MAY 2011

tunnels & tunnelling INTERNATIONAL


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Focus: South East Asia
Diving in to booming Asia with a look at the region's longest drill and blast rail tunnel

Technical: Excavation methods
The first of a two-part exploration of the new parameters and choices

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Recovering Lake Mead

Betting on a new angle to quench the growing thirst of Las Vegas

Stubborn to a fault

Construction of Intake No. Three at Lake Mead, Nevada, requires tunnelling beneath the lake and blasting at Saddle Island. With a deadline driven by the region's drought conditions and drinking water at stake, progress on the project's longest tunnel has been marred by a fault near the starter tunnels as Nicole Robinson reports from site

Reflecting the cloudless Nevada sky, the blue waters of Lake Mead are the physical embodiment of a diamond in the rough, glistening amidst the dramatic desert landscape. Far from the brash bustle – and debauchery – of Las Vegas, framed by mountains, it's a recreational haven often dotted with boats and the gentle waves of their wake.

Increasingly, those boats are spotted among previously submerged landmasses. Driving along the shoreline, from Boulder City one can spot an auxiliary building leftover from the construction of Hoover Dam. Once a popular spot for divers, it now sits in the sun in the middle of the lake.

The United States' largest reservoir was created by the construction of Hoover Dam in the 1920s and '30s and it provides 90 per cent of the Las Vegas Valley's water supply. That's about two million residents. A severe drought in the past 10 years has caused water levels to drastically recede, leaving the lake marked by a grayish and white ring.

Normal elevation in 2000 was 1,200ft (365.7m), explains Erika Moonin, project manager with the Southern Nevada Water Authority (SNWA), an agency that procures and treats water for its seven regional member agencies. "At 1,060ft (323m) we'll be about 10ft (3m) above losing Intake No. One, but we'll start seeing impacts on water quality, which does cause problems with our capacity for processing and treatment," she explains.

With two intakes in operation, SNWA began planning to construct Intake No. Three. Studies carried out during this time indicated that should the drought continue at the same rate of severity, water levels could recede to 1,050ft (320.04m) as early as 2013 or 2015.

"It did get dangerously low already," says Moonin. In autumn 2010, the lake reached its lowest point ever since it was filled after construction of the dam, 1,083ft. "We typically do see a rise in the winter as the demands decrease. It comes up about 10 to 15ft [3.05 to 4.57m]. And then we'll see a drop of 10ft [3.05m], possibly 20ft [6.1m] or even 25ft [7.62m] like we saw this summer."

As of late March, Lake Mead had a 1,096ft (334.06m) elevation, already starting to drop.

To protect the water supply, the SNWA chose to undertake a four-year project to build Intake No. Three, which includes three tunnels (Figure 1, opposite). Vegas Tunnel Constructors (VTC), a joint venture of Impregilo and their subsidiary, S.A. Healy, has a USD 488M design-build contract for a 4.5km tunnel and the intake structure. Renda Pacific, a joint venture of Oscar Renda Contracting and Southland

Contracting, is excavating the connector tunnel (around 860m), a contract worth USD 45M. In spring 2010, Barnard of Nevada completed a small tunnel (174m) that will connect the new Intake No. Three with the existing Intake No. Two. That contract was worth USD 32M. Engineering services for Intake No. Three include program manager Parsons Corporation, and a joint venture of MWH and CH2M-Hill is the designer.

Stops and starts

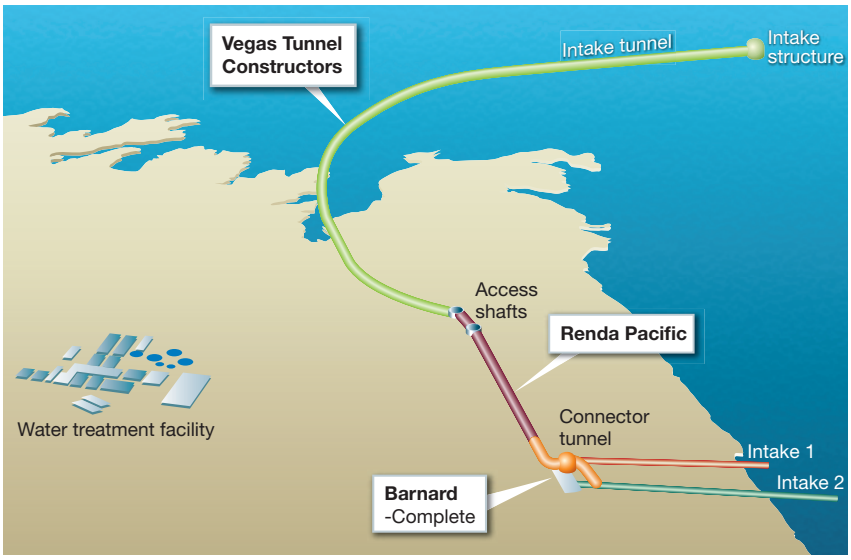
Several locations were looked at for the intake to ensure water quality before the options were narrowed down to three. The 14,904ft (4.5km) tunnel was the preferred alternative with its comparatively lower cost, despite having more difficult construction (Figure 2). A straight alignment had also been considered once the intake location had been chosen, but the curved alignment afforded better geological conditions, Moonin explains. "We get into what is called the Muddy Creek formation earlier, and that is less fractured."

