North Orbital Road.

4.4.3 The Grand Union Canal is located between Savay Lake and Harefield No.2 Lake where the viaduct crosses the Colne Valley. The canal may be lined with low permeability material over part of its length, particularly where the water table fluctuates significantly, although it is understood that several sections are unlined. We also understand that some sections of the canal were constructed in the former channels of the River Colne. This notwithstanding it is likely that any interaction between the canal and local groundwater is limited, particularly as the canal is not a natural groundwater outflow feature. Therefore, no significant impacts associated with groundwater are expected on this particular feature.

4.5 Construction proposals

4.5.1 The viaduct will be approximately 3.4km long and will rise from approximately 46m AOD in the south east to 52m AOD in the north west. It will be supported on 58 piers, two of which will be part of the embankments at either end, and the remaining 56 will support the viaduct. The piers will comprise several designs, including a number of fixed buttresses, although these designs will not have any effect on the groundwater regime.

4.5.2 The design of the piling for the viaduct is under review, and will not be finalised until after completion and interpretation of the additional ground investigation. However, it is likely to comprise bored piles with a diameter of about 1.8m and a depth of 50m to 80m below ground level. Pile construction methods are not yet finalised and may include the use of bentonite and or polymers during the drilling and pile installation process. The piles would be cast *in situ* with reinforced concrete.

4.5.3 The piles will require a casing to support the upper non-cohesive layers above the chalk, with the depth of the casing being dependent upon ground conditions at each location. In the case of the piles constructed over water the casing will also prevent lake water from entering the pile hole during construction and placement of concrete. The temporary casing will be removed following completion of the concrete at piles constructed over land, but will remain in place at piles constructed over water.

4.5.4 The piles will be constructed in groups, with between 4 and 9 piles per group, with greater numbers of piles required where ground conditions are poor, or where the required load bearing capacity / rigidity is greater (e.g. at the fixed buttresses). The weight of the viaduct will be transferred to each pile group by means of a concrete pile cap which will be constructed across all of the piles in each pile group. The pile caps on land will be some 2.5m thick and those in the water sections will be about 1m thick. The pile caps will generally be 10m long, increasing to up to 20m long at the fixed buttresses, and will be between 10 and 15m wide. The construction method for the pile caps will differ between the lake and land. Those on land will be constructed in situ and will require soil to be excavated to allow the top of the pile cap to be located at, or just below, ground level.

4.5.5 Where water levels are high (anticipated for the majority of the viaduct route) this will require construction of a coffer dam using sheet piles. The sheet piles will be driven or vibrated through the superficial deposits and into the top of the chalk to form the coffer dam and the pile caps will be constructed within the enclosed area. In the first instance a basal concrete plug will be installed and allowed to cure. This will prevent groundwater upflow and will allow the area inside the cofferdam to be dewatered. Following construction of the pile cap the sheet piles will remain in place. The pile caps for the piles installed over water will be constructed within a shell that will be placed over the piles, sealed and then dewatered, which will not require any sheet piling.

4.5.6 In order to construct the piles and pile cap within the water features of the Colne Valley, it will be necessary to construct a temporary jetty, which itself will involve piling. The design of the piling for the temporary jetty is under review and will not be finalised until after completion and interpretation of the additional ground investigation. However, it is likely to comprise steel tube piles that will be push driven through the superficial deposits and weathered chalk and into the top of the chalk rock. Pile dimensions would be of the order of 900mm diameter and would be installed to a depth of approximately 25m, with the expected number of piles exceeding 300. The piles would remain in place following removal of the jetty as their removal could compromise ground conditions around the piles for the viaduct. The top of the driven piles would be cut off at lake bed level.

4.5.7 In some instances it may be necessary to improve ground conditions by injecting grout, or to construct a grout curtain around a pile group in order to limit groundwater movement. There remains uncertainty regarding whether this will be required, and it is considered here for completeness.

4.6 Potential effects on groundwater

4.6.1 Potential effects on the Chalk aquifer, public abstraction boreholes, licensed and unlicensed abstractions and on surface water are considered below. Although the piles for the aquifer penetrate superficial deposits in the Colne Valley, these have been subject to extensive mineral extraction and have been restored as lakes in many areas. The remaining sand and gravel deposits are often of limited lateral extent and / or are silty and are unlikely to form an effective resource and so the superficial aquifer(s) are not assessed further.

Groundwater quality

Chalk turbidity

4.6.2 Chalk generally comprises coccoliths, foraminifera and other shell debris, cemented together to lesser or greater degrees. The coccoliths are particularly small being several µm across. Any construction work can result in disintegration of the chalk mass into these fine particles which, when the work is below or close to the water table, has the potential to induce chalk turbidity. Due to their small size these particles do not settle quickly and can rapidly migrate through fissures in the aquifer. The Affinity Water abstractions are very close to the line of the viaduct and have very low limits on turbidity as it can limit the effectiveness of UV water treatment. The limit on turbidity is 1 NTU[6], but as a precaution Affinity Water take boreholes out of supply at 0.8 NTU.

4.6.3 In addition to chalk turbidity, there are other sources of natural turbidity such as from sediment that could be washed into fissures from surface water runoff. This sediment can be washed through the groundwater system to Affinity Water abstractions, natural discharge points, or it can become deposited in fissures in the Chalk aquifer and remobilised at a later date, particularly if there are changes (e.g. due to piling) to the rate and direction of groundwater movement.

Bentonite turbidity

4.6.4 Bentonite includes a number of naturally occurring clays with sodium bentonite and calcium bentonite being most widely used in industry. As clays, they have very fine particle sizes and so do not settle quickly and can rapidly migrate through fissures in the aquifer. For the piling, bentonite is mixed with water to form a 5% (or thereabouts) solution which is used to help keep the piled hole open prior to installation of the concrete and reinforcing bars. It forms a skin on the walls of the pile hole and can restrict water movement into or out of the hole.

4.6.5 Where the pile hole encounters a void the bentonite can move out of the hole and if the void is well connected to the aquifer can result in migration. However, what is not known is what flow velocity is required for bentonite migration, nor how quickly it would settle out in the aquifer, nor whether changes in pumping rates could re-instigate migration in the future.

Cement / concrete / grout

4.6.6 Cement / concrete / grout tends to be highly alkaline and can pollute water supplies if it gets into them with pH of 10 to 12 not being uncommon. Drinking water has a pH limit of 9.5. There is a risk that migration of cementitious materials could impact water quality, although the potential for this can be restricted by careful use and by using quick setting materials. For

[6] The Water Supply (Water Quality) Regulations 2016 (SI 2016/614).

these there is limited potential for migration if the raw materials are appropriately managed and those pumped underground are quick setting.

Fuels, oils, chemicals and grease

4.6.7 There are no current proposals for any chemicals (including fuels, oils and greases) to be used below ground during piling operations. They will be used above ground in plant and machinery, but any loss from these would be associated with accidents or equipment failure and would be managed through the Code of Construction Practice. Therefore they are not assessed in this report.

4.6.8 Currently the potential for using polymers rather than bentonite is being considered by Align. If polymers are approved for use by the Environment Agency, and if they provide an acceptable material from a geotechnical perspective, then the effect of polymers on the environment and abstractions would need to be assessed.

Groundwater flow

4.6.9 Changes to groundwater flow have been considered at the local scale in terms of potential effects on groundwater abstractions and at the regional scale in terms of effects on the aquifers. Effects on WFD water bodies are considered in the WFD Compliance Assessment report (see Section 4.2).

Creation of preferential vertical pathways

4.6.10 Affinity Water has indicated that the water pumped from the Blackford and Northmoor abstraction boreholes have elevated concentrations of manganese. Like pH, there is a limit for the concentration of manganese in water that can be used for public water supply (50µg/l manganese). The manganese is thought to come from the lake water / sands and gravels that overlie the Chalk aquifer. Although the sands and gravels may naturally be in hydraulic continuity with the Chalk, the degree of water movement may be limited by the presence of silts in the sand and gravels in addition to the presence of putty chalk at the top of the weathered horizons. Any construction activity that could result in a preferential pathway between the lake water / sand and gravel and the chalk aquifer, particularly where the latter is well fissured, could result in greater water movement than is currently the case. This in turn could increase manganese concentrations in the aquifers and at the abstraction boreholes. There is also a risk that other contaminants present in the lake waters and superficial deposits could get into the Chalk aquifer and subsequently the abstracted water.

