Robust Geotechnical Hazard Identification and Assessment for Major Underground Projects in Qatar. Case Study: South of Wakrah Pumping Station and Outfall (SWPSO) Project

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Abstract

The recent global development in geotechnical and geophysical investigation methodologies has continued to improve the possibility of early identification of critical geohazards and mitigation of risks associated with construction of large underground projects. This is not only limited to highlighting the potential risks, but also minimizing the cost and time for construction by avoiding or mitigating unexpected risks. A case study is presented by a recent unprecedented tunneling project in the State of Qatar featuring a 4.5-8.5 meters diameter, 55 kilometers in length, with various deep shafts, pumping station, and outfall in the Al-Wakrah city. Following an extensive desk study from available geotechnical and geophysical data in the vicinity of the project area and from previous practical experience from similar projects, a thorough geotechnical and geophysical investigation campaign was planned and executed. The result of the comprehensive ground investigation gave a clear picture of expected geohazards and prospective mitigation measures to be taken during the construction of the works. The paper presents a description of the main identified geohazards, including the presence of chert bands, karstic areas, massive caverns, high permeability areas, and high aggressiveness ground conditions along with its implications and mitigation measures, to be taken into account in the next stages of the project. A similar approach can be adopted for future infrastructure projects to support the geotechnical risk assessment and to minimize the impact of construction activities on the environment.

Keywords: Geotechnical hazards; Geohazard; Risk assessment; Deep excavations; Underground project

1 Introduction

In the State of Qatar, the recent, fast urban development around the capital city, Doha and its commercial and residential areas, Al-Wakrah city and Al-Khor city (all three collectively named Greater Doha), has led to an increase in the population and, consequently, an increase in the demand for all life needs, which has necessitated fast planning and construction of adequate and efficient infrastructure such as roads, drainage systems, water distribution networks, and all other related facilities. This rapid development in residential and commercial buildings without the presence of suitable infrastructure services has resulted in the rise of groundwater table and led to the creation of isolated water bodies (commonly called perched water) exacerbated by the presence of sabkha soils (which always facilitate the creation of perched water).

Historical events of recent storm rains that caused complications and even flooding in key areas were recorded and various levels of damage to the existing infrastructure was observed. In fact, a recent study carried out by Public Works Authority (Ashghal) in Greater Doha to monitor the existing groundwater conditions illustrated the continuous rise in groundwater and surface water tables. Thus, a strategic plan to find solution to these undesirable occurrences was considered as part of the local development strategy in line with the Qatar National Vision 2030.

Even though the extensive experience gained during the execution of significant infrastructure projects in Qatar, like the Inner Doha Re-sewerage Implementation Strategy (IDRIS), the Doha South Terminal Pumping Station (DSTPS), and the Musaimeer Pumping Station and Outfall (MPSO) (Ashghal and Stantec, 2019), has improved current understanding of the expected hazards, the role of geotechnical, hydrogeological, geophysical, and geo-environmental conditions in the proper project risk assessment continues to be one of the major challenges during the engineering design and construction stages.

Therefore, to support the geotechnical risk assessment and reduce the negative effects of construction activities for upcoming infrastructure projects, a more objective and consistent assessment of hazards is proposed using the information obtained during the respective ground investigation campaign (Ashghal & ZETAS, 2022). This information consists of geotechnical, hydrogeological, geophysical, and geo-environmental assessments employing lessons learned from a recently completed ground investigation program for the South of Wakrah Pumping Station and Outfall (SWPSO) project.

2 Project Background

2.1 General

The South of Wakrah Pumping Station and Outfall (SWPSO) project is a key capital project in the State of Qatar, whose major goal is to provide a long-term optimum strategic drainage system for stormwater and groundwater in the catchment area of Al-Wakrah city and South of Wakrah area. This is one of the most severely affected areas by the water rise and flooding during storm events. The project is currently in the tender design stage with Public Works Authority (Ashghal) at an estimated value (Capex) of $2 billion USD. The SWPSO project is divided into three biddable contracts, as presented in Fig. 1, and comprises the following main components:

1. Catchment area of 475 square kilometers approximately.
2. Onshore micro tunnels and tunnels:
   - Total length – 46 kilometers approximately.
   - Internal diameter ranges 1.0 – 8.0 meters approximately.
   - Depth ranges 15 – 50 meters approximately.
3. Onshore access and tunnel boring machine (TBM) launching/receiving shafts:
   - Internal diameter ranges 8.0 – 20.0 meters approximately.
   - Depth ranges 15 – 50 meters approximately.
4. Onshore pumping station shaft and screen shafts:
   - Internal Diameter ranges 40 – 80 meters approximately.
   - Depth ranges 45 – 55 meters approximately.