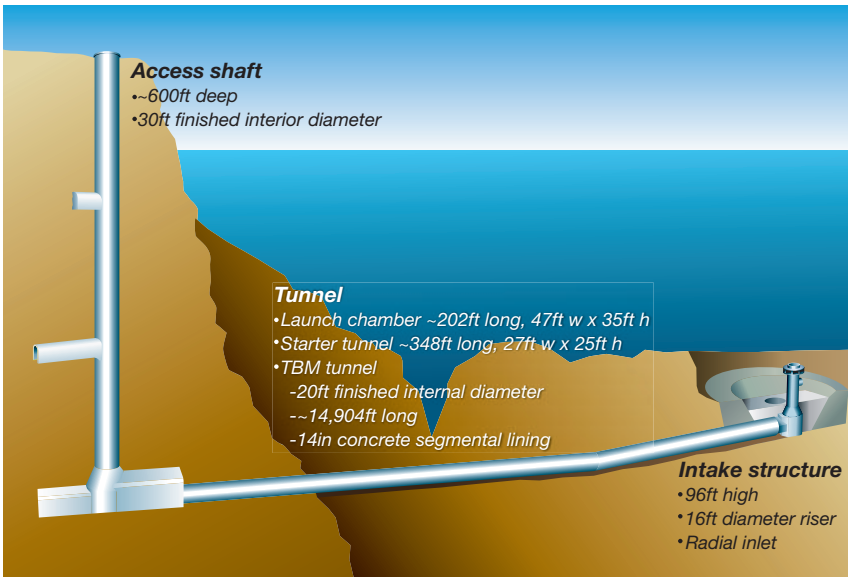
In addition to the urgency of protecting capacity if the first intake is out of commission, one of the main challenges of the project is dealing with varying ground conditions of solid to weak and highly fractured rock, with the potential for high water pressure up to 17bar.

VTC did its first blast at the surface in June 2008 to start excavation of the 600ft (183m) deep access shaft with a 30ft (9m) internal diameter. In September the shaft hit water and the contractor began pre-excavation grouting, reaching the bottom by February 2010. The 200ft (61m) long launch chamber is 47ft wide by 35ft tall (14.3m by 10.6m).

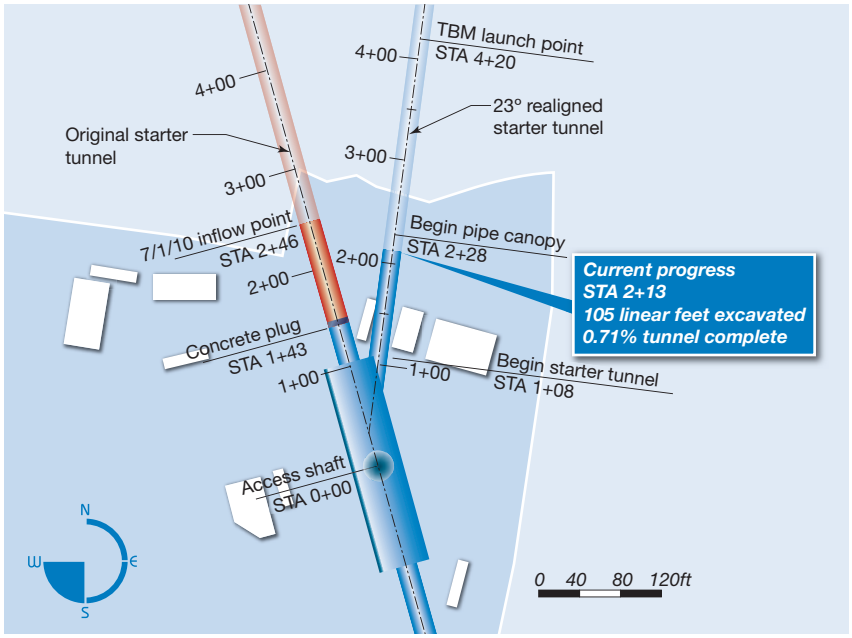
Initially, the 348ft long starter tunnel (modified horseshoe shaped 27ft (8.23m) wide by 25ft (7.62m) tall) only required rock bolts and shotcrete for support, but soft ground was eventually encountered. In March 2010 VTC started installing steel ribs after finding loose ground, and in late June, about 150ft (45.7m) into the starter tunnel excavation, water started coming in, bringing ground with it over a period of four days.

