Restoration of the Machu Picchu Railway Line after the January 2010 Floods

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ABSTRACT

The Machu Picchu line of PeruRail in the high Andes is a 3-foot gauge, single track line of 68 miles stretching between Cusco and Machu Picchu Pueblo (Aguas Caliente). The line is the only means of access to Peru's most popular tourist destination, the Inca city of Machu Picchu. PeruRail operates 40 passenger trains daily that transport 3.6 million riders annually. The operating environment is especially challenging with the northern end of the line being squeezed into the narrow gorge of the Urubamba River, a major tributary of the Amazon. Operations use both locomotive hauled passenger trains and DMUs on non-signaled railway.

At the end of January, 2010 record rainfall in the Urubamba watershed caused massive flooding which ultimately was concentrated into record high flows in the Urubamba gorge near Aguas Caliente. The weather eroded the railway alignment or caused landslides blocking the track at 44 locations. Over 2000 tourists were stranded in Aguas Caliente and had to be airlifted out by the Peruvian government. Restoration of the line was of utmost priority as tourism to Machu Picchu generates over $800 million annually to Peru and travel cancellations were costing in excess of $1.0 million daily. Suspension of rail service indirectly caused 17,000 people to be put out of work. Initial estimates to reopen the line were as long as one year.

Railway concessionaire Ferrocarril Transandino S.A.(FTSA) used its own employees augmented with contractors to assess the damage and implement the phased repair program that reopened the critical northern 20 miles three days early. Limited passenger service began operating March 29, 2010 between Piscacucho (KP82) and Aguas Caliente (KP110) using rail diesel cars. Full service between Cusco (Poroy) and Machu Picchu was offered on July 2 in time for the 2010 tourist season. The work effort was especially challenging due to the lack of off-track access and the continuing rain and recurring mudslides.

THE NARROW GAUGE SOUTHERN RAILWAY OF PERU; ITS ORIGINS AND IMPORTANCE

In 1918, the Peruvian government commenced construction of the Southeastern Railway at Cusco (KP 0)[1] as a 750mm gauge line (30") to provide a transportation link to the rich Amazon basin. Construction was slow, including a conversion to 914mm (36"), ultimately reaching Paschar (KP62) in 1925 and Agua Caliente (Machu Picchu) (KP110) in 1928. A twelve mile extension to the hydroelectric project at Hidroelectrica (KP121) was made in the mid part of the 20th century and is currently the end of track.

The railway is critical to the economy of Peru and Cusco state. It is the only means to access the UNESCO WORLD HERITAGE site of Machu Picchu, the Inca citadel high in the Andes. See Figure 1. Machu Picchu is Peru's single greatest tourist attraction, generating over $800 million in tourist revenue annually and representing close to 1% of the country's GDP.

Figure 1

In 2010, the railroad operated over 3.5 million trips of which half were tourists. Paved highway access is available to Ollantaytumbo (KP68) and the end of the road is at Piscacucho (KP82). PeruRail operates 20 round trips per day between Ollantaytumbo and Machu Picchu. Four of those trips continue to Cusco Station (Poroy) at KP 17. Rail services consist of the Luxury "Hiram Bingham" train run by Orient Express Hotels, Domeliner rail diesel cars, locomotive hauled "Backpacker" coach trains for the trekkers, and local services available only to Peruvian citizens. PeruRail also operates freight service on the line two to three nights per week to supply Aguas Caliente and Hidroelectrica. Aguas Caliente is the support village for Machu Picchu with 8000 permanent residents and up to 4000 visitors daily during the high travel season, all dependent upon reliable rail transportation.

[1] KP indicates Kilometer Post distance from Cusco

The railroad starts in Cuzco at an elevation of 10,900 feet above sea level and climbs to a maximum of 12,200 feet elevation before descending into the Sacred Valley of the Inca and the watershed of the Urubamba River, a tributary of the Amazon. The end of the line is at an altitude of 5,600 feet above sea level. The line follows the river closely with much of the last 25 miles clinging to a bench carved out of the slide of the narrow canyon. See Fig. 2.