5. Emergency flooding area/lagoon (EFA) next to the Pumping Station.
6. Marine outfall tunnel:
   - Total length – pending authority's decision.
   - Internal diameter – 8.5 meters approximately.
7. Cross-catchment connection tunnel options:
   - Total Length – 9 kilometers maximum.
   - Internal diameter ranges 3.0 – 4.5 meters approximately.
   - Depth ranges 20 – 40 meters approximately.

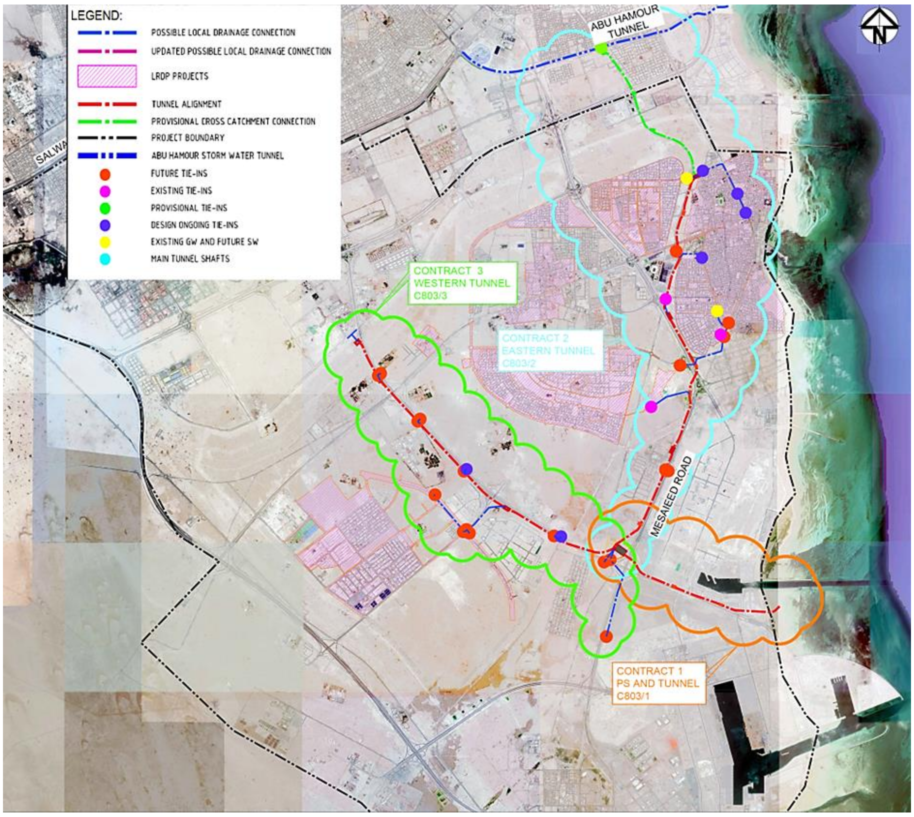

Fig. 1: SWPSO Project Plan Showing Pumping Station Area with EFA (Middle Junction) and Tunnel Alignment for Contract 1 (Orange), Contract 2 (Blue), and Contract 3 (Green)

2.2 Ground Investigation

The construction of deep underground works with changing ground and geological conditions, excessive groundwater inflow, presence of potential cavities and karstic features, aggressive chemical conditions, and the existence of chert bands and other hard strata as identified from previous major infrastructure projects in Qatar constitute the majority of the SWPSO project's potential geohazards.