4.6.11 The potential for creation of preferential flowpaths is from:

- installation of the push driven steel piles and the potential to create a flowpath around their edges, although this will be limited due to the effect of material compression around the outside of the pile;
- installation of sheet piles;

- the potential for the steel piles to degrade in the long term and for the resulting degraded steel to form a pathway; and
- the cast in-situ piles could form a pathway.

4.6.12 The potential for creation of preferential pathways has been assessed[7] and it has been concluded that there is very limited potential for creation of such pathways in either the short or long term.

Changes to horizontal flowpaths

4.6.13 There is the potential for the installation of piles of the viaduct to change flow characteristics in the aquifer and also to potentially reduce yields at public water supplies in the vicinity of the viaduct. The changes could take the form of local changes to flow routes due to the obstruction of preferential flowpaths by piling or ground improvements, and/or a reduction in flow through the aquifer due to a reduction in the cross-sectional area of the aquifer through which groundwater can move.

4.6.14 This principally applies to the piles for the viaduct piers due to the number of these across the full width of the Colne Valley, their size and spacing and their depth. However, any effect could be exacerbated by the piles for the temporary jetty which would remain in place, although this only applies at the locations over water.

4.6.15 This has been assessed[7] and it has been concluded that there is limited potential for any significant change in groundwater movement at the aquifer scale. There will be changes at the local scale around the piles, but this will not be significant for the Chalk aquifer. Furthermore, there will be limited potential for a significant reduction in yield at the Blackford supply borehole and no reduction is likely at Northmoor.

4.6.16 As noted above, records held by Affinity Water indicate that the Blackford and Northmoor abstraction boreholes are unstable and have suffered several collapses in the past. There is therefore concern that piling activities close to the abstractions, even if they do not include hammer action, could result in further collapse at one or both of these supplies and this could affect flowpaths and well yield. This has been assessed[7] and it has been concluded that there is limited potential for any significant reduction in yield at either the Blackford or Northmoor boreholes.

4.6.17 The potential for groundwater flooding to result from disruption to groundwater flow paths caused by the piles is not considered likely as groundwater would discharge into the lakes before it emerged at surface and predicted increases in head immediately upgradient of the piles are not anticipated to be large[1]. This is consequently not considered further.

[7] Align, 2018, Options for mitigation of the effects of piling on groundwater, Document no.: 1MC05-ALJ-EV-NOT-CS01_CL01-000001

4.7 Potential effects on surface water

4.7.1 Below ground construction associated with the viaduct piles could lead to contamination of the River Colne, the Newyears Green Bourne and the lakes of the Colne Valley by chalk or bentonite turbidity, or above ground storage and use of concrete and/or grout.

4.7.2 The potential for any direct effects of construction on these watercourses is limited as they will be managed through the Code of Construction Practice and so these effects are not considered further in this assessment.

4.7.3 Indirect effects could occur if chalk or bentonite turbidity migrates within groundwater which subsequently discharges at one of the water features listed above. This is not considered to be a significant risk due to that fact there are no major springs feeding these watercourses in this area, which indicates that baseflow supporting these features is largely diffuse and so less sensitive to any increased turbidity carried within it.

4.7.4 Affinity Water has confirmed that there is movement of water from the lakes into the Chalk due to leakage where the gravel has been excavated and there is only a thin layer of sediment / weathered chalk separating the lakes from the chalk rock. It is plausible that during periods of low abstraction (e.g. if Blackford is shut down) and low lake levels that groundwater could upwell into the lakes, but this is not thought to be significant, especially in areas where chalk soil is thick.

4.8 Proposed mitigation

Options for mitigation of chalk turbidity

4.8.1 There is no requirement for mitigation of turbidity on the Chalk aquifer due to its localised effect (compared to the aquifer size) and its temporary nature. Mitigation of chalk turbidity at the public supply abstractions will take the form of turbidity treatment and the cessation of pumping from the Blackford abstraction. This mitigation has been commenced and Affinity Water is having an appropriate treatment solution designed and installed. These mitigation options are discussed in detail in the piling mitigation report[7]. No further specific mitigation for this is proposed, although it is recognised that some mitigation for bentonite turbidity may also limit chalk turbidity.

Options for mitigation of Bentonite turbidity

4.8.2 There is no single option that will mitigate all risks to Affinity Water abstractions whilst allowing the construction of the viaduct to continue to a reasonable cost and within a reasonable programme. A route map has therefore been prepared (reported in detail in the piling mitigation report[7] that shows the route to defining the preferred mitigation solution, with a variety of mitigation solutions likely to be used along the viaduct. This approach will include the preparation of risk assessments for each pile group at the planning stage to identify those locations that would benefit from particular mitigation approaches. This will then be updated during the construction stage with information on ground conditions to ensure the mitigation option selected will be the most appropriate to limit the potential for bentonite turbidity. This strategy to manage risk is designed as a live approach to be updated as more information becomes available, with a range of mitigation options available to be implemented including timing of the works and/or restriction of use of specific material.

4.9 Monitoring requirements

4.9.1 The ES states that monitoring to determine the potential impacts to Affinity Water PWS will be undertaken and will consist of measurements taken before, during and after completion of viaduct construction.

4.9.2 Groundwater monitoring largely comprises manual dipping of water levels which takes place in about 130 boreholes, albeit that a small number monitor water levels in different strata at the same location. Of the 130, 12 boreholes have water level loggers installed and these are downloaded on a quarterly basis.

4.9.3 Water quality samples are collected from about 15 boreholes. The suite of analytical determinands varies with the location of the monitoring borehole, selected based on a risk based monitoring approach. Water quality loggers are installed in 7 boreholes in order to monitor pH, electrical conductivity, redox, temperature and turbidity. These are downloaded on a quarterly basis.

4.9.4 In addition, monitoring of specific boreholes at locations that are particularly significant or sensitive has been agreed by HS2 with the EA. A total of 35 priority locations have been identified which require monitoring before, during and after construction.

4.9.5 A small number of priority boreholes have also been designated as sentinel boreholes, which are locations in the vicinity of Affinity Water abstraction boreholes. These sentinel boreholes have been drilled to provide an early warning system for a potential effect upon the public abstraction boreholes.

4.9.6 Additional monitoring for chlorinated solvents and bromate has been requested by the EA in the area around Denham laboratories. An initial screening of SVOC's will be undertaken and dependent upon the results further monitoring will be undertaken at targeted locations.

4.9.7 Blackford and Northmoor boreholes will be inspected by down hole CCTV to form a baseline condition. The survey would be repeated post construction to assess if there has been any change.

4.9.8 Full details of the monitoring being undertaken and that proposed during construction are provided in the Monitoring Position Statement[8] .

[8] Align, 2018a, Section C1 Monitoring position statement, Document no.: 1MC05-ALJ-EV-NOT-CS01

5 Consent requirements

5.1.1 The HS2 Technical Standard "Water resources and flood risk consents and approvals" (HS2-HS2-EV-STD-000-000015) requires consents to be obtained for:

- below groundwater construction activities, such as piling; and
- use or application of chemicals, additives or lubricants to works below the groundwater table.

5.1.2 Construction of the viaduct will include extensive piling, include use of additives such as bentonite and will therefore require a consent for these activities. As the activities are in a Principal aquifer and in some cases within SPZ1, the level of consent specified in the Technical Standard is "detailed".

5.1.3 The construction for the viaduct will therefore require application for a consent. This hydrogeological assessment provides supporting information for the consent application with regard to the hydrogeological setting and the proposed construction activities and potential effects on groundwater.

6 Stakeholder liaison

6.1 Environment Agency

6.1.1 As the regulator of the water environment in England the Environment Agency was a statutory consultee for the Environmental Statement. In addition, discussions have been held on a number of occasions regarding the potential effect on the water environment and the need to demonstrate environmental compliance for the scheme. The meetings that have taken place and the topics of discussion are listed below.

6.1.2 01/05/18 - Piling at the viaduct - EA and HS2. The piling proposals and mitigation proposed at the viaduct were discussed with the EA along with the scope and content of the management strategy required to discharge U&A 49 and general update regarding progress of the designs and construction preparation.

6.1.3 09/01/18 – Ground Investigation consents and related issues – EA, Align, HS2. This included discussion about the proposed Ground Investigation programme, position locations and the consenting requirements necessary for it to go ahead including from a groundwater and flood risk perspective.