"It would come in gushes," says Moonin. "The ground would arch, the





Top right: **A distintive grey and white band round the lake shows the drop in water level**
Middle right: **Figure 1, The layout of the tunnels and shafts at the project site**
Bottom right: **Figure 2, The VTC tunnel and intake riser structure**



Left: Figure 3, A new alignment has been approved 23 degrees off of the original

water pressure would build back up and come again."

VTC made the decision to allow the underground space to flood, and allowed the water to come 150ft up the shaft to help equalise the water pressure and stop the material from coming into the starter tunnel. The contractor mobilised drills on the surface over the alignment within one week to locate any voids and found one that was filled with 3,000 cubic yards of concrete. During July and August, drilling continued and 26 holes were grouted at the original face of tunnel, from the surface.

Going back

In September VTC returned underground to clean out the material that flowed in and recover lost equipment. As work started to continue toward the face—almost at the same location, within a metre or so—there was another inflow on October 27. Similar to the event earlier that summer, water flowed in bringing rock material mixed with amounts of clay.

This time VTC had a pre-fabricated temporary bulkhead it was able to install to minimise flows to the rest of the starter tunnel. Recovery work started again, but on December 31 there was another inflow, burying the drill VTC was using for grouting. This inflow was smaller than the other two, but the contractor decided to back up and bulkhead it off.

VTC recommended to SNWA the tunnel be realigned because of the challenges of the ground and presented a proposed alignment and geotechnical investigations. In January, it carried out three horizontal cores and 15 surface holes before selecting an alignment 23 degrees offset from the original (Figure 3 above). SNWA negotiated a change order for USD 40M, approved on February 25.

The first starter tunnel has been filled in with concrete—plus a concrete bulkhead and roughly 15ft (4.5m) concrete pillar at the chamber. At the time of *T&TI*'s visit to the site in March, VTC had excavated 120ft (36.58m) of the new starter tunnel.

Jim McDonald, VTC project manager, explains the launch chamber needed to be widened another 20ft (6m) to get a face to start a new tunnel. "It's a very challenging project, but it's getting better," he says. "We had a difficult time there with the ground conditions, but with any luck we're past that."

In waiting

Arriving at the job site in the Lake Mead national recreational area, there is a sea of pre-cast segments awaiting installation. Made in nearby Sloan, Nevada, all of the 6ft (1.8m) long steel-reinforced segments will be produced by mid May. Among the stacks of five segments plus a keystone are portions of the Herrenknecht TBM's gantry, having been delivered (on time) in September 2009 via the Port of Long Beach and shipped to the site by 61 trucks.

McDonald says he hopes to start installing the TBM in September. "We'll put a little more than half in and mine 400 to 500ft (122 to 152m) then we'll stop and put the rest of it in. We should be launching the TBM by the end of year."

The 23.5ft (7.16m) diameter TBM is a slurry and hard rock hybrid, roughly 190m long. There will be a continuous conveyor throughout the length of the tunnel, as well as a full slurry system. McDonald estimates 70 per cent of the tunnel will be done in open mode, with the last stretch, at least 2,000ft (609m), in closed mode. Mining operations will be 24-hour, and overall average progress rates of 35 to 40ft (10 to 12m) per day are expected. The project is scheduled to finish construction in 2015.

After completing the tunnel, the TBM will drive into the bottom section of the concrete intake riser at the bottom of the lake. This structure has steel reinforcement, overall, with fibreglass where the TBM will mine and dock. Once the connection is sealed and watertight, the TBM's shield will be welded into a 30ft (9m) steel ring in the structure and left in place.

The other component of VTC's contract is marine operations to excavate by drill and blast the hole for the intake riser, some 300ft (91.44m) below the surface of the water. Lake excavations are projected to complete by the end of 2011.

Once the intake riser is in place, surveying its location is critical for the TBM to make its connection within 12in (0.31m) considering there are no access shafts along the alignment. McDonald says it should be possible within 2 to 3in (51 to 76mm).