As such, a comprehensive subsurface investigation program was planned and conducted to delineate the soil, rock, and groundwater conditions in the project area. The program consisted mainly of land-based geotechnical exploratory borehole drilling along the tunnel alignments and pumping station area followed by field testing efforts conducted in the boreholes and laboratory testing works conducted on extracted rock core and groundwater samples. The ensuing onshore site characterization and geotechnical interpretation are based on an integrated approach that combines the site-specific data collected from exploratory borings, field, and laboratory testing in combination with subsurface geometry imaged by the onshore geophysical survey works.

The purpose of this geotechnical exploration program was basically to reveal the site data obtained by exploratory core drilling, in-situ, and laboratory testing, geophysical and hydrogeological surveys in the perspective of physical, dynamic, and chemical properties of encountered soil and rock units towards geotechnical assessment of subsurface conditions in project area. This exploration program was undertaken to provide information necessary for the assessment of ground and groundwater conditions, and in turn the identification and assessment of potential geohazards, at the underground tunnels, launching/receiving shafts open excavations, and the pumping station site.

3 Geotechnical Hazard Identification & Assessment

3.1 Purpose

The main goal of the proposed methodology is to provide a more objective and consistent assessment of geohazards along SWPSO project tunnel alignment using the factual information obtained during the respective ground investigation campaign. The proposed methodology enables both qualitative and quantitative risk assessment, risk mitigation, and contingency planning by prospective future bidders for SWPSO project. The following main criteria are to be considered in the geohazard assessment based on applicable construction-related risks as identified from previous similar projects in Qatar all with consideration to the existing ground environment in the project area:

1) Groundwater Inflows/Permeabilities at tunnel footprint and open excavations.
2) Karstification/Cavities/Geophysical Anomalies at tunnel footprint and open excavations.
3) Chert/Hard strata (UCS over 50 MPa) at tunnel footprints and open excavations.
4) Ground conditions for open excavation (extent of soil cover and weak rock).
5) Ground/groundwater chemical aggressiveness at tunnel footprint and open excavations.

3.2 Proposed Methodology

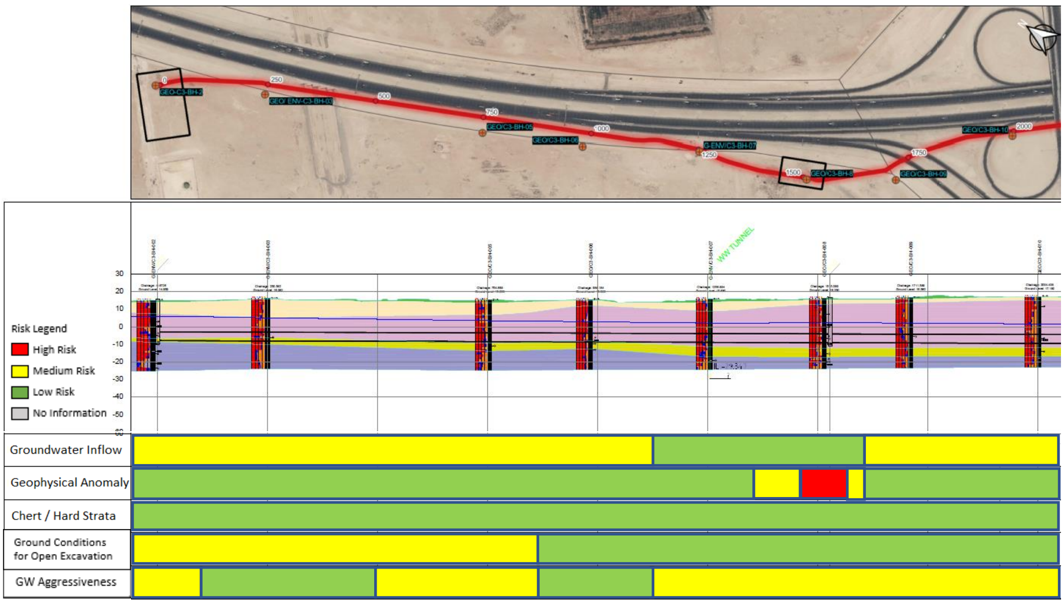

Fig. 2: Hazard Identification and Assessment Sample Schematic

A sample hazard identification and assessment for the first two kilometers (CH 0 – CH 2000) for Contract 3 (C3) project tunnel alignment is shown above in Fig. 2. The five (5) specific construction-related geohazards are presented along the tunnel alignment longitudinal profile with a color scale for an easy visual identification of the geohazards. In assessing and eventually deciding on the corresponding occurrence probability (color) of each geohazard, an objective, and systematic approach was adopted to ensure consistent assessment that inherently takes into consideration the varying encountered conditions along the tunnel alignment profile. The geohazard-pertaining calculation is explained in detail below.