6.1.4 12/12/17 – liaison regarding programme and the South Portal – Align, Affinity Water, EA, HS2. Discussions covered programme of mitigation installation at AW assets, shaft construction programme and GI programme.

6.1.5 06/12/17 – introductory meeting – Align, Affinity Water, EA, HS2. Discussion included initial statement of AW's concerns, introduction of Align JV and discussion on current views of construction methods.

6.1.6 28/11/17 – Consents for abstraction and discharge– EA, Align, HS2. This included discussion about viaduct foundation design and issues surrounding turbidity caused by pre-drilling, piling and bentonite loss to aquifer. Discussions also covered consents associated with shaft dewatering activities, including consents for abstraction, discharge and pumping tests, as well as consent requirements for tunnelling. It was agreed during this meeting that this date would be accepted as the beginning of the consultation process and form part of the pre-application discussions for abstraction consent under the protective provisions.

6.2 Affinity Water

6.2.1 The approach to piling has been discussed with Affinity Water on several occasions during 2017 and 2018 in order to understand their key concerns and to discuss options for mitigation in addition to the timing of the works. Consideration of multiple effects on abstractions from construction of different HS2 assets at the same time has also been considered. This document takes into account Affinity water concerns and opinions. The meetings that have taken place and the topics of discussion are listed below.

6.2.2 22/05/18 - Piling and Shaft Mitigation Assessment - Align, Affinity Water, HS2. Discussion of draft versions of the piling and shaft mitigation reports.

6.2.3 18/04/18 - Piling mitigation options – Align, Keller, Affinity Water, HS2. This included more detailed discussion about piling for the viaduct, temporary jetty and embankments, including detailed assessments of affects and proposed mitigation.

6.2.4 12/03/18 – Piling mitigation options – Align, Keller, Affinity Water, HS2. This included discussion about piling for the viaduct, temporary jetty and embankments as well as shaft construction, turbidity treatment systems and AW held monitoring data.

6.2.5 19/12/17 – Viaduct and shaft construction design options and potential risks to Affinity Water supplies – Align, Affinity Water, HS2. Discussed the piling methods being considered, shaft construction options as well as cross passage construction and turbidity treatment at AW assets.

6.2.6 07/12/17 - Align-Affinity Water liaison regarding tunnelling – Align, Affinity Water, HS2. Discussion focussed around likely approach to tunnelling and raising of any issues associated with that.

7 Next Steps

7.1.1 The operators of the private abstractions associated with the laboratory and the sailing club will be contacted for additional details in order to properly assess the likelihood of any impacts upon their water supplies.

7.1.2 Further liaison will be undertaken with the Environment Agency regarding consent applications for construction, and in particular the supporting evidence and any mitigation that is required.

7.1.3 This assessment would need to be updated if polymers are taken forward as an appropriate support fluid for the piling holes.

Appendix A – Viaduct engineering geology interpretation

(note: the geological interpretation between figures displaying Pier 33-41 and Pier 42-52 is not continuous with regard to the weathered chalk due to the absence of boreholes through this section to establish the exact nature of the ground conditions).

Figure A-1: Pier 1 to 14. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100106

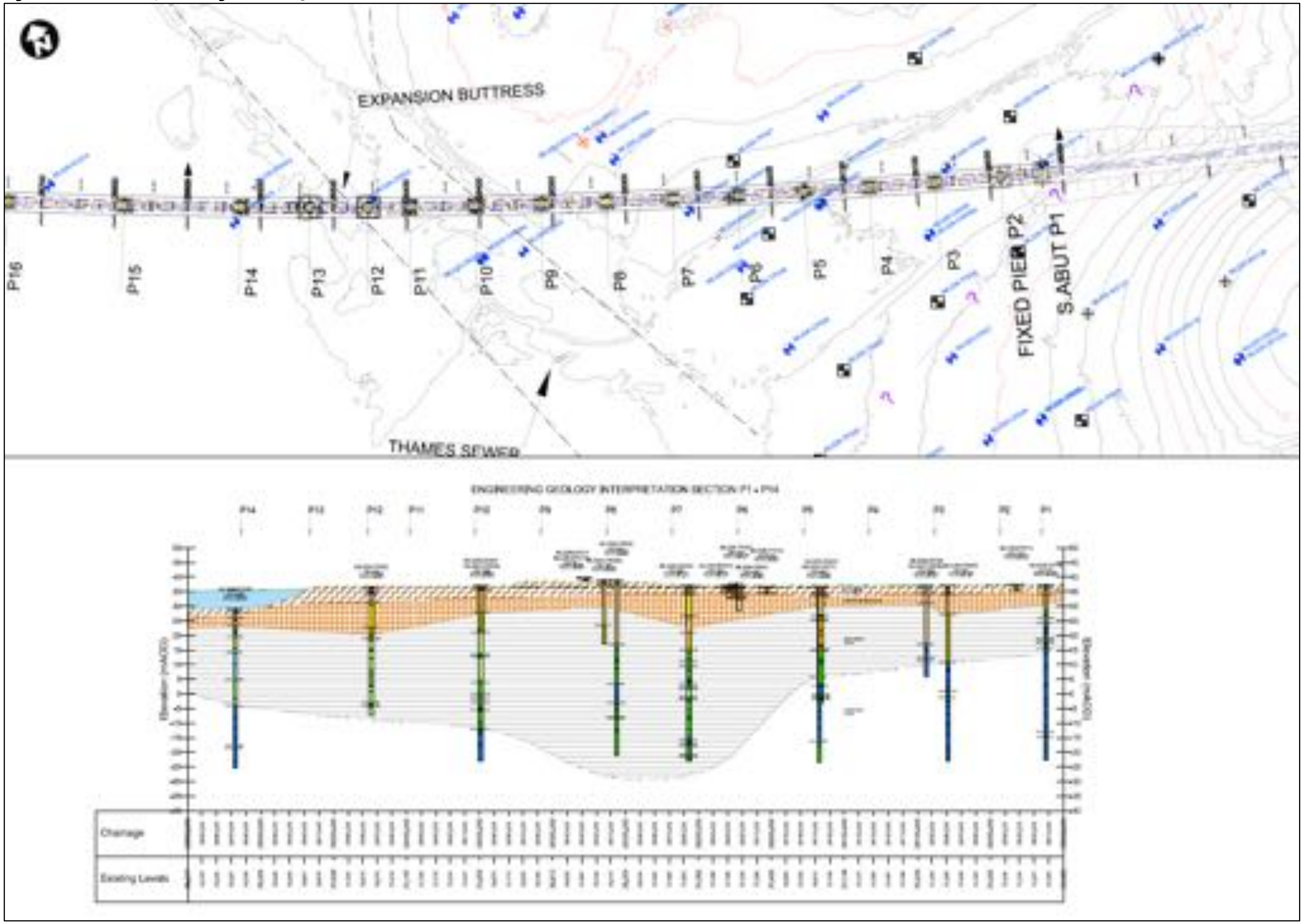


Figure A-2: Pier 15 to 22. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100108

