Two Rivers Platinum Mine: the orebody, the mining method—a perfect match

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Transaction Paper

Synopsis

Two Rivers Platinum Mine (TRP) is a 55:45 joint venture between African Rainbow Minerals and Impala Platinum, respectively. TRP is situated on the farm Dwarsrivier 372KT, in the southern sector of the eastern limb of the Bushveld Complex. Dwarsrivier is underlain by rock formations of the Critical Zone (Winterveld norite-anorthosite) and the Main Zone (Winnarshoek norite- anorthosite).

Two economically significant PGE-bearing layers namely the Merensky Reef and the UG2 chromitite are found within the upper Critical Zone. These are approximately 140 m vertically apart, separated by a series of barren norites and anorthosites. At Two Rivers Platinum, only the UG2 chromitite layer is currently being mined for PGEs.

The UG2 sub-outcrops north/south along the Klein Dwarsrivier river valley with a very gentle dip to the west of 7º–10º. At Two Rivers the UG2 averages about 120 cm in thickness, overlain by a waste pyroxenite parting about 20 cm thick, above which is a leader seam about 20 cm in thickness. The mineable cut consists of the leader seam, the waste pyroxenite parting, the UG2 chromitite layer including 25 cm of pegmatoidal pyroxenite footwall, below the UG2 reef to a minimum of 185 cm trackless mining cut.

The mining method is a mechanized bord and pillar layout, which will yield a total of 185 000 tons at full run of mine production from the underground UG2 mine.

Introduction

Two Rivers Platinum mine (TRP) is situated in the southern lobe of the eastern limb of the Bushveld Complex, about 60 km north west of the town of Lydenburg (Figure 1). The current workings are planned to extract the UG2 PGM bearing reef and then exploit the Merensky Reef in later years as well. The project began with an extensive trial mining programme, which involved the mining of a mechanized stoping section and preliminary mine development work, both along strike and on dip of the orebody. The trial mining exercise offered the mine operators, both contract miner and client, a valuable learning experience to test and experiment with mining methods and their applicability to the orebody.

The UG2 stratigraphy at TRP and neighbouring mines

In the projects north of TRP such as Modikwa and Marula Mines, the UG2 chromitite horizon is a dominant marker about 60 cm thick sandwiched between 30 cm–150 cm of footwall pegmatoid and 200 cm–1 000 cm of hangingwall pyroxenites.

The UG2 chromitite consists of fine to medium size cumulus chromite grains with substantial amounts of post-cumulus orthopyroxene crystals. The footwall is a coarse-grained pegmatoidal pyroxenite with sporadic occurrences of chromitite blebs, lenses and stringers. The hangingwall is predominantly fine to medium grained orthopyroxenite with three or more chromitite stringers referred to as the UG2 leaders. In particular the UL2 Cr stringer 1–10 mm wide, occurring between 50–60 cm above the top of UG2 reef contact, is significant. These are poorly mineralized and have a negative impact on mining since they are non-cohesive partings in terms of hangingwall beam stability and dilution (Figure 2). At Modikwa where the UG2 averages 50–60 cm with about 60-80 cm of hangingwall pyroxenite to the UL2 chromitite parting above it, the planned Modikwa mining cut is about 110 cm with the aim of scalping out the barren hangingwall pyroxenite prior to crushing (Figure 2).

The UG2 seam at Two Rivers is 1.2 m–1.4 m and has one or two chromitite leader layers above it, which are included in the optimum mine cut, depending on their distance above the main reef band. An ideal mining cut of 185 cm is arrived at TRP by including some

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Figure 1—Locality map showing the positioning of Two Rivers Platinum Mine in the eastern limb of the Bushveld Complex