3.2.1 Hazard #1: Groundwater Inflows/Permeabilities

Experience shows that the primary hazard to be immediately identified from the ground investigation campaign for this type of underground project in Qatar is the potential high groundwater inflows during open excavations or tunnel boring machine (TBM) advancement due to:

1) Existing high rock mass hydraulic conductivities/permeabilities.
2) Excavation through Simsima limestone/Midra shale or Midra shale/Rus formation interfaces.
3) Presence of interconnected karstic features and associated preferential groundwater flow paths.

The impact of an unexpected high groundwater inflow is the potential flooding of deep excavations and tunnels, which will in turn cause delays and additional design and construction costs, making this a considerable risk that needs to be identified and prepared for before starting construction. To address each of the above three (3) reasons for potential high groundwater inflows, the following three (3) criteria are considered along the tunnel footprint (1.5 diameter above and 1.5 diameter below the tunnel centerline):

1) Lowest rock quality designation value (*RQD*%), as determined from exploratory boreholes.
2) Coefficient of hydraulic conductivity, *k* (m/s), as determined from Falling head or Packer tests.
3) Number of geological formations crossed (e.g., Simsima limestone, Midra Shale, RUS formation).

Both the RQD and k-value criteria are assigned specific contributions (weights) to the overall hazard score based on their relevance and how they compare against the respective practical maximum values. An additional hazard score is added whenever more than one formation is crossed along the tunnel footprint during TBM advancement or during open excavation. A sample calculation is shown in Table 1 below, with the hazard criteria and hazard scores for the first two kilometers (CH 0 – CH 2000) for Contract 3 (C3) project tunnel alignment, as shown above in Fig. 2.

Table: 1 Groundwater Inflow Hazard Assessment Calculation

Groundwater Inflow Hazard Assessment		**Max RQD = 100%**		**Max k-value = 1x10^{-5}**				
Tunnel Footprint (1.5D Above & Below)	BH-02	BH-03	BH-05	BH-06	BH-07	BH-08	BH-09	BH-10
Lowest RQD (%)	20	15	60	50	30	60	25	0
Permeability (m/s)	5.4 x 10^{-7}	5.4 x 10^{-7}	5.4 x 10^{-7}	1.7 x 10^{-6}	2.4 x 10^{-6}	3.0 x 10^{-6}	3.2 x 10^{-6}	3.4 x 10^{-6}
Formations Crossed	2	2	2	2	1	1	1	1
Lowest RQD (%)	16%	17%	8%	10%	14%	8%	15%	20%
Permeability (m/s)	4%	4%	4%	13%	19%	24%	26%	27%
Formations Crossed	40%	40%	40%	40%	0%	0%	0%	0%
Hazard Score (Out of 100%)	60%	61%	52%	63%	33%	32%	41%	47%
Hazard Criteria	0-33% Low	33-66% Medium	66-100% High		Weights: RQD → 20% k-value → 80% Crossing more than one formation → +40%			

3.2.2 Hazard #2: Geophysical Anomalies/Cavities

Experience also shows that one of the critical hazards to be identified from the ground investigation for this depth, especially for the encountered ground conditions, is the presence of karstic features, cavities, caverns, or sinkholes, all of which constitute geophysical anomalies, specifically when clashing with vicinity of open excavations or tunnels footprint.

As evident from multiple previous similar underground projects, the fractured sedimentary rock mass of Qatar exhibits karstic features due to progressive dissolution of soluble carbonate sequences, such as limestone, dolomite, and gypsum, which may or may not be filled with groundwater. The impact of an unexpected geophysical anomaly is the potential relocation of open excavation shafts or shifting of tunnel level and the additional time and cost for adjusting the design, construction, and remedial works, marking this as another considerable risk that needs to be identified and accounted for.