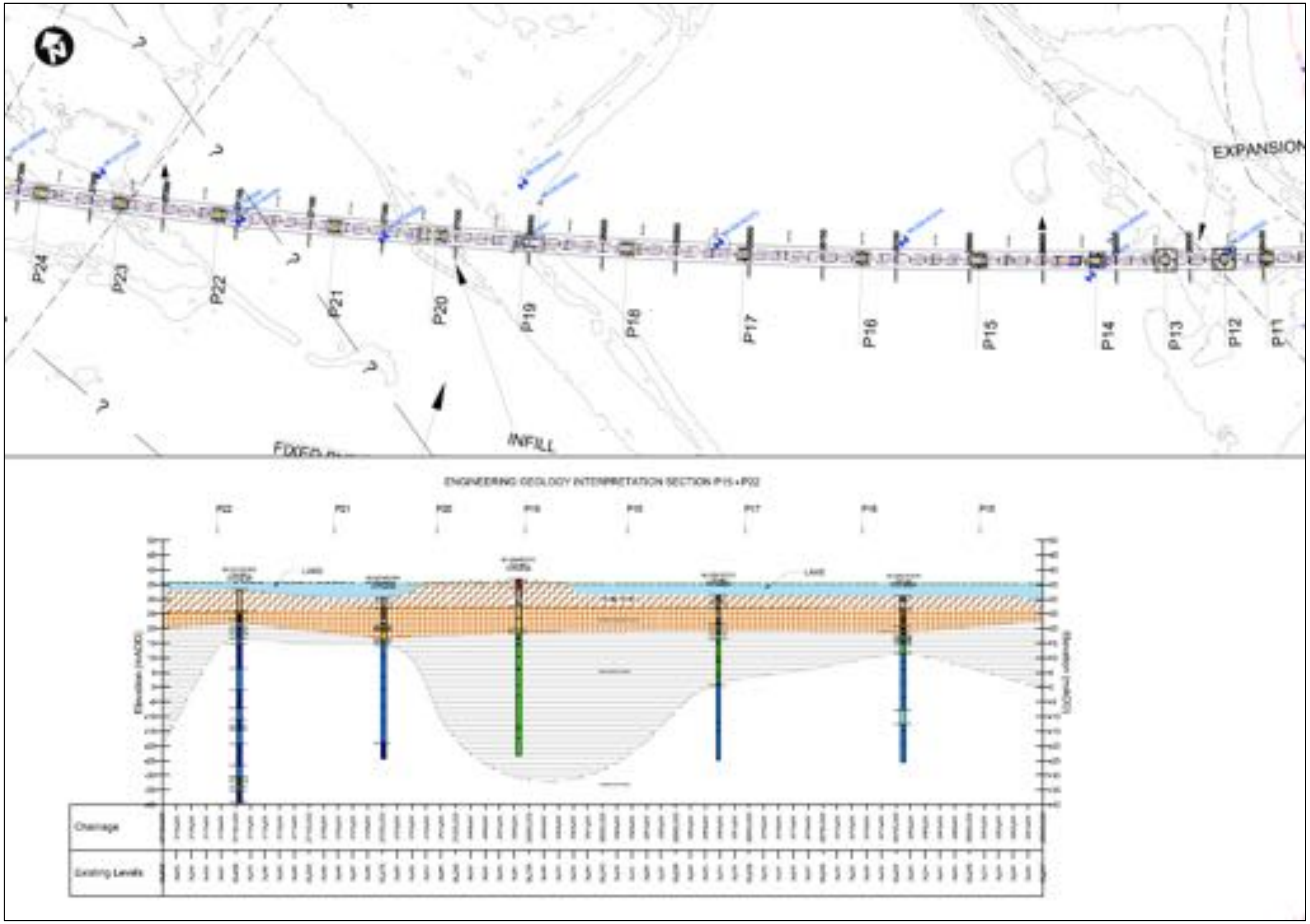


Figure A-3: Pier 23 to 32. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100110

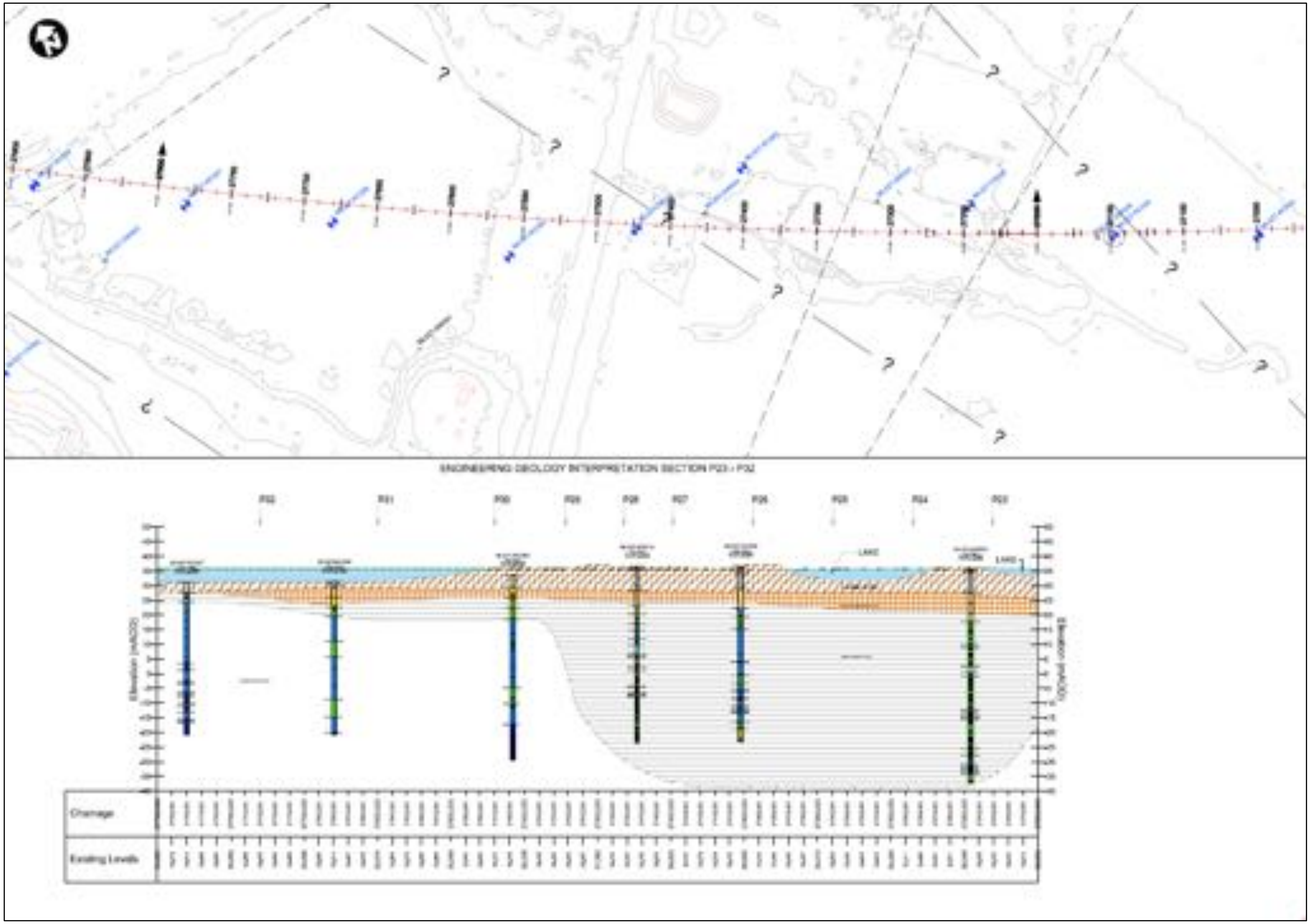


Figure A-4: Pier 33 to 41. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100112