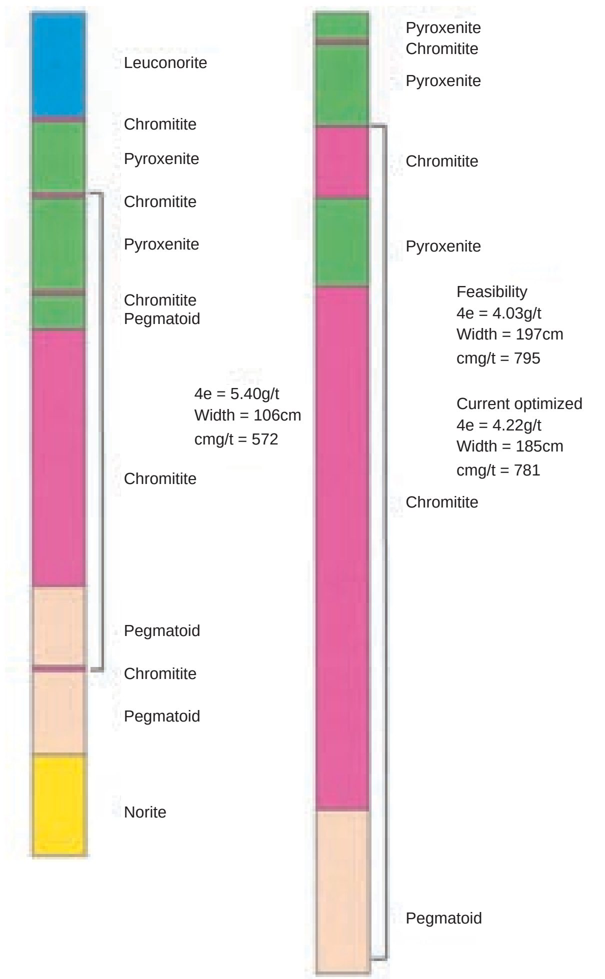

Figure 2—A stratigraphic comparison between the Modikwa Mine cut (left), and TRP mine cut (right). The Modikwa cut is equivalent to the lower UG2 split reef facies in the southern portion of the Two Rivers farm (see Figure 3)

allowable footwall dilution. It is this quality of the Two Rivers UG2 layer that favours mechanized mining when compared to other projects on the eastern limb of the Bushveld Complex.

Within the TRP UG2 seam there may also be the presence of internal pyroxenite partings, which in cases may result in split reef facies whereby the UG2 is separated into two or three seams (Figure 3), especially in the southern-most portion of the farm. Comparatively the TRP second split of the UG2 seam is analogous to the UG2 being mined at Modikwa and Marula.

In terms of PGM metal content, the TRP UG2 mine cut has about 800 cmgt compared to about 600 cmgt in the Modikwa idealized cut. These are based on 4E grades of 4.22 g/t and 5.40 g/t for TRP and Modikwa respectively.

Reef morphology

The strike of the UG2 at Two Rivers has been consistent with the feasibility study borehole interpretations, in a north-south direction. This is clearly evident in the current 800 m development of the Level 1 reef drive that did not experience any significant strike changes.

An average dip of 8 degrees has been recorded from underground development and mining, which compares very well to the 9.7 degrees average on which the geological model was based from drilling. TRP areas where the reef displays more regular dips with favourable ground conditions for mechanized mining are termed ‘normal geozones’, Figure 4.

The igneous layering displays strike-parallel ‘terracing’ similar to that developed in mines of the Western Bushveld. This is the phenomenon whereby the UG2 dips in a step-wise manner, with strike-parallel zones of shallow dip separated by monoclinal zones of steep dip (Figure 4). Over much of