To identify the possibility of having a geophysical anomaly, the following three (3) criteria are proposed to be considered along the tunnel footprint (2 diameters above and 2 diameters below the tunnel centerline):

1) Shear wave velocity, V_s (m/s), from geophysical survey (e.g., MASW, Seismic refraction).
2) Shear wave velocity, V_s (m/s), from P-S logging at exploratory boreholes locations.
3) Penetration drilling rate (m/h) from diagraphy drilling method.

Both shear wave velocities (*Vs*) are indicative of the stiffness of the scanned rock mass and, thus, are direct indicators of open/filled cavities or vugs. Both are relatively assigned the same contribution (weight) to the overall hazard score based on how they compare against a practical range of Vs values that were selected based on actual observations from previous projects.

Although seldom occurring, geophysical anomalies can be readily identified through normal and diagraphy borehole rotary drilling operations through an abnormal freefall of drilling rods or a considerably low total core recovery (TCR %) at which the drilled area shall also be marked as high possibility of having a geophysical anomaly. Hazard level may be exceptionally chosen based on other evidence or project location (e.g., near the shore). A sample calculation is shown in Table 2 below, with the hazard criteria and hazard scores for the first two kilometers (CH 0 – CH 2000) for Contract 3 (C3) project tunnel alignment.

Table 2: Karstification/Cavities/Geophysical Anomalies Hazard Assessment Calculation

Karstification/Cavities/Geophysical Anomalies Hazard Assessment									
Tunnel Footprint (2D Above & 2D Below Centerline)	BH-01	BH-02	BH-03	BH-05	BH-06	BH-07	BH-08	BH-09	BH-10
Vs from Geophysical Survey (m/s)	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Diagraphy Drilling Rate	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	High Risk	Low Risk	Low Risk
Hazard Level	(green)	(green)	(green)	(green)	(green)	(green)	(red)	(green)	(green)
	Hazard Determination: Vs > 1250 m/s → Low Risk 750 m/s < Vs < 1250 m/s → Medium Risk Vs < 750 m/s → High Risk					Diagraphy Drilling Rate: Low Risk: < 200 m/h Medium Risk: 200-500 m/h High Risk: > 500 m/h			

3.2.3 Hazard #3: Chert / Hard Strata

Experience also shows another crucial hazard to be identified from the ground investigation campaign for this deep underground project: the presence of chert bands within the Simsima limestone formation. These are high-strength sedimentary rock with unconfined compressive strength (UCS) values of 120-250 MPa, which can cause damage to excavation and drilling equipment.

Previous similar underground projects reported multiple occurrences of chert bands at varying depths during the excavation and construction and were mainly documented as follows:

- Chertified zones in Simsima limestone that were typically found at 6 to 10 meters depths and,
- RUS chert veinlets that were mostly at 35 to 50 meters depths, but much thinner.

The presence of unusually strong rock bands or hard strata can impose detrimental time and cost impacts due to low excavation production rates and potential damage to the cutting tools of the excavators and the TBM's discs and cutter heads during tunnel drilling operations. Therefore, this hazard constitutes a considerable risk that needs to be properly identified and planned against.

To identify all locations with problematic hard strata, the following two (2) criteria are proposed for consideration along the tunnel footprint (1.5 diameter above and 1.5 diameter below the tunnel centerline) and open excavation/shaft footprint (up to tunnel depth):

1) Presence of chert bands of any thickness or form as determined from exploratory borehole logs.
2) Hard Rock Strata of UCS values greater than 50 MPa as determined from laboratory testing.

Both the above parameters are direct indicators of the hardness and excavatability of the rock mass. The presence of chert bands is assigned a higher contribution (weight) to the overall hazard score since they are considerably stronger than any of encountered rock formations.

The UCS value of 50 MPa is statistically nominated as the upper bound value ($\mu + 2\sigma$) based on findings and distribution of UCS testing results from previous similar projects, and thus, any UCS value exceeding 50 MPa is deemed an outlier. Other than that, the hazard score may be exceptionally chosen based on other evidence that supports the need for stronger excavation or tunneling equipment. A sample calculation is shown in Table 3 below, with the hazard criteria and hazard scores for the first two kilometers (CH 0 – CH 2000) for Contract 3 (C3) project tunnel alignment.