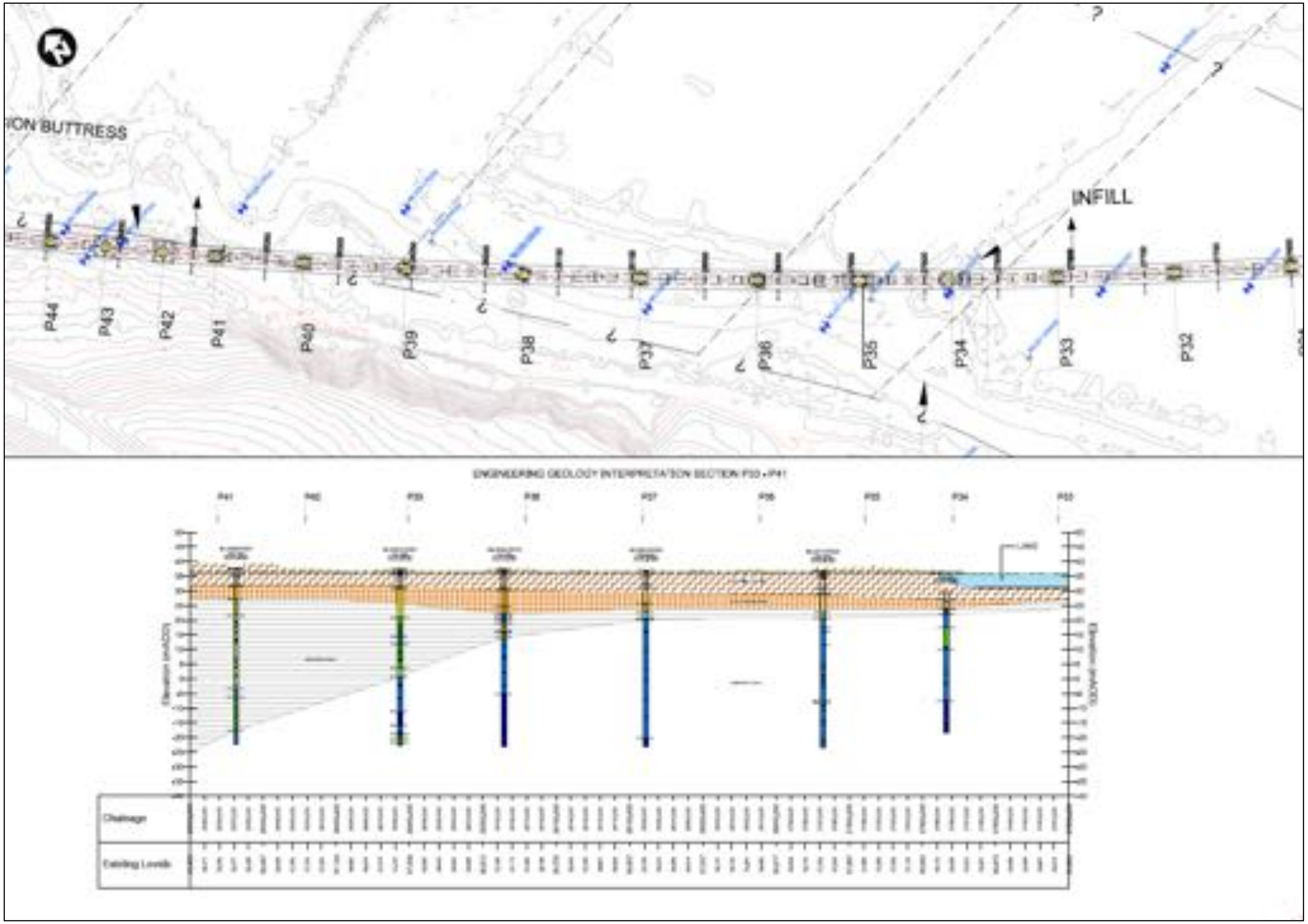


Figure A-5: Pier 42 to 52. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100114

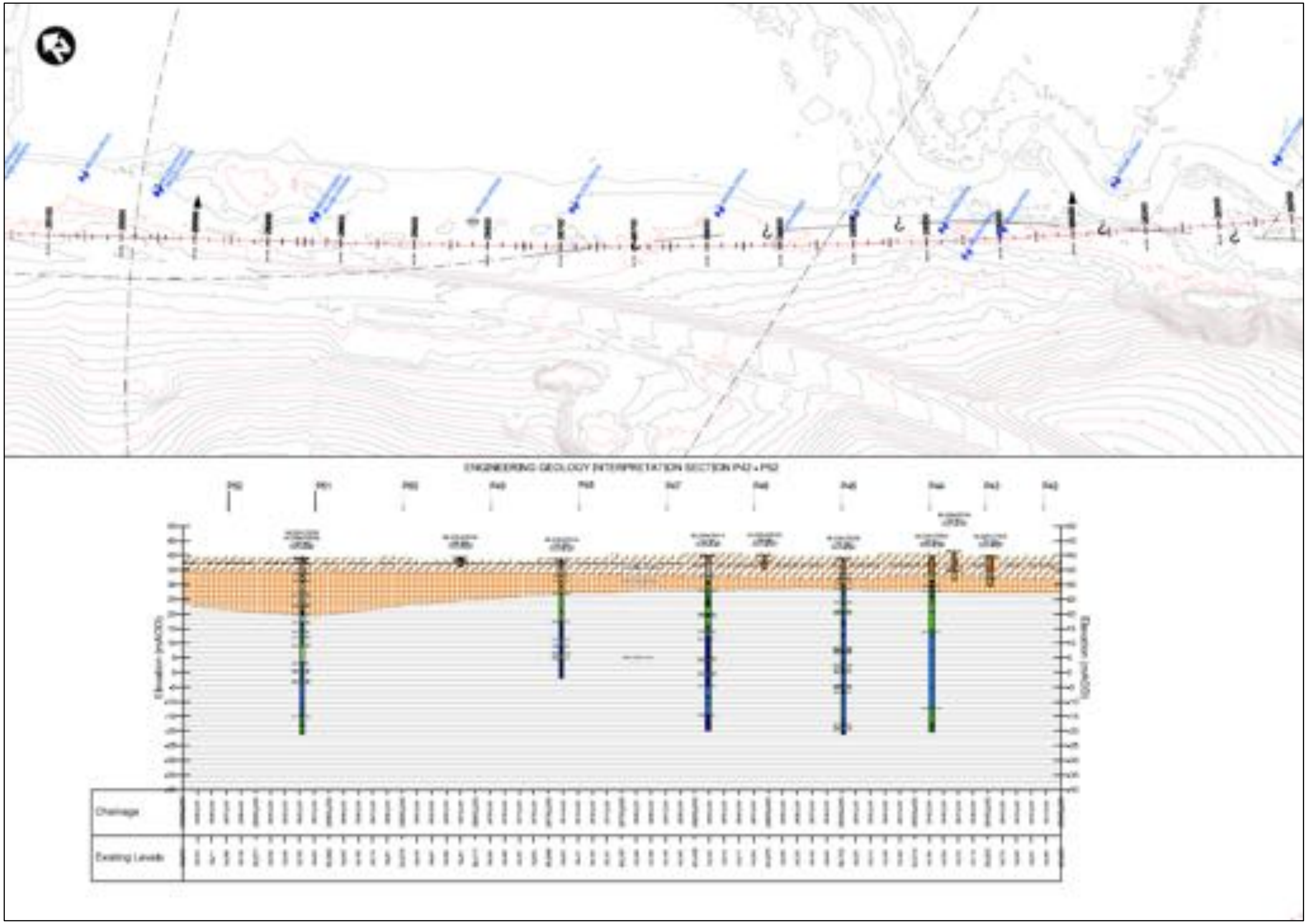


Figure A-6: Pier 53 to 58. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100116