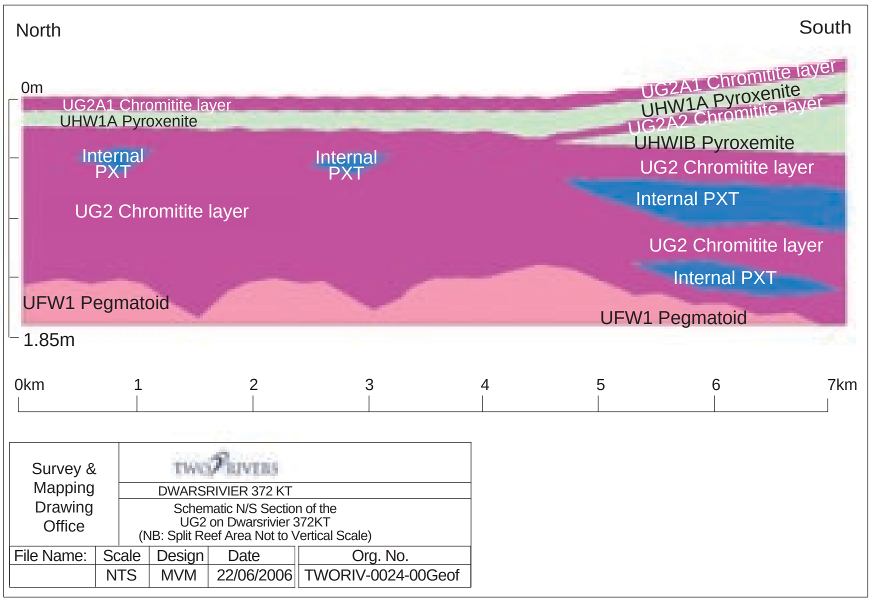

Figure 3—A section N-S of TRP showing the UG2 layer, leaders and pyroxenite partings to the south (after R. Hornsey, unplublished 2003)

