Southern Nevada Water Authority (SNWA) Risk Management Strategy to Create a Win-Win Situation for the Contractor, the Insurer, and the Owner on the “Lake Mead Intake No. 3 (LMIN3), Las Vegas, Nevada”

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1. INTRODUCTION

The Southern Nevada Water Authority (SNWA) awarded the construction of Lake Mead Intake No. 3 Project to Vegas Tunnel Constructors (a joint venture of S.A. Healy of USA and Impregilo of Italy). The Project consists of a deep-water intake, and a large-diameter (~ 20 feet internal) water supply tunnel between the intake and the construction shaft that connects to the existing pumping stations through a separate tunnel.

The project area is about 20 miles east of the City of Las Vegas, in the Lake Mead National Recreation Area, and the tunnel and intake are being constructed beneath Saddle Island and Lake Mead, terminating approximately 15,000 feet northeast of Saddle Island. The Project will pump the water through the existing pumping stations to the existing Alfred Merritt Smith Water Treatment Facility (AMSWTF) for treatment. Refer to Figure 1 for general location of various project components.

The intake will be north of the Las Vegas Wash, in the Boulder Basin of Lake Mead, and will be designed for a capacity of 1,200 million gallons per day (mgd) at an intake elevation of 860 feet (above mean sea level [amsl]). The intake will be a lake tap structure with a riser structure above the lake bottom and a shaft below lakebed that connects the riser to the intake tunnel. The riser structure will provide for a future extension to deeper waters northeast of the planned location.

In order to evaluate the risks associated with this project it was necessary to address what components of the project pose risks to successful completion of the project. Issues related to planning, bidding using design-build option for the construction of the project. The following paragraphs briefly describe the project components, site conditions and geologic underground conditions for the project that impact risks associated with the construction of the project.
2. LAKE MEAD INTAKE NUMBER 3 TUNNEL DESCRIPTION

The intake tunnel will connect the existing pumping stations on Saddle Island to the new intake riser. Elements that determine the location and alignment of the intake tunnel were:

- Location of the intake riser,
- Hydraulic requirements,
- Topography,
- Ground conditions, and
- Tunneling technology.

The LMIN3 tunnel will be constructed from a shaft near the existing pump stations with an uphill gradient to the connection with the intake riser. The topography between the intake riser and pumping station is highly variable as confirmed by pre-lake impoundment historic photographs and the results of the geophysical, bathymetric, and geotechnical field investigations. The most significant topographical feature between the intake riser and the existing pumping stations is the submerged continuation of the Las Vegas Wash. The intake tunnel needs to cross the submerged wash with adequate ground cover, creating a vertical constraint for the intake tunnel alignment.

This tunnel will be the deepest sub-aqueous tunnel constructed with a pressurized-face TBM in the world to date. The current lake level is 1,125 feet amsl; however, the lake has the potential to
rise to 1,230 feet. With a tunnel elevation of approximately 650 feet amsl, this Project will have a current hydrostatic pressure of approximately 14.6 Bar, but with a potential pressure of approximately 17.4 Bar. Tunneling in pressures of this magnitude in closed (pressurized-face) mode presents significant risks. Mitigation of these risks involves developing alignments and profiles that minimize this pressure, and tunneling in geologic units that minimize the amount of pressure necessary for stability and water control. These issues are discussed later in this paper.

Based on current evaluations, the selected corridor appears to offer the best potential to minimize the potential number of cutter-head interventions in hyperbaric conditions. The route also appears to offer the least adverse geological conditions and shortest construction period. Consequently the selected route should offer the lowest relative risk and lowest construction cost. However, this should not be interpreted that there will be no risk or challenges during construction.

3. PRELIMINARY ASSESSMENT OF SITE CONDITIONS

The geotechnical investigations included a desktop study of literature, field geologic mapping, bathymetric surveys, reflection seismic testing, and borings. The literature provided geologic information about origin and structure of the metamorphic bedrock of Saddle Island and areas northeast of Saddle Island that are now under Lake Mead. Field geologic mapping provided information about the three major geologic elements of Saddle Island, namely the lower plate, the upper plate, and the intervening detachment fault. The reflection seismic test program involved seismic lines on Saddle Island and seismic lines in Lake Mead within the corridor defined by the three tunnel alignments. The seismic results show two and three geologic units of different properties to a reported depth of 600 feet. The geotechnical program along the alignment consisted of nine fully cored land borings more than 600 feet deep and 16 borings in Lake Mead with depths below mudline ranging from 128 to 512 feet. Most of these borings were logged by temperature, gamma, optical, and acoustic devices and were water pressure tested. Laboratory tests on core samples have consisted of point load tensile and unconfined compression strength tests, and abrasivity tests.