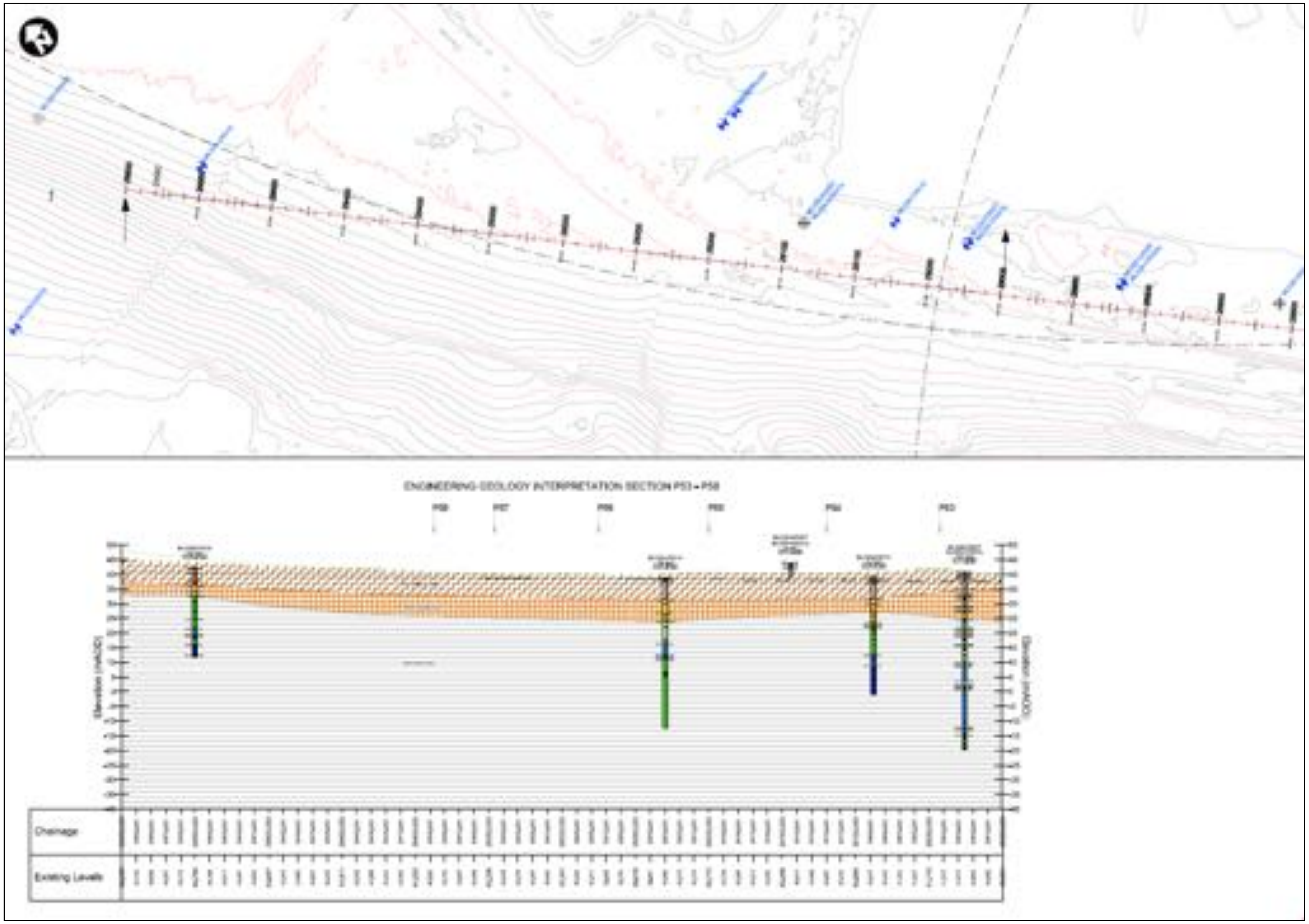
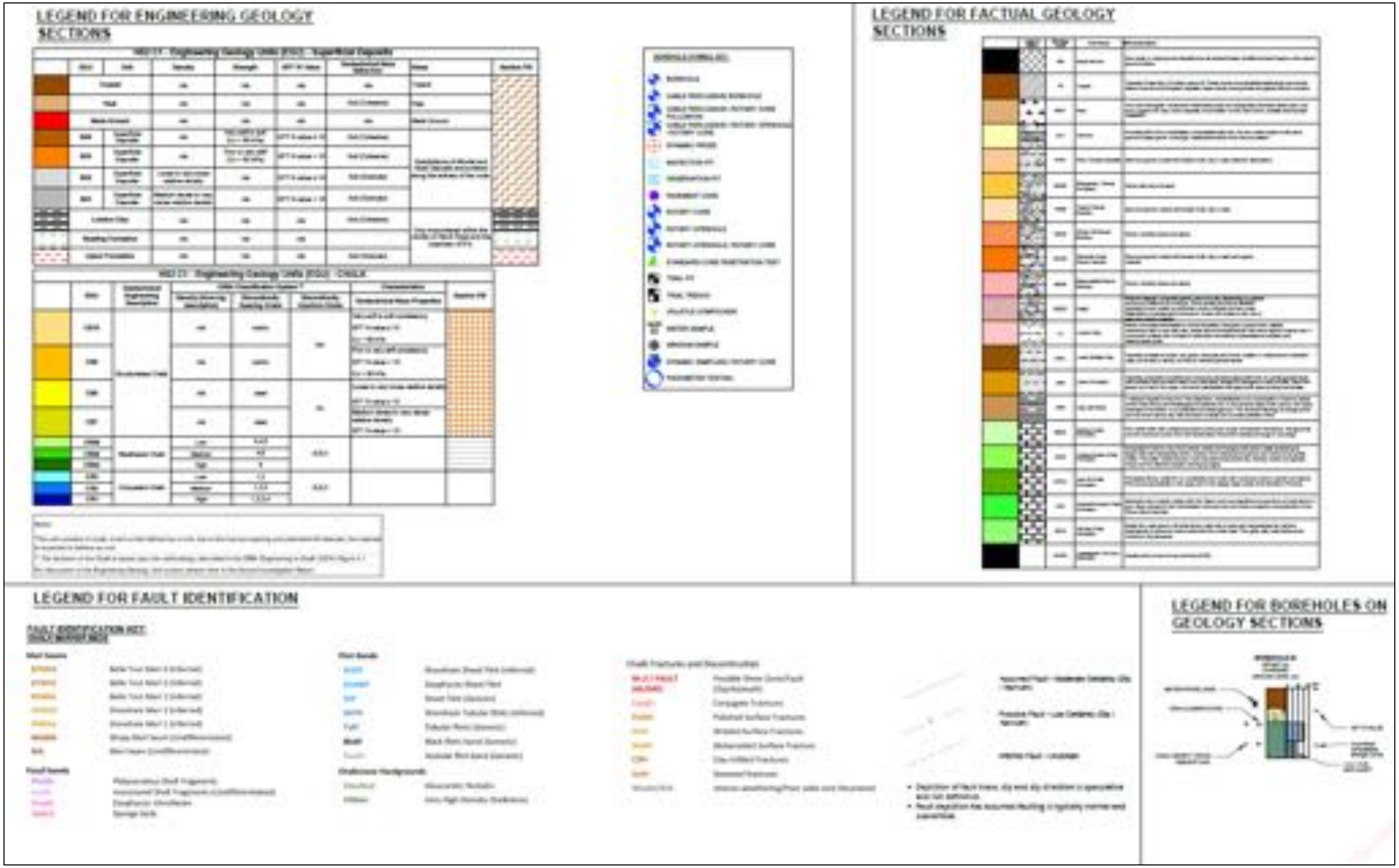


Figure A-7: Legend sheet. Drawing No: 1MC05-ALJ-GT-DGA-C001-000012



Appendix B – Viaduct geological section

Figure B-1: Pier 1 to 14. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100107

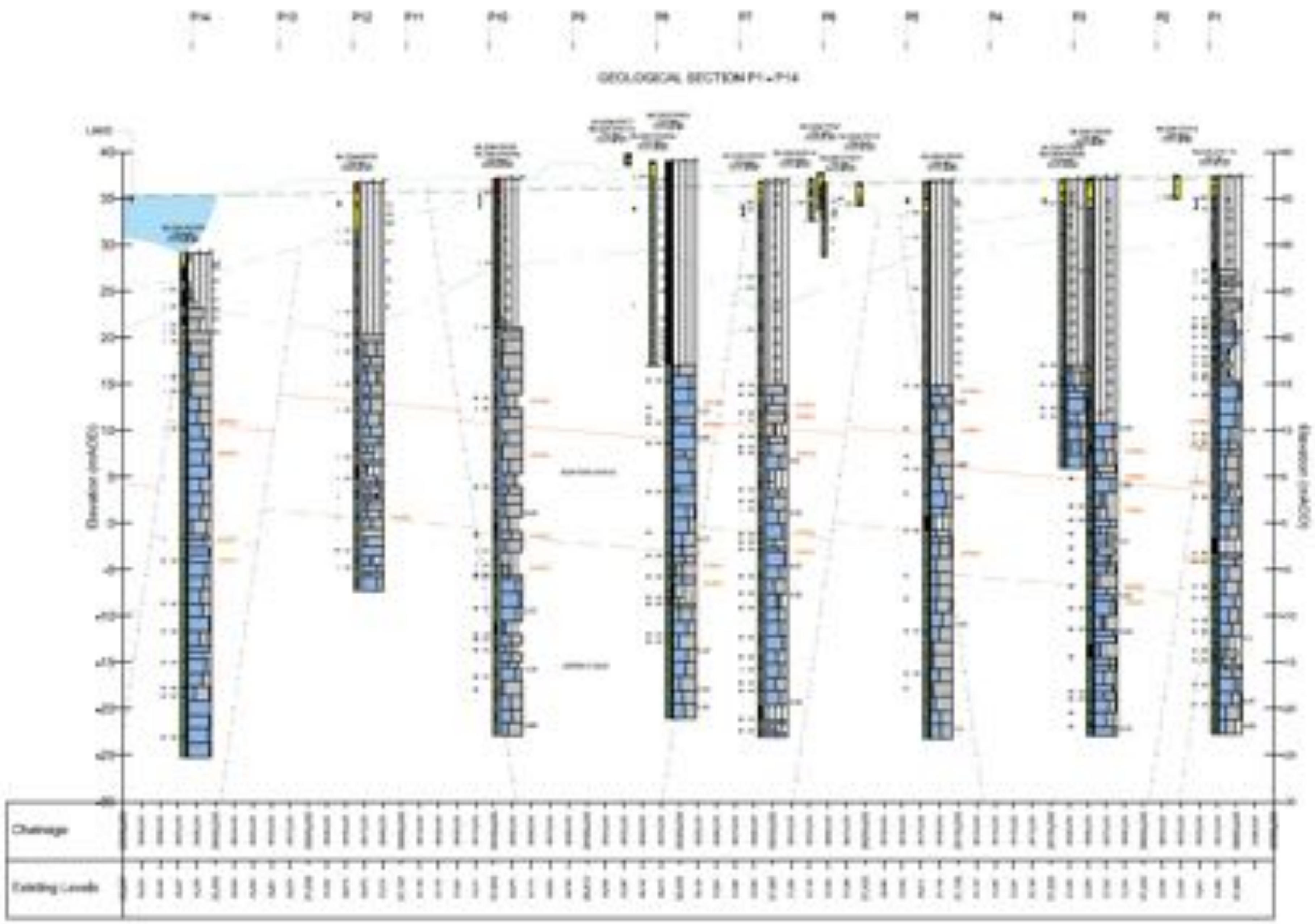


Figure B-2: Pier 15 to 22. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100109