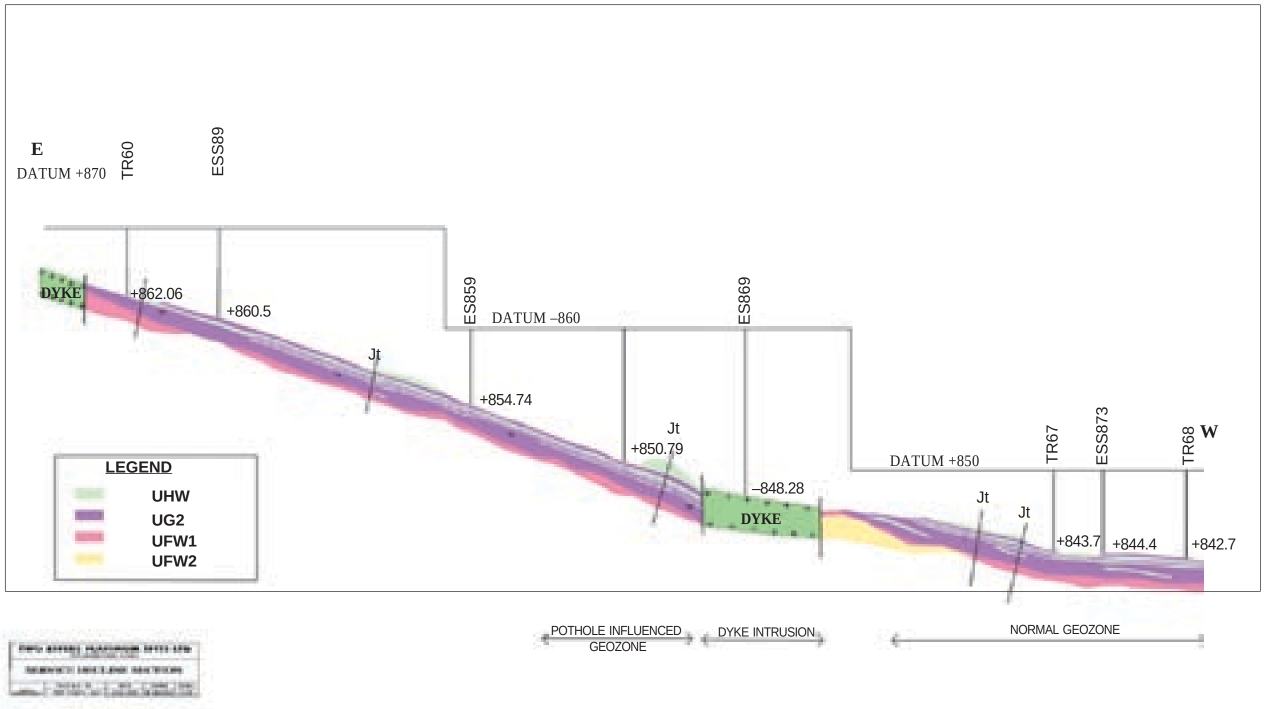

Figure 4—A dip section along part of the on reef service decline, showing the morphology of the reef. Note sections of hangingwall over break where the dip is slightly steeper than average

the stoping area the layer dip averages 5 to 8 degrees, separated by narrow zones where the dip increases to 10–15 degrees. The areas where the dip changes are termed monoclinal rolls.

Monoclinal rolls of the UG2 layering are spatially associated with pothole intersections at Two Rivers as well as dyke intrusions. Increased jointing (layer-parallel and normal), associated hangingwall instability and over break are commonly observed in the areas affected by monoclinal rolling, (Figure 4). Areas of monoclinal rolling tend to be localized, hence are mappable and can be projected on strike. This means that mining can be forewarned of the prevailing ground conditions in such areas and take the necessary precautionary measures as they approach such areas.

Mining method

Access to the underground workings is through a main conveyor decline system developed from surface as well a chairlift decline for man transport. The conveyor/service and chairlift declines have separate surface portal entries. Due to poor, highly weathered hangingwall, the first leg of the conveyor decline was developed on strike. On intersection with the UG2, the service decline branches off from the main decline's first leg and is developed on the plane of the UG2 on true dip (approximately 8 degrees). The chairlift decline has been developed from surface at 34.5 degrees in the direction of true dip until intersection with the UG2. The chairlift decline is then developed on true dip on the plane of the UG2, parallel with the service decline (Figure 5).

The conveyor decline is rectangular in cross-section (3.0 m high x 6.5 m wide), and has been developed in the centre and 20–25 m below the two reef declines, namely the service and chairlift declines. The service and chairlift declines are 22 m apart, measured from their respective centres.

Reef production at Two Rivers is through a fully mechanized room and pillar stoping method. A mining section consists of eight 12 m rooms, with pillar sizes increasing with depth below surface. In the shallow areas of up to 100 m below surface, the pillars are for instance 6 m x 6 m in size. These rooms are mined mainly on strike except when re-establishing sections affected by geological disturbances (faults, dykes and potholes).

Figure 5—The TRP bord and pillar layout for mechanized mining with the level down dip and strike roadways

The purpose of the strike production sections is to produce the majority of the ROM production of the mine. They are designed to meet the following requirements:

- To break the maximum amount of ore and create minimum amount of waste
- To provide a safe and healthy working environment for employees
- To deliver 20 500 tons/month of broken ore from each mining section to the decline system
- To continuously provide an orefeed without degradation on the production system itself.

Mining cycle

The mining cycle is structured so as distinctly to separate the operation of the various activities of the primary production equipment during a shift. On any shift two panels are cleaned, two panels supported and two panels drilled and blasted, aiming for 3-metre advances per blast. Two panels stand for a shift providing spare face capacity in the event of misfires, ground loss, potholes, dykes, faults and replacement pegmatoid. One shift thus prepares the panels for the next shift to blast, load and support. An illustration of the face stope cycle is given by Figure 6.

A complete crew of 11 per mining section comprises a miner, a team leader, a drill rig operator, one roof bolter operator, a UV operator, two LHD operators, two PTVs and two tip attendants. Per 3 m advance with two stopes blasted per shift, 500 tons are produced by a crew.

Figure 6 illustrates the face mining cycle within a production section.

Drilling

A single boom Atlas Copco S1L Rocket Boomer is used for drilling the face in stoping operations. This unit proved itself during trial mining and was found to be the most productive whereby each rig drills two 12 m faces per shift with 3 m rounds being blasted.