Figure 2

The line has maximum 4.12% grade and uses switchbacks to gain elevation climbing from Cusco city. Structures are designed for maximum of 22 ton axle loads. Since taking control of the rail line in 1998, Ferrocarril Transandino, S.A. (FTSA), the private sector concessionaire, has totally rebuilt the track structure with new wood ties, granite ballast and some heavier rail. The government requires FTSA to establish and maintain the track to FRA Class 2 track suitable for 40 mph operation. The railroad is non-signaled with computer assisted radio dispatching using track warrants.

THE RAILWAY ORGANIZATIONAL STRUCTURE AND GOVERNANCE

The railroad throughout its century plus of life has been under multiple ownership schemes. In modern times, all of Peru's railways were nationalized in 1972 and operated by the government railway company ENAFER. Conditions and service became unreliable and assets deteriorated which further diminished the traffic and revenue. By the mid-90s, there were two remaining rail systems, the Central Railway and the Southern Railway. In 1996, the government sought a private sector concessionaire to manage the properties and provide rail service, the Southern network being most critical to support the tourist traffic to Machu Picchu. The government established a transportation regulator OSITRAN, that provides oversight and management of the railway and other modal

concession contracts. The competitive solicitation picked Ferrocarril Transandino SA (FTSA) as the infrastructure manager and PeruRail, a joint venture of the British company Orient Express Hotels and FTSA, to run the trains. As a condition of the concession, FTSA must provide open access to other passenger operators on the Machu Picchu route. In 2011, two other operators have begun train service.

THE BIG EVENT; WILL THE RAINS EVER STOP?

In December 2009 and January 2010, rainfall in the watershed had been heavier than normal and river levels were high. The region historically experiences flooding conditions every four to five years with limited damage to crops and highways. The railway line due to its precarious location adjacent to the river, has been interrupted multiple times over the past decade. The weather in Cusco state turned even wetter around January 20 with heavy showers and high bursts of rainfall that raised the river levels significantly and flooded huge expanses of the valley. Throughout the month of January, forces of FTSA had been stabilizing the alignment with sandbags, gabions, and additional fill. The rainfall climaxed between January 24 and 26 when the railroad was closed at multiple locations with mud flows and washouts. See Figure 3.

Figure 3

At Aguas Caliente, the river was flowing at 39,000 cubic feet/second through a gorge a mere 200 feet wide, a level not seen in over 90 years. The last train left Aguas Caliente for Ollantaytumbo on January 26.

No trains were derailed or equipment lost but 2000 visitors were stranded in Aguas Caliente with no means to escape and with limited accommodation and food supplies. See Figure 4.

Figure 4

Bad weather continued for two more days before helicopters from the Peruvian and US governments could be mobilized for an aerial evacuation. It took another three days to rescue all the tourists and then evacuate residents who had no employment with the railroad being closed and the town cut-off. Fortunately, the historic site on top of the mountain was unharmed due to the high quality drainage system constructed by the Incas 500 years ago. Unfortunately, the road to the site was washed out in many locations and over 500 tourists in the ruins had to be rescued by helicopter. The historic site was officially closed by the government to discourage adventurers and trekkers from risking their personal safety to reach the site on foot and to allow repairs to be made.

THE DAMAGE

The line was washed out or inundated by mud slides and rock falls at 44 locations, the majority between Ollantaytumbo and Aguas Caliente. See Figure 5.