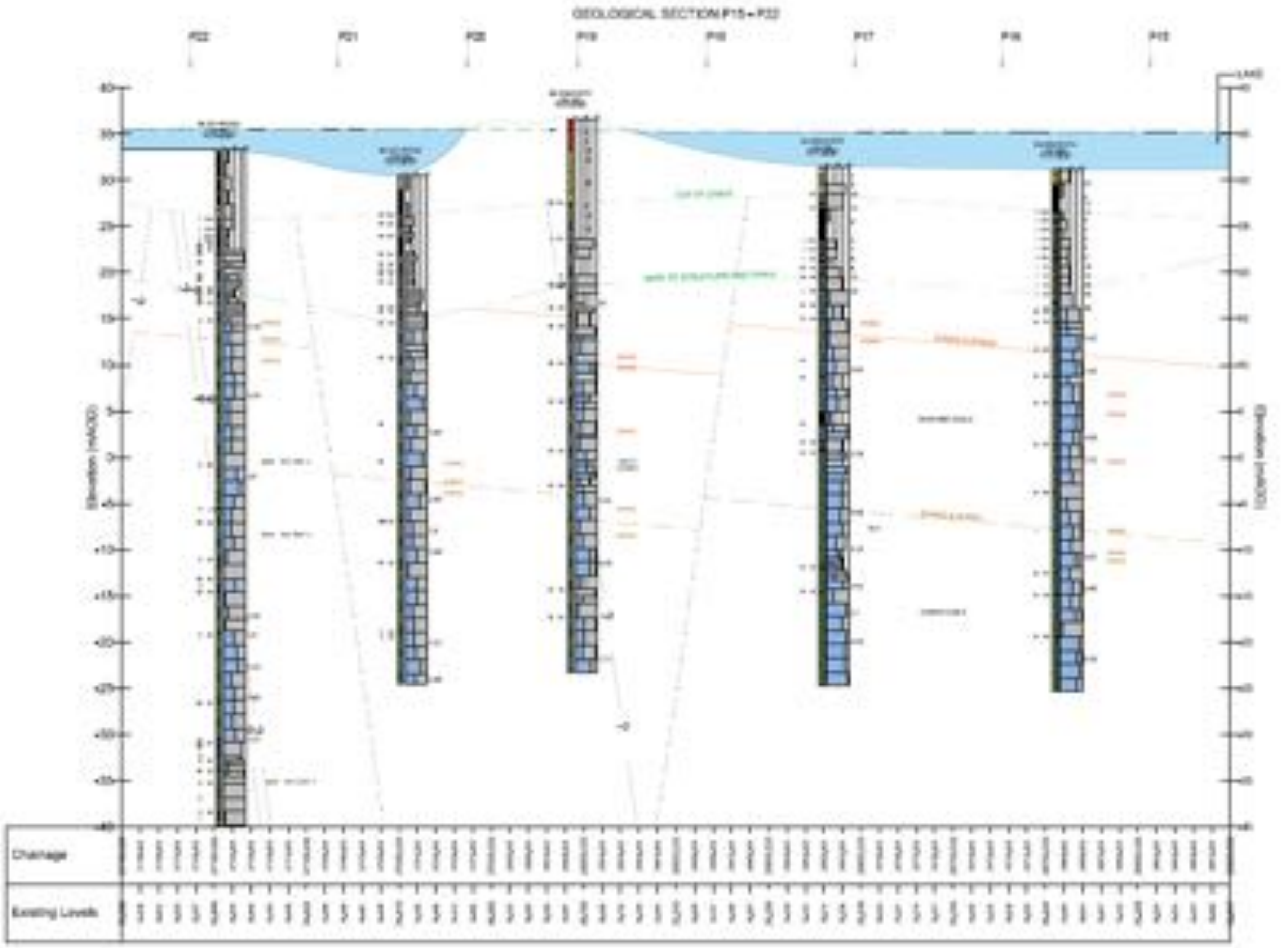


Figure B-3: Pier 23 to 32. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100111

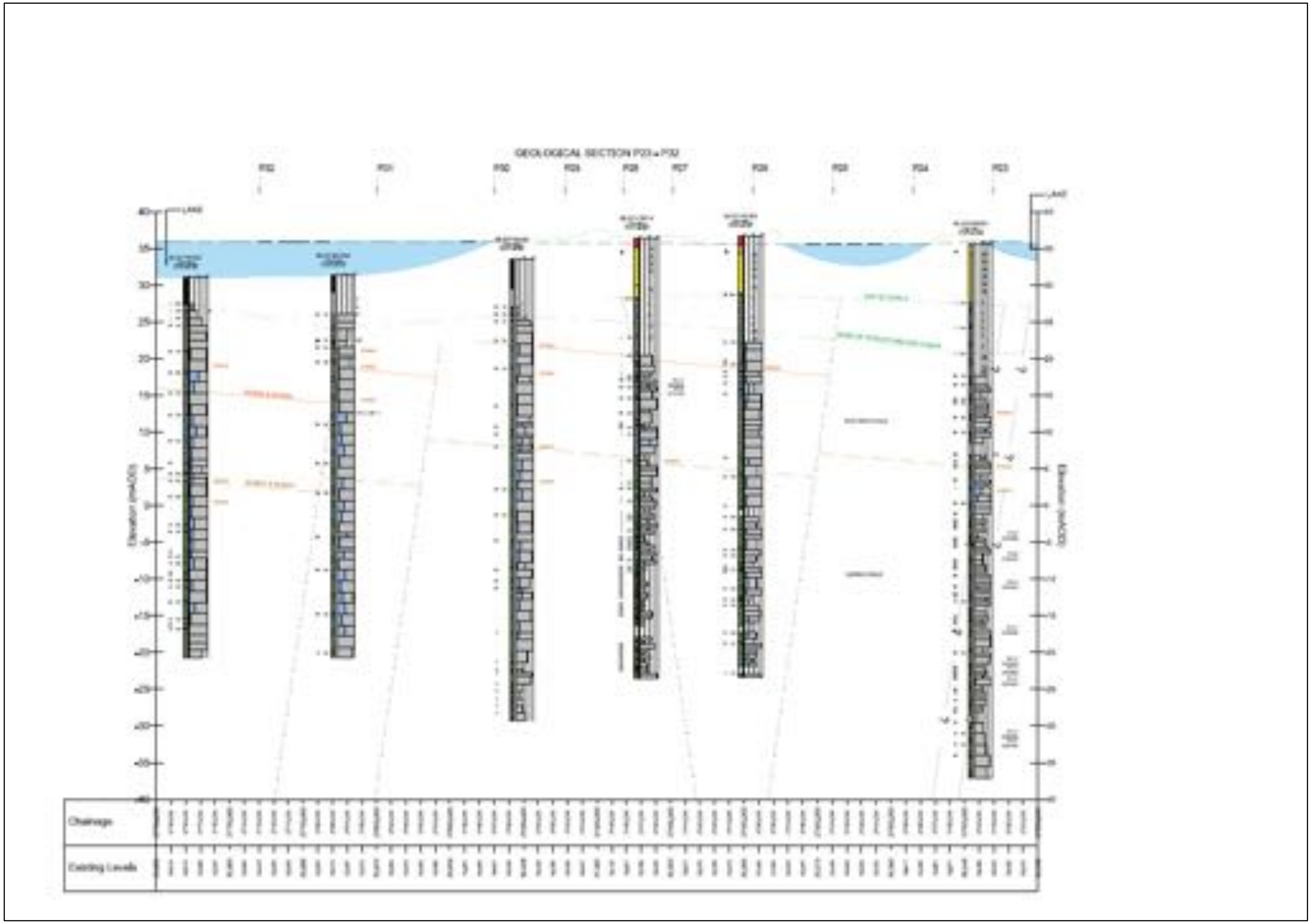


Figure B-4: Pier 33 to 41. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100113