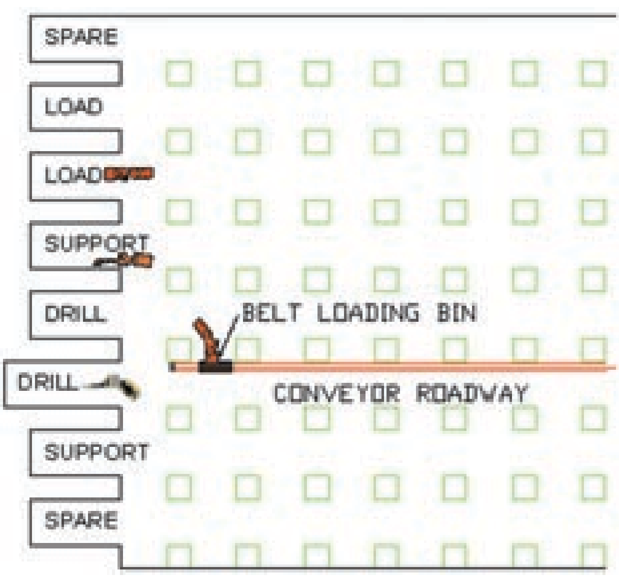

Figure 6—A typical stoping section panel cycle at TRP

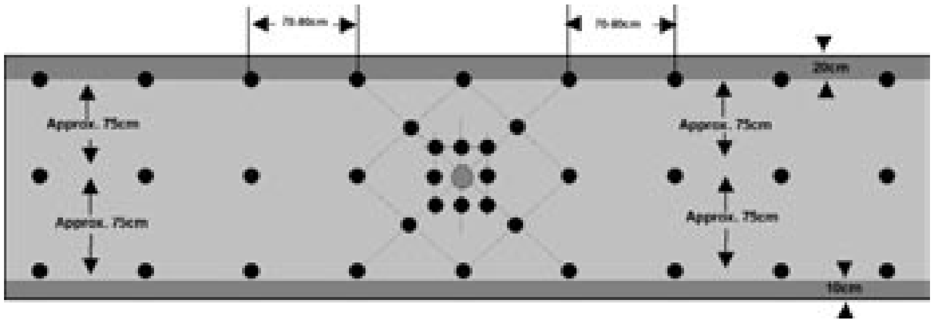

Figure 7—The drill and blast pattern employed in the TRP stoping sections

Blasting

A pumpable emulsion explosive with shock-tube initiation system is utilized in the stoping operations. A utility vehicle equipped with an emulsion pump is used to charge up production holes. Blasting is on a time blast system at the end of a 10.5 hour shift. Half an hour is allowed between the two shifts for the dilution and extraction of blasting fumes via two exhaust fans north and south of the service decline (Figure 9).

Extensive experimentation was carried out on blast patterns and fragmentation during trial mining with ANFO type explosives. This explosive selection was made with the following aims for the blasting operations:

- to break ore as finely as possible
- to break waste as large as possible
- get maximum face advance per blast
- do as little as possible damage to surrounding rock, mainly hangingwall and footwall.

The enhanced blasting performance is achieved using the drilling and blasting pattern in a 12 m panel stope as shown in Figure 7.

Mucking

Mucking is carried out with two EJC 115LPs loading broken ore in the face, hauling and dumping it on a strike belt conveyor grizzly. The strike belt transfers ore to the level orepasses. The strike conveyor roadway is placed in the third roadway from the bottom of the section. The reason for this placement is to have a shorter hauling distance for the up-dip hauling LHD and a longer hauling distance for the down-dip hauling LHD, reducing the strain on the LHDs and thus reducing the related maintenance requirement.

Waste scalping

In order to reduce the amount of waste material in the run of mine orestream, the blasting practice aims at breaking any significant waste portions in the mining cut larger and UG2 finer. The large waste rocks will then remain on the grizzly and are pushed off and stacked away in worked out and swept areas. The aperture size in the grizzly is 40 cm x 40 cm.