3.1 Anticipated Ground Conditions

Table 3-1 presents general assessments of the geology and expected ground behavior in the selected tunnel alignment corridor. The preliminary opinion of lateral extent and expected behavior of the lower and upper plate metamorphics, weak and strong sedimentary rocks, and volcanic rocks along the tunnel corridors is based on limited subsurface information and, therefore, is subject to revision as new data become available. These preliminary assessments provide a framework on which to evaluate the relative ground conditions along the selected tunnel corridor. The main strata are terrestrial sedimentary rocks and volcanic rocks, which are likely to vary both laterally and vertically. Both units lack the “key beds” that assist in the stratigraphic definition of marine rock units. The site does not provide exposures of these units to allow correlations between the borings.

<table>
<thead>
<tr>
<th>Geologic Unit</th>
<th>Lower Plate Metamorphic</th>
<th>Upper Plate Metamorphic</th>
<th>Weak Sedimentary</th>
<th>Strong Sedimentary</th>
<th>Volcanic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Rock Condition</td>
<td>Strong, hard metamorphic rock with very hard igneous intrusions</td>
<td>Strong to weak metamorphic host rock with closely spaced very hard igneous intrusions</td>
<td>Massive, dense, generally low-strength mudstone, siltstone, sandstone, conglomerate/breccia</td>
<td>Massive, dense, medium-strength sandstone, conglomerate/breccia</td>
<td>Very weak andesite, diorite, and basalt mainly hydrothermally altered</td>
</tr>
</tbody>
</table>
### Table 3-1
Evaluation of Tunnel Corridor (Anticipated Conditions)

<table>
<thead>
<tr>
<th>Geologic Unit</th>
<th>Lower Plate</th>
<th>Upper Plate</th>
<th>Weak Sedimentary</th>
<th>Strong Sedimentary</th>
<th>Volcanic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metamorphic</td>
<td>Metamorphic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical Groundwater Condition</td>
<td>Dry except for high-pressure inflows at major discontinuities</td>
<td>Mostly wet because of high-pressure inflows at major discontinuities</td>
<td>Mainly dry, wet where the unit is porous</td>
<td>Mainly dry with wet zones where joints connect to the lake</td>
<td>Mainly dry except in non-altered zones where the rock is jointed</td>
</tr>
<tr>
<td>Abrasiveness</td>
<td>High</td>
<td>Very high</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Face Stability</td>
<td>Excellent; Face condition - firm</td>
<td>Generally good, fair where rock is weak and jointed; Face conditions - firm and raveling</td>
<td>Generally good, fair where ground is weak, poor where ground is wet; Face conditions - firm, raveling and flowing</td>
<td>Excellent; Face condition - firm</td>
<td>Fair to poor depending on degree of alternation and water; Face conditions - raveling and flowing</td>
</tr>
<tr>
<td>Risk of Hydrostatic Pressure over 10 Bar</td>
<td>High risk near and under Lake</td>
<td>High risk near and under Lake Mead</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Point Load Test, UCS, psi (high/low)</td>
<td>45,000/&lt;700</td>
<td>49,500/700</td>
<td>2,400/0</td>
<td>13,500/0</td>
<td>37,800/&lt;700</td>
</tr>
<tr>
<td>Approximate station intervals</td>
<td>0+00 to 10+00</td>
<td>10+00 to 65+00</td>
<td>65+00 to 120+00</td>
<td>120+00 to 160+00</td>
<td>160+00</td>
</tr>
<tr>
<td>Approximate total length (ft)</td>
<td>1,000</td>
<td>9,500</td>
<td>5,500</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 4. TUNNELING ISSUES IDENTIFICATION

Critical issues for the intake tunnel include design and operational criteria, ground conditions, constructability, and contractor means and methods. Methods of construction are typically determined by contractors for tunnel projects, with significant corresponding influence on cost, schedule, risk, and related construction impacts. A critical issue for tunnel construction is air quality in underground spaces. Underground ventilation systems that consist of portal fans, ducts, and booster fans in the tunnel provide sufficient air flow to dilute and remove carbon monoxide and other toxic gases and maintain an appropriate level of oxygen at all times. Ventilation systems are designed in consideration of the maximum number of workers and
diesel-powered equipment expected in the tunnel. Air quality can also be adversely affected by high concentrations of naturally occurring toxic gases in the ground and groundwater. The two most likely toxic gases to be found underground are methane (CH₄), which is lighter than air, and hydrogen sulfide (H₂S), which is heavier than air. Table 4-1 presents the Key Risk Issues to be considered in the selection of a tunnel alignment during the design phase.

