HORNSEY, R. and VAN DER MERWE, P. Optimization of geological lead-time in a feasibility study drill out—Two Rivers Platinum, Mpumalanga, South Africa. *Application of Computers and Operations Research in the Minerals Industries,* South African Institute of Mining and Metallurgy, 2003.

Optimization of geological lead-time in a feasibility study drill out—Two Rivers Platinum, Mpumalanga, South Africa

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The Two Rivers Project is a feasibility study to evaluate the UG2 chromitite layer on Dwarsrivier 372KT, Mpumalanga Province, South Africa. The project, which commenced in August 2001, is expected to receive go-ahead early in 2003. The project sponsors (AVMIN 55%, Implats 45%) required project delivery within a short timeframe requiring optimization of the geological and geostatistical programme. Geological modelling was carried out in parallel to the drilling programme, and significant up-front geostatistical preparatory work was done. The time saving was approximately 4 – 6 months on project delivery. The cost saving to the project (excluding NPV considerations) is estimated at R20–30 million.

Keywords; Two Rivers Platinum, Dwarsrivier 372KT, UG2 chromitite layer.

Introduction

The Two Rivers Project is a 55/45% Joint Venture between AVMIN and Implats to evaluate the UG2 Chromitite Layer on Dwarsrivier 372KT in the Lydenburg district. The surface and mineral rights were purchased from Associated Manganese Mines of South Africa Ltd. (ASSMANG) in 2001 for R551 million, and the feasibility study commenced in August 2001. This paper provides an overview of the scope and objectives of the project and illustrates how the use of computerized modelling methods has resulted in significant time and cost savings in project completion.

Location of the project

The project is located on Dwarsrivier 372KT in the Lydenburg district of Mpumalanga Province, South Africa. (Figure 1) The main road between Lydenburg and Sekhukuneland traverses the northern part of the property. A major electrical transmission line runs along the Klein Dwars River valley and an Eskom substation is located near to the proposed mine. The Dwarsrivier Chrome Mine, owned by ASSMANG, is situated on the eastern side of the property. The farm takes its name from the Groot and Klein Dwars Rivers. The Inyoni Dam, situated on the Klein Dwars River, will provide much of the water requirements for the mine. Significant topographical constraints are apparent due to the location of the 1400 m (amsl) high mountain range situated to the western side of the property, resulting in a potential shortage of suitable ground for the development of mine infrastructure, as well as access difficulties when drilling the orebody.

Exploration history

Dwarsrivier was first prospected during the 1920s following the discovery of platinum at Maandagshoek. Limited mining of the Merensky Reef by Lydenburg Platinum Areas Ltd took place. In 1970, Goldfields of South Africa purchased the surface and mineral rights to the farm to prospect the LG6, UG2 and Merensky Layers for chrome and PGEs. In 1998, ASSMANG purchased the farm primarily to mine the LG6 at the recently established Dwarsrivier Chrome Mine. The decision was taken in 2000 to sell the PGE rights, as they were not deemed to form part of ASSMANG's core business. The AVMIN/Implats joint venture was formed to evaluate and bid for the property, and a due diligence study was completed prior to the submittal of the successful bid for the property in June 2001.

Geology

The geological sequence present over the Two Rivers Project area comprises the upper part of the Upper Critical Zone and the lower part of the Main Zone of the Bushveld Complex (Figure 2). The regional strike of the layering is north-south, generally dipping at 7–10 degrees to the west.

Figure 3 illustrates the stratigraphic columns of the Upper Critical Zone sequence from the Merensky hangingwall through to the UG2 footwall. Comparison with the sequences from the remainder of the Bushveld Complex[1] supports the observation that there are significant differences between the stratigraphy at Dwarsrivier and to the north of the Steelpoort lineament. In many respects, the geological sequence is more similar to the Marikana to Brits section of the Western Bushveld[1]. The middling between the Merensky pyroxenite and UG2 chromitite layer is approximately 140 m.

The UG2 chromitite layer has been intersected in 126 boreholes (at end July 2002) on Dwarsrivier, of which 35 were drilled by GFSA, 18 by ASSMANG, and 73 by Two Rivers (Figure 4). This has provided 324 individual intersections for the feasibility study.

The lowermost FW2 Unit consists of fine-medium grained melanorite displaying poorly defined layering. Some intersections host patchy zones and layers of more harzburgitic composition with olivine present. The FW1 Unit is a coarse grained to pegmatoidal pyroxenite/ harzburgite and is approximately 1 m thick.