Strike conveyor belt extensions

In order to minimize the hauling distance between the face and the reef tipping position, belt extensions of about 30 m/month are required to keep the belt as close to the face as possible. At TRP the aim is to keep this distance to a maximum of about 60 m. This ensures a belt extension exercise every two to three months, depending on the rate of advance over those months. The belt extension method comprises the following activities:

- A slot is blasted in the footwall and hangingwall to give sufficient height for the tip and for an LHD bucket to tip into it
- A spare tip and tail-end of the belt is placed and pinned in the required position
- The belt frame and idlers are constructed to the required position
- The current tip is then decommissioned, the belt reeled in and spliced to the extended position
- The new tip is then commissioned
- The old tail-end and bin become the spare units.

Ideally the belt extensions are planned in such a way that the tip should not be further than four pillar splits from the face. An average section advance of 30 m/month is planned indicating a belt move every second month. A separate construction crew, doing only belt construction and moves is responsible for this specialized work.

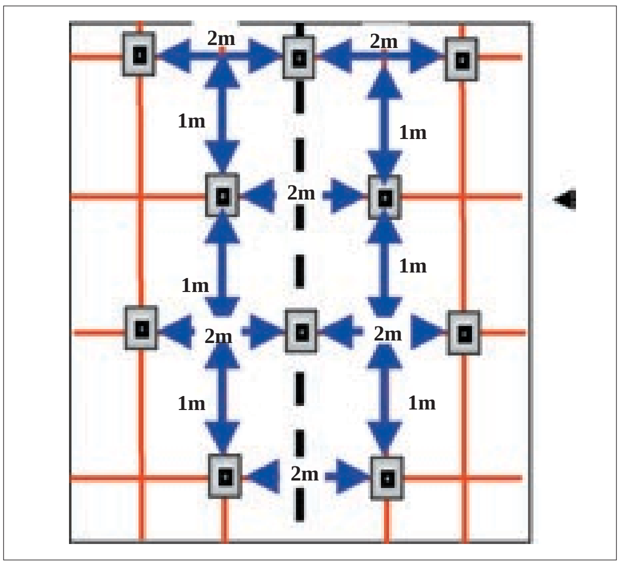

Figure 8—Stope support pattern at Two Rivers Platinum

Support

Resin bolts, 1.5 m long, are installed on a 1 m row and 2 m line spacing for beam support in the stopes (Figure 8). The installation of support is achieved by means of a mechanized roof bolter, the low profile Robolter 126 LP supplied by Sandvik. The machine was chosen due to proven performance during trial mining, its reliability over its competitors and Sandvik's back-up capability in the eastern limb of the Bushveld Complex. This machine is shared with the on-reef development due to the reduced support requirement in the 6.5 m wide development ends.

Two such machines are used between three mining sections but due to reliability and availability concerns, some spare capacity for bolting is required and at steady state, nine machines will be available for nine production sections (8 stoping and 1 development).

In areas with more challenging ground conditions or where critical infrastructure is installed, 35 ton 4 m long tension cable anchors are installed at a 2 m staggered pattern.

Ventilation

The Two Rivers ventilation design was evolved from the original feasibility study into the current philosophy by Dr. C. Alex Rawlins. The latest ventilation provisions are described below.

Ventilation design philosophy

Mine ventilation is the continuous supply of adequate and qualitative air to all parts of a mine underground, where people are required to travel or work. This continuous supply of air is required to:

- Supply oxygen for breathing purposes and must be above 19% by volume
- Remove heat and provide comfortable working conditions and hence improve production
- Dilute and remove noxious and flammable gases that may be encountered during mining operations
- Dilute and remove hazardous airborne pollutants created by various mining operations underground (e.g. dust, fumes, aerosols, vapours, etc.).

The above are required to create and maintain an underground working environment that is conducive to productivity, health and safety of people.