Table 3: Chert or Hard Strata Hazard Assessment Calculation

Chert or Hard Strata (UCS >= 50 MPa) Hazard Assessment								
Borehole Location	BH-02	BH-03	BH-05	BH-06	BH-07	BH-08	BH-09	BH-10
Tunnel Footprint (1.5D Above & Below)	None	None	None	None	None	None	None	None
Shaft Footprint (Up to Tunnel Depth)	None	None	None	None	None	None	None	None
Hazard Score	Low	Low	Low	Low	Low	Low	Low	Low
Hazard Criteria	Low	Medium	High	Hazard Determination: If Either has Chert → High If Either has Hard Strata → Medium If Both are None → Low				

3.2.4 Hazard #4: Ground Conditions for Open Excavation

It is foreseen that at the open excavation locations, the overburden soils shall be retained by an engineered slope and that the excavation in the rock strata shall be near-vertical to vertical open cut excavation that is either unsupported or supported using shotcrete, combination of shotcrete and rock bolting, secant pile walls, or diaphragm walls depending on the overall geotechnical designs for temporary and permanent works. Thus, an additional important hazard that must be identified from the ground investigation campaign for this underground project is the presence of weak ground conditions that can affect ground stability of deep excavations, wherever they may be (not necessarily at open excavation locations only). Indeed, varying thicknesses of weak ground conditions (soil and weak rock) were encountered along the project tunnel alignments, with the thicknesses characteristically increasing toward the shoreline.

The impact of a considerable extent of loose quaternary deposits (QD) and/or highly-weathered Simsima limestone rock (WSL) will detrimentally affect the overall stability of deep unsupported open cut excavations and may cause large displacements that might affect assets in the vicinity of the excavation, all of which can cause additional time and cost impact for the design and construction of a proper excavation lateral ground support (shoring) system to guarantee the stability of the excavation and construction of additional remedial works.

To identify locations with problematic weak zones, the following two (2) criteria are proposed to be considered along the tunnel alignment, most confidently at the exploratory borehole locations:

1) Extent of Soil / Quaternary Deposits (QD) formation in meters (m).
2) Extent of Highly Weathered Simsima Limestone (WSL) formation in meters (m).

Summation of above two formation thicknesses is indicative of risky weak zones for the vertical excavation of unsupported shafts since the loose QD layer will not sustain itself vertically and the WSL layer is highly susceptible to progressive degradation due to air exposure and weathering.

The hazard criteria values are conservatively selected based on safe uptime of an unsupported excavation depth in zones with similar weak ground conditions as evident from previous excavations in Qatar, with more attention paid to the depth of QD layer to not exceed a limiting value of 5 meters. A sample of the calculation is shown in Table 4 below, with the hazard criteria and hazard scores for the first two kilometers (CH 0 – CH 2000) for Contract 3 (C3) project tunnel alignment.

Table 4: Ground Conditions for Open Excavation Hazard Assessment Calculation

Ground Conditions for Open Excavation Hazard Assessment								
Borehole Location	BH-02	BH-03	BH-05	BH-06	BH-07	BH-08	BH-09	BH-10
Soil / QD Depth	1	0	1	0.5	1	0.5	0.5	0
WSL Depth	4	7	4	2	3	1.5	1.5	1.5
Hazard Score	5	7	5	2.5	4	2	2	1.5
Hazard Criteria	Good (0-5 m) Low	Medium (5-10 m) Medium	Poor (< 10 m) High					

3.2.5 Hazard #5: Ground/Groundwater Chemical Aggressiveness

For the design of deep tunnels and shafts, the expected exposure conditions, driving deterioration mechanisms (chloride-induced corrosion, sulfate attack, and/or abrasion), and the measures taken against them are considered the principal factors which may influence the long-term durability of the concrete structures. In terms of groundwater exposure conditions, the most important parameters are the availability of oxygen and moisture, temperature, surface levels of chlorides, sulfates, and pH levels.