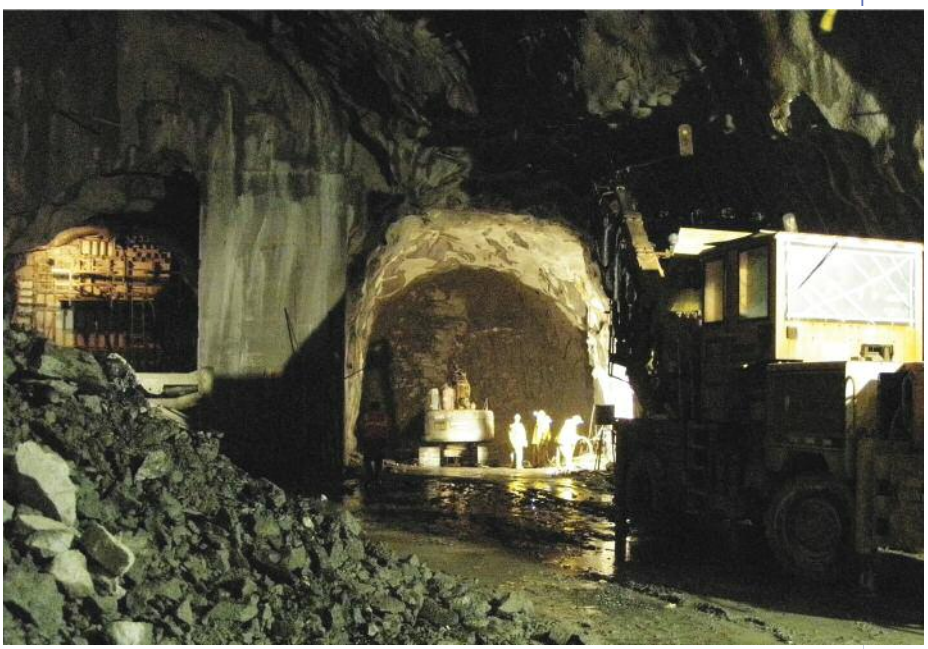
At the other end, back on land, VTC's tunnel will connect with those being built by the Renda Pacific joint venture.

Connections

Renda Pacific has excavated by drill and blast a 26ft (7.9m) diameter shaft and lined it with block concrete to a depth of 450ft (137m). This is the depth at which the JV will build a 320ft (97.5m) tunnel to VTC. In the other direction, it is excavating by drill and blast a 2,500ft (762m) tunnel to the existing pump station.

Both tunnels are supported with 8ft long CT bolts on 5ft (1.5m) centres, and lined with 4in (100mm) of fibre-reinforced shotcrete. There is a 6in (152mm) concrete slab at the bottom. The shorter tunnel to VTC is 20ft by 20ft (6m) and for the most part flat, while the longer tunnel to the pump station is 16ft tall by 14ft wide (4.9 by 4.2m) with a 3.3 per cent grade. There are also two curves, each with a 160ft (48.7m) radius.

Ground conditions vary from highly fractured to fairly good, quality rock. To



Right: The new tunnel alignment on the right runs 23 degrees off the original
Bottom right: A rig operator copes with inflows of water as he advances

complete each excavation cycle, Renda Pacific drills and grouts for 80ft (24.4m) but only excavates 60ft (18.3m).

"Water is a big part of this job," says Michael Cash, project manager for the Renda/Southland JV, who explains the grout program is owner-directed and the JV meets daily with the construction manager to discuss the ground.

"The last grout cover, we put in over 80t of grout for an 8ft (2.4m) section," he explains. "Interestingly, you can actually see the grout in the face when we excavate."

The bigger, but shorter tunnel to VTC hasn't hit much water, but the opposite is true for the smaller, longer tunnel. "Of the four months excavating, approximately three months of it has been just drilling and grouting," Cash says. It can take as few as two days to do the 80ft (24.38m) covers. "However if we do hit a lot of water, it has been taking us up to three weeks."

Renda Pacific is using one Terex Jumbo, diesel over hydraulic, with two drill booms for both tunnels. For the drill and blast, 12ft (3.6m) holes on a 3ft by 3ft (0.9m) spacing are drilled out. It takes around one to one-and-half weeks to do the 60ft of excavation in each cycle. As of *T&TI*'s visit, the JV had completed the 450ft (137.16m) of shaft excavation, and another 450ft of tunnel excavation. Cash says they're looking at two more months of excavation in the shorter tunnel, and another nine months on the other side—though that estimate doesn't account for the time needed for grout if required.

"The grouting program on this job, although being very time-consuming, has been a great success in what it has achieved," Cash says. "We probe out and get massive amounts of water from the probe holes—a couple hundred gallons a minute from a single 2in (50mm) hole."

Toward the end of its contract, the JV will install a temporary steel bulkhead between the VTC tunnel and Renda's shorter tunnel to allow the completed connection to be flooded. Separately, a bulkhead will be installed at the bottom of the shaft to all water to be conveyed in the tunnel during future construction of a pumping station for Intake No. 3 that had been put on hold.

Three contracts for the pumping station, a discharge pipeline and associated electrical work have been deferred in response to declining revenue for SWNA since 2006.