The amount of air required at the point of operation must ensure that any gas/fumes caused by blasting or mechanical equipment is adequately diluted to legally allowed occupational exposure limits (OELs). Any dust generated by mining activities should also be directed away to return airways and, generally, the workers should not be exposed to occupational risk. Where heat is problematic, the cooling power of the air (ACP—air cooling power) is governed by the prevailing air temperature and air velocity.

The four main air quantity determinants for a mechanized platinum mine face are:

- The diesel unit exhaust outlet pipe dilution factor, in the case of Two Rivers Mine, quoted as 0.06 m^3/s per kW of diesel rated power at the point of operation (general dilution factor). As actual diesel equipment technical information becomes available, actual tested ventilation perscription values will be used as determined by CANMET and MSHA. Furthermore, low sulphule fuel (<0.05%) will be used on all trackless equipment on the mine
- The amount of air required to satisfy a mining related re-entry period. This re-entry period for development ends is 30 minutes at TRP. For the overall mine during centralized blasting, the re-entry period is currently set at 144 minutes for adequate fume and dust dilution to acceptable limits (measured and calculated results verified the re-entry period required)
- Sufficient air to dilute flammable gas encountered and to dilute dust that could be created during normal mining operations, i.e. drilling, tramming, etc. To satisfy cooling of workers, a minimum air velocity of 0.5 m/s is advocated, and where tramming is carried out from the face area, a dust and fume-clearing velocity of 1.0 m/s is required in the last through road (LTR)
- The heat load of the mine with reflection on the diesel machinery heat load (virgin rock temperatures (VRT) are low due to the relatively shallow mining operation, i.e. ±150 mbc).

The TRP production ramp-up profile started at about 45 ktpm and is gradually building up to 185 ktpm.

The 4 x 75 kW exhaust fans located on the south upcast shaft have been replaced with two 145 m^3/s main exhaust fans. Each fan was set to handle 75 m^3/s and operated in this mode over the period August 2005 to August 2006.

The bulk sample shaft (BSS) previously operated as a 3 m ∅ fresh air intake shaft until February 2006. A new 5 m ∅ upcast shaft has since been developed alongside the BSS. This has facilitated the commissioning of two main exhaust fans (2 x 145 m^3/s) on this shaft.

Furthermore, the new upcast shaft, the main decline and the chairlift decline are in parallel and any increase in quantity required reflects equally on all three intake systems. Thus to reduce the main decline intake (also the conveyor belt system) velocitv (4 m/s) to about 3 m/s, the chairlift had to be included as an intake system svstem from November 2005 (intake air regulated to reduce air velocitv in this chairlift decline). One new main downcast shaft (5 m ∅) has been operational from January 2005, thus reducing the intake air velocitv in the main decline conveyor belt.

Thus the intakes are as of February 2006:

- One new downcast shaft (70 m^3/s),
- Chairlift intake (30 m^3/s), and
- The main decline conveyor belt (48 m^3/s).

The return air is exhausted through the Level zero south upcast shaft using the two main exhaust fans operating at full capacity.

Due to the increase in air requirements in parallel with the increase in production, the second new downcast shaft will be available in August 2006. The BSS is alreadv being