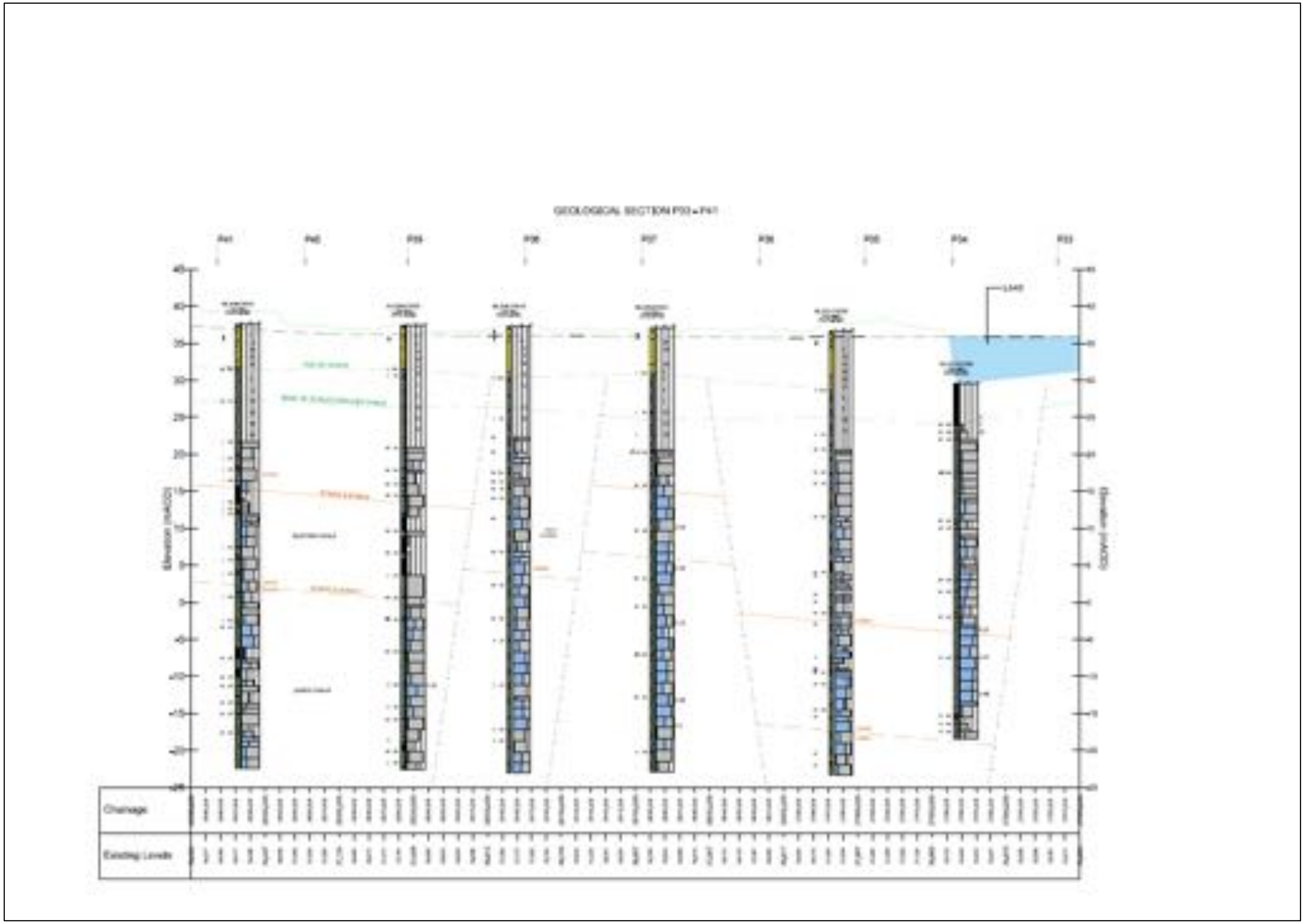


Figure B-5: Pier 42 to 52. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100115

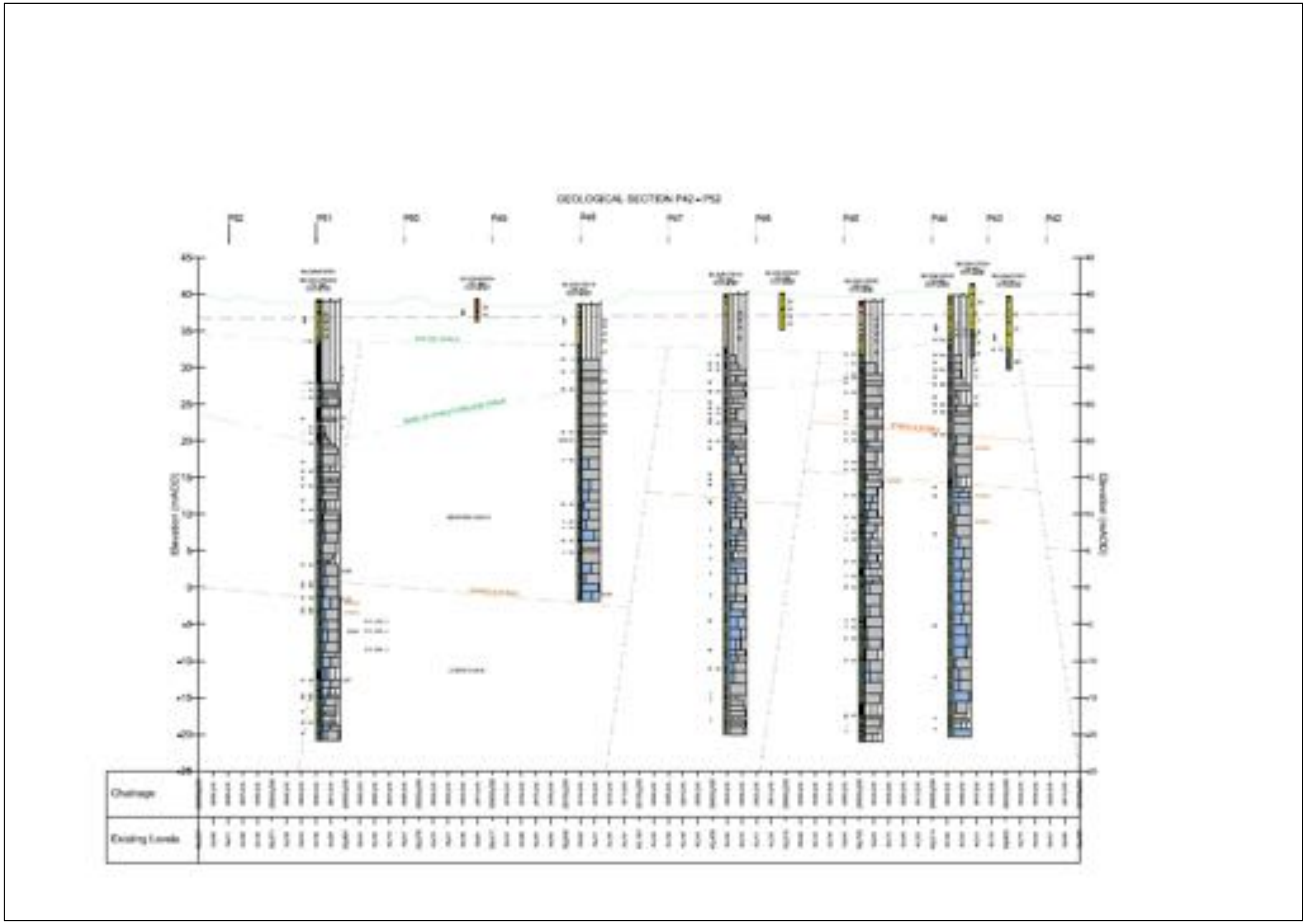


Figure B-6: Pier 53 to 58. Drawing No: 1MC05-ALJ-GT-DGA-CS01_CL01-100117