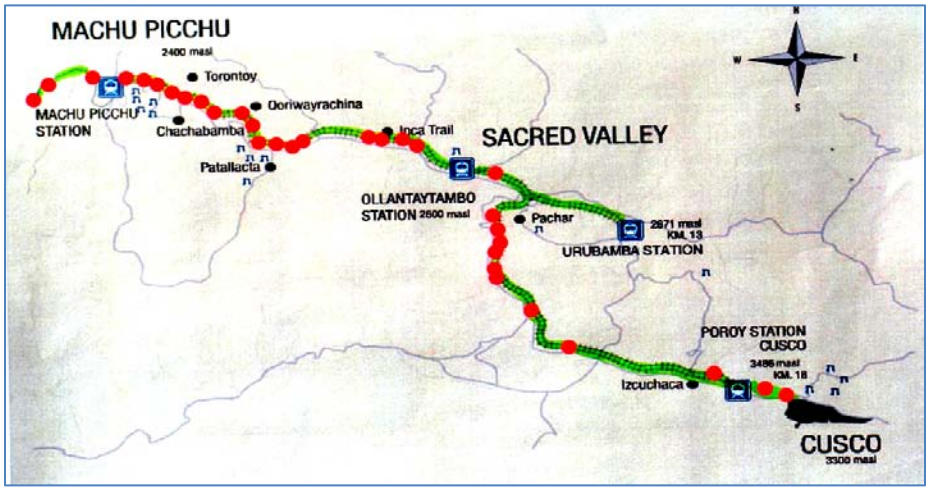

Figure 5.

It was clear that this was a calamity for Peru of epic proportions with economic losses of a million dollars per day in lost tourism revenue and over 17,000 persons in Cusco state put out of work with Machu Picchu being closed. Early press reports quoted officials expecting it to take up to a year to restore rail service.

The worst condition was at KP79 where close to 600 feet of alignment was scoured away and the river had eaten into the hillside well beyond the centerline of track. See Figure 6 taken in late March, 2010..

Figure 6

At this location, the top of rail was 30 feet above the river which meant a large fill or a totally new alignment would have to be created.

The second week of February, FTSA and OSITRAN engineers walked the most critically damaged sections to assess the magnitude of the damage and to establish priorities that would allow Machu Picchu to reopen as soon as possible. It was also important that the citizens of Aguas Caliente and Hidroelectrica be able to receive necessary supplies. The walkout was video-taped and at the end of this paper, the You Tube links are posted to permit viewing of the damage.

Except in locations with solid rock, the soil conditions are generally loose deposits and clays with cobbles that have washed down from higher elevations over the years. This caused significant mud and rockslides that would ultimately provide much of the material to reconstruct the line. Lack of heavy earthmoving equipment meant that indigenous materials would have to be used for repairs. See Figure 7. Due to their portability, the most universal

building element turned out to be wire cage gabions filled with local river excavated cobbles. Tracked hydraulic backhoe excavators were the primary machines used because of their immediate availability at several locations.

Figure 7

FTSA personnel have experience in responding to the flooding from previous events although none were as severe as January 2010. The primary difficulty was no "off-track" access from KP 82 to KP 121and hence all repairs and material logistics had to be moved linearly along the right of way after temporary construction paths or roads were put in place. Before substantial work could begin, the river levels had to subside. One of the first actions was salvaging track materials and shoring up the rails at the major washouts with timber cribbing or gabion pedestals. See Figure 8.

Figure 8

This enabled motor cars and material trailers to move up and down the line to get hand tools and workers quickly to worksites. This was a manual labor project supported by small machines due to the logistics imposed by the topography.

THE RECOVERY PLAN

After the inspections it was determined that the rail line between Hidroelectrica and Aguas Caliente had only three locations with blockages that could be repaired quickly. Hidroelectrica was accessible by unpaved road from Santa Terese which in turn was connected by highway to Cuzco via Urubamba abet over the top of the Andes. PeruRail established a passenger and freight shuttle service between Hidroelectrica and Aguas Caliente in March and the Peru government made emergency repairs to the road to permit bus and truck traffic to access Hidroelectrica. The alternate trip required over eight hours compared to the three hours previously by train.