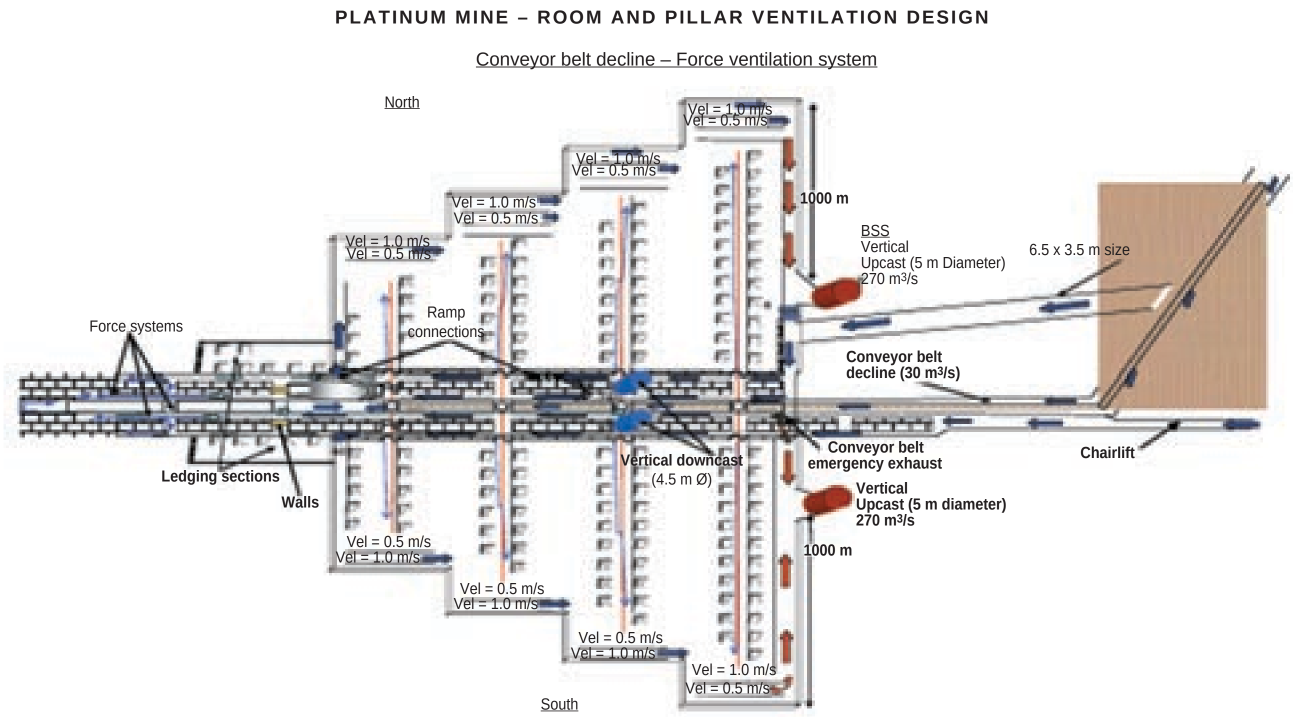

Figure 9—The steady state ventilation design and layout at TRP

used as an upcast facility with the two new main exhaust fans installed. The four main fans installed will operate at a reduced capacity (75 m^3/s each: August 2006 to Mav 2007) and gradually increased as production requires. At peak production for this profile, all four exhaust fans will operate at 112 m^3/s each, thus providing the required quantity of about 450 m^3/s.

Thus, two main downcast shafts are available for fresh air intake and two upcast shafts are available to exhaust the spent air to surface.

It must be noted that walls along the primary dip and strike intakes should have minimal leakage and strike ventilation curtains are maintained to ensure adequate air velocities in stope panels.

An overall schematic diagram of the Two Rivers ventilation system is shown in Figure 9.

Working calendar

Two Rivers Platinum works on full calendar operations, which comprise two, 10.5 hour shifts per day. Three production teams are cycled on a 14–7 day system. A crew works for 7 days morning shift and then changes over to night shift. A new crew then cycles into day shift and the third crew goes off duty. This effectively gives the crew cycling from day shift to night shift 24 hours break between the day and night shift cycles.

Conclusions

The wide UG2 reef seam at Two Rivers has enabled the mine successfully to implement the mechanized bord and pillar mining layout in the Eastern Bushveld Complex compared to other similar mines in the area. The extended trial mining exercise, which lasted more than 18 months prior to full project release, was fundamental to the current success of the project.

Ongoing technical interaction and information sharing between the main shareholders, namely ARM and Implats, have added a lot of value in alleviating further pitfalls and risks that have been encountered in other projects from re-occurring at TRP.

On mine dilution management continues to be critical for the further success towards high profitability, high safety standards and the lowest cost mining at Two Rivers Platinum Mine.

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