<table>
<thead>
<tr>
<th>Design Considerations</th>
<th>Health, Safety and Environmental Impacts</th>
<th>Cost Impacts</th>
<th>Schedule Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid high permeability rock</td>
<td>Reduced potential for compressed-air interventions.</td>
<td>Lower pumping cost during construction.</td>
<td>Less potential for slow production.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost of face interventions decreases.</td>
<td></td>
</tr>
<tr>
<td>Avoid rock with potential hydraulic connectivity to lake</td>
<td>Reduced pressure if hyperbaric intervention is required.</td>
<td>Cost of face interventions decreases.</td>
<td>Less potential for slow production.</td>
</tr>
<tr>
<td>Minimize depth</td>
<td>Reduced pressure if hyperbaric intervention is required.</td>
<td>Lower shaft construction cost.</td>
<td>Less potential for slow production.</td>
</tr>
<tr>
<td></td>
<td>Increased separation from potential underlying igneous intrusions.</td>
<td></td>
<td>Shaft construction periods reduced.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Shorter decompression period.</td>
</tr>
<tr>
<td>Minimize length</td>
<td>Shorter exposure time to risks.</td>
<td>Cost is generally related to length in comparable ground conditions.</td>
<td>Schedule is generally related to length in comparable ground conditions.</td>
</tr>
<tr>
<td>Minimize number of curves</td>
<td>N/A</td>
<td>Increased production and fewer special segments reduce cost.</td>
<td>Potential faster production.</td>
</tr>
</tbody>
</table>

### 4.1 Risk Management Approach

As discussed in the previous sections the expected construction challenges and associated design and construction risks for the new projects were evaluated both by the Owner during the planning and bid stage and by the Contractor during the bid and construction stage. SNWA prepared a Risk Management Register during the planning stage. This Register was provided to the bidders for evaluation and to supplement it further based on their selected means and methods for design and construction. The results of shared risk management used by Owner and Design-Build Contractor provided an excellent vehicle for addressing and managing the risks associated with the design and construction of this project. The potential for high contingency to be included in the Owner’s budget and Contractor’s lump sum bid was eliminated by conducting proprietary meetings with the potential bidders to address potential issues and to jointly develop mitigating solutions. The paper discusses the use of the transparent risk management approach and the development of the Risk Register that complied with the intent of the international code.
“International Tunneling Insurance Group” (ITIG). The joint risk management goals were to: minimize cost to the Owner, maximize profit for the Contractor, demonstrate risk management process to the Insurers, and successfully design and build the project on schedule and budget.

5. Code of Practice for Risk Management of Tunnel Works

The objective of the Code is to minimize and manage risk. The Code sets forth requirements for advance planning and continuous management to ensure the objective of the Code is met. The Code specifies a number of deliverables that the Contractor is to prepare and provide to the Owner. The Contractor, by preparing and implementing the provisions of each deliverable is thereby better equipped to meet the intent of the Code objective.

A list of these deliverables is included in Appendix B of the Code, which are needed for Code compliance. Each specified deliverable item on the list states which party is to prepare the document, (whether it is the Owner or the Contractor or others) and the scope and intent of the deliverable.

5.1 Project Risk Management Plan

The Risk Management Plan’s purpose and scope is to describe the process and methods that should be implemented for project risk management. Through the confines of the plan, the Contractor is to manage uncertainties and their subsequent potential consequences. The overall goal is to construct the project with safety and quality, on time, within cost, and in an environmentally sensitive manner. Processes covered by the plan include how to identify and evaluate risks of the project, define the risks and their mitigating actions, and who will identify risk owners. The VTC Risk Management Plan described the responsibilities for each person engaged in the risk management processes.

To meet the intent of the Code, VTC created their Risk Management Plan with guidelines for regular monitoring and review of the Risk Register, a means for identifying and formally recording hazards, identifying risk reduction/mitigation actions of the impact and number of risks, and updating of the Risk Register.