Following the above brief narrative, the last, but not least, hazard that must be identified from the ground investigation campaign for this underground project is the existence of aggressive ground and/or groundwater conditions affecting the durability of the permanent concrete structures. Historically, the majority of the recorded ground and groundwater chemical compositions in Qatar ground environment are indicative of an aggressive/corrosive environment to reinforced concrete members and structures. The considerable amounts of sulfates and chlorides in the encountered groundwater are expected to be particularly corrosive to steel reinforcement.

The impact of unaddressed high concentrations of sulfates and chlorides in the ground and groundwater can cause chemical and physical attacks on concrete structures, leading to surface deterioration, corrosion, and loss of reinforcement cover, causing the durability and service lives of permanent structures to be immediately damaged and reduced, eventually leading to additional time and cost impact for operations and maintenance works and increasing the life-cycle cost of the project.

To identify all locations with potential high ground/groundwater aggressiveness, the following main two (2) chemical contents were proposed to be measured along the tunnel alignment, as readily available from laboratory-tested groundwater samples from exploratory borehole locations:

1) Chloride (Cl) Groundwater Chemical Content (mg/L).

2) Sulfate (SO_4) Groundwater Chemical Content (mg/L).

Experience shows that the above two chemical contents are the most relevant factors in the durability of concrete structures in Qatar's ground conditions, as evident from concrete durability assessments from previous similar underground projects and as referred to immensely in Qatar Construction Specifications (QCS Technical Committee and Associated Subcommittees, 2014). The hazard criteria values are conservatively selected based on ranges of groundwater chemical composition and recommendation of durable concrete properties as stated in *QCS 2014, Section 05: Concrete*. A sample of the calculation is shown in Table 5 below, with the hazard criteria and hazard scores for the first two kilometers (CH 0 – CH 2000) for Contract 3 (C3) project tunnel alignment.

Table 5: Groundwater Chemical Aggressiveness Hazard Assessment Calculation

Groundwater Aggressiveness Hazard Assessment								
Borehole Location	BH-02	BH-03	BH-05	BH-06	BH-07	BH-08	BH-09	BH-10
Chloride (Cl)	Low	Low	Low	Low	Low	Medium	Low	Medium
Sulphate (SO_4)	Medium	Low	Medium	Low	Medium	Low	Medium	Low
Hazard Score	Medium	Low	Medium	Low	Medium	Medium	Medium	Medium

Hazard Criteria	Low	Medium	High	Hazard Determination:
				Both Low → Low
				Both Medium → Medium
				Both High → High
				If (1) Medium → Medium
				If (1) High → High
						CHLORIDE CONTENT (mg/l)
						< 3,000
						3,000 – 6,000
						> 6,000
								SULFATE CONTENT (mg/l)
								< 1,500
								1,500 – 3,000
								> 3,000

4 Conclusion

The main purpose of this paper is to document the assumptions, methodology, and lessons learned from the proposed geotechnical hazard identification and assessment exercise carried out for South of Wakrah Pumping Station and Outfall (SWPSO) project.

The main goal of the proposed methodology is to provide a more objective and consistent assessment of geohazards along deep underground projects using the information obtained during the respective ground investigation campaign. The proposed methodology enables both qualitative and quantitative risk assessment, risk mitigation, and contingency planning by prospective future bidders for deep underground infrastructure projects in the State of Qatar.

The five (5) main construction-related geohazards pertaining to Qatar were explained in detail throughout the course of the paper and the assessment of geohazards was presented along the tunnel alignment longitudinal profile of a case study project with a color scale for a rapid and simple understanding of the geohazards and their probability of occurrence.

References

Public Works Authority (Ashghal) and Stantec. (2019). Geotechnical Desk Study Report South of Wakrah Tunnels, Pumping Station and Outfall Project, Doha, Qatar.

Public Works Authority (Ashghal) and ZETAS, (2022). Geotechnical Interpretative Reports for Contracts 1, 2 and 3, South of Wakrah Tunnels, Pumping Station and Outfall Project, Doha, Qatar.

QCS Technical Committee and Associated Subcommittees. (2014). Qatar Construction Specifications Revision IV (QCS 2014), Doha, Qatar.

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