The second step of the recovery plan was to repair the tracks between Piscacucha (KP82) and Aguas Caliente (KP110) to allow a rail shuttle operation to meet buses at the end of the dirt road. PeruRail estimated they could have this service operating in eight weeks. Service commenced three days ahead of schedule on March 29 using the diesel rail cars that had been isolated at Aguas Caliente on January 26. Many of the repairs were temporary in nature and the diesel rail cars had lighter axle loadings than locomotives to facilitate an early start. The Cusco regional government constructed a temporary rail platform and parking area at Piscacucha to facilitate this service. See Figure 9.

Figure 9

The third phase of the recovery was to repair the blockages between Poroy (KP18) and Ollantaytumbo (KP68) both for materials movement and to be ready for through passenger service once the work at KP79 was completed.

RESTORING SERVICE AND CONSTRUCTION TECHNIQUES

The goal was to have full service restored by the start of the tourist season on July 1, 2010. At many of the locations, the roadbed had been flooded or been inundated with mudslides which required excavating materials from the high side of the slope and depositing them on the river slide. Large boulders were retrieved from the river to build up protection or gabion walls were fabricated using local materials. While work was proceeding, there was still considerable rain and additional rock falls made further cleanup necessary. In some locations, it was necessary to realign the track to a new bench cut into the hillside due to river erosion and scouring. See Figure 10.

Figure 10

At KP 83, the rail line runs in front of a high Inca-built wall. To protect the track and the foundations of the Inca wall, the hillside below the tracks was covered in tarpaulins to prevent further erosion until additional fill could be placed. See Figure 11.

Figure 11

The biggest challenge was the washout at KP79 between Ollantaytumbo and Piscacucha. At this location, the river had cut well behind the centerline of track. The repair method selected was to construct an engineered fill faced with gabions. This new fill was 600 feet in length and close to 30 feet high. The fill was reinforced with geo-mesh plastic grid mats and tiebacks to anchor the gabions. The bottom of the wall was armored with concrete and rock to reduce likelihood of future scouring. See Figures 12 and 13.

Figure 12

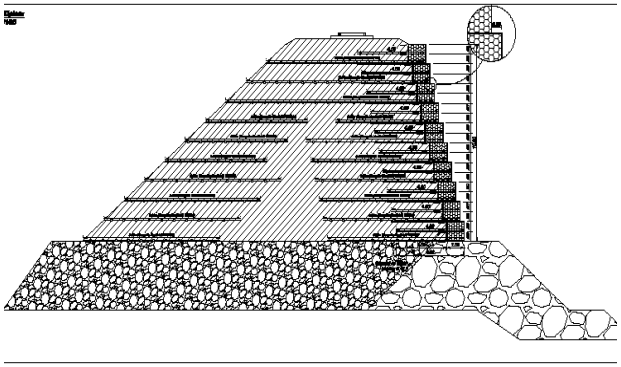

Figure 13

Prior to the resumption of full service, the reworked areas were all surfaced with new ballast. See Figure 14.

Figure 14

Work was completed on June 25 and after inspection by OSITRAN officials, the re-opening occurred on July 2, 2010. The July opening allowed PeruRail to retain almost all of its passenger traffic for 2010 by meeting the start of the primary travel season and addressing pent up demand from the five month closure. See Figure 15.

Figure 15

FTSA intends to conduct additional studies to determine what further steps are prudent to reduce future weather related disruptions.

ADDITIONAL INFORMATION

The links to OSITRAN video of the inspection of the damaged line follow. Each video is approximately 9 minutes in length:

http://www.youtube.com/watch?v=SBIW4RfjZ0Y&feature=related 1/5

http://www.youtube.com/watch?v=Qx7JLbUMa8I&feature=related 2/5

http://www.youtube.com/watch?v=KvnmyNTYMF4&feature=related 3/5

http://www.youtube.com/watch?v=lLhDJoU-c90&feature=related 4/5

http://www.youtube.com/watch?v=fcObJySJPMw&feature=related 5/5

Additional information on Peru Rail services available at www.perurail.com