5.2 Transfer of Risk Register to Contractor

VTC, upon entering into a contractual relationship with the Owner, subsequently became owner of the project risks. Although the Owner is a significant stakeholder in the outcome of the project and risk management is of importance to the Owner, VTC determined that project risks were now their responsibility to avoid, mitigate, or accept. VTC felt that transfer of risks to other parties was not an appropriate risk management tool and thus struck it from the Risk Register.

- Construction Stage Risk Register

The Code states, the Client's pre-contract Risk Register shall be integrated with the Contractor’s Construction Stage Risk Register. Since VTC has taken responsibility for the Risk Management, they have continually updated and revised the Risk Register. This has been done through brainstorming sessions, risk workshops, individual identification of risk, etc. All risks that are entered into the Risk Register are fully evaluated. Each risk is categorized, the risk is clearly identified, risk ratings are established, mitigating actions are developed, and a risk owner is assigned to manage the risk. Through this active management process, the Risk Register is maintained as a “Living Document,” and it is continually evolving through the progression of construction.

- Management Plan

The Management Plan for the project incorporates several plans that are specified by the Code. These plans are discussed in detail and generally ensure forethought is put into the construction
operations. Major plans include the Audit Plan, Training Plan, Inspection and Test Plans, Method Statements, and a Project Risk Management Plan.

- **Site Organization Chart**
  VTC has created a chart that clearly identifies the site organization in accordance with the Code requirements. To comply with the Code, the Organizational Chart is to identify lines of communication of key personnel. Although, the main objective is to identify those individuals responsible for safety, critical work, and self-certification. These key individuals are then named as Risk Owners of their specific related tasks.

- **Constructability Review**
  Constructability reviews are done by VTC in close coordination with the design engineer and the Owner. All parties associated with the project have the ability to comment on the review of the design. Reviews of the design are carried out at several stages through the design process. With this approach, the project design is verified to meet the requirements of the contract, the wishes of the Owner, and the needs of the Contractor. Integration of these key elements into the “For Construction” plans and specifications ensure the project is appropriate and is constructible.

- **Monitoring**
  
  a. **Method Statements**
  At each new phase of work, Construction Method Statements are written. These method statements detail the sequence of work, how the work is to be performed, personnel that will perform the work, and equipment that will be used. Since the project is design build, VTC has prepared Method Statements concurrently with the design phase. Through this simultaneous development of design and means and methods there is a minimization of a potential disconnect during construction thus in itself reducing risk to the project. The Method Statements are shared with the Owner and discussion of the plans is encouraged by all parties.

  b. **Inspection and Test Plans**
  Inspection and Test Plans are developed in conjunction with the Construction Method Statements. These plans identify the quality control and quality assurance requirements that are associated with each phase of work. Again, these plans are shared with the Owner. The Owner and the Contractor control the quality of the work based on these plans.

6.0 **Conclusions**

SNWA used a shared risk management approach. The potential for high contingency to be included in the Owner’s budget and Contractor’s lump sum bid was eliminated by conducting proprietary meetings to address potential issues and to jointly develop mitigating solutions. The purpose of the proprietary meetings was to receive feedback from the Finalist bidders on the RFP requirements, including the contract agreement and allocation of risk issues considered during RFP Process. The following issues were discussed:

- Appropriate and fair allocation of risk between D-B and Owner was accomplished
- Technical Requirements by Code of practice were monitored and satisfied.
- Use of Allowances to compensate Contractor for unforeseen conditions for specific Unit Items provided a win win situation for both the Design-Builder and the Owner.
- Differing site conditions clause applied after allowance item is fully used for specific Unit Items was equitable for the Design-Builder and the Owner.
- Providing more flexibility for Finalist to determine appropriate means and methods for design and construction was beneficial to the overall project.
- Allowing the Finalist to establish the contractual completion date by specifying the number of days in proposal minimized the risk of liquidated damages to the Design-Builder.
• Providing additional time for Finalists to complete and submit proposal.

In order to meet the Project Insurer Requirements a Risk Register was prepared by the Owner and supplemented by the Design-Builder such that it complied with the intent of the International Code “International Tunneling Insurance Group” (ITIG). The joint risk management goals were to: minimize cost to the Owner, maximize profit for the Contractor, demonstrate risk management process to the Insurers, and successfully design and build the project.