The UG2 averages approximately 120 cm in thickness.

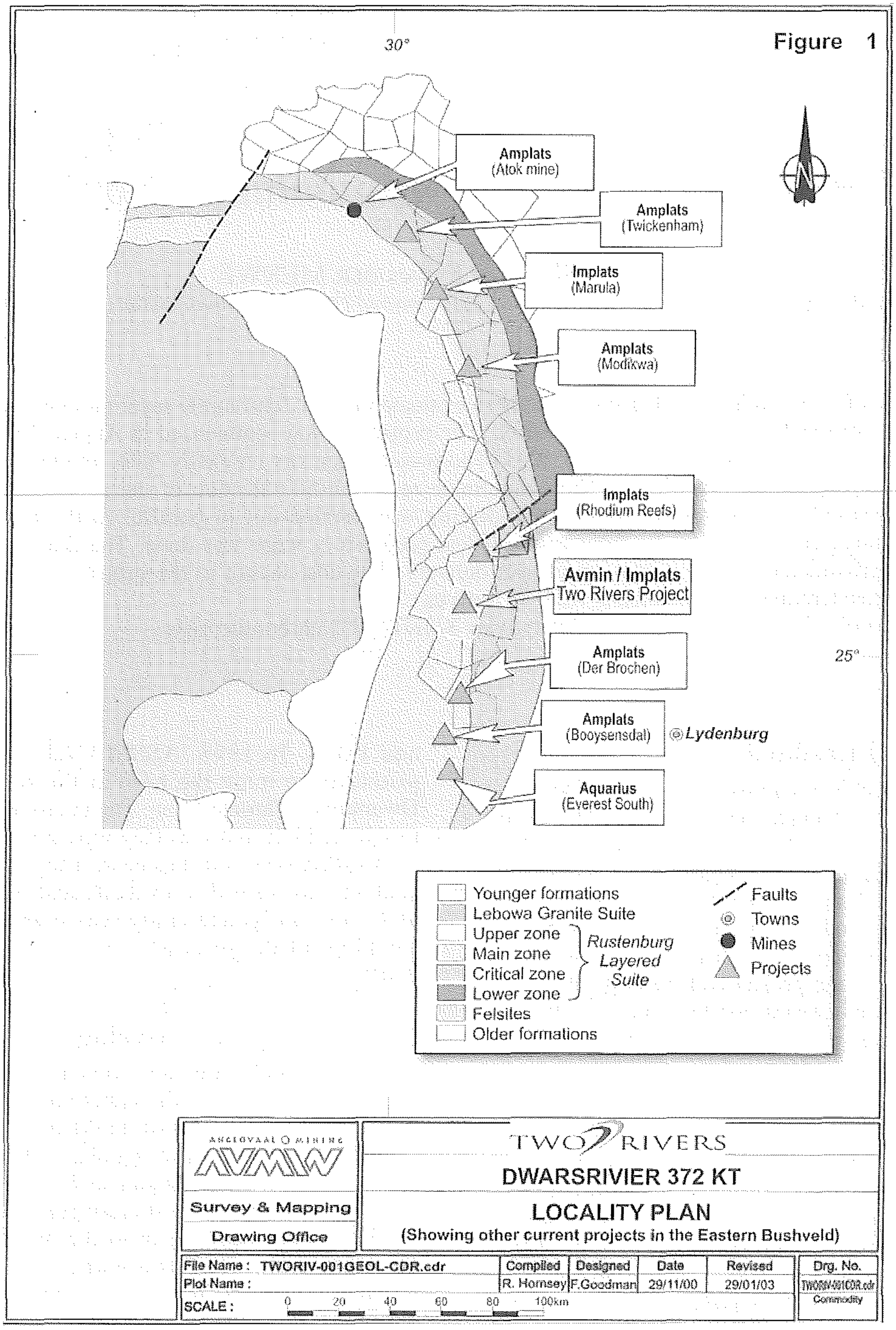


Figure 1

Internal pyroxenite and norite partings may be present. Other lenses are flat and lensoidal, varying in scale from centimetres to kilometres. To the south and deep central part of the farm, a large area is characterized by the presence of 'split reef' with a pyroxenite or norite lens up to 6 m thick situated approximately two-thirds from the base of the UG2 (Figure 5). A more localized area to the south contains a second 'split' within the chromitite, which is situated approximately one-third from the base of the UG2.

The UG2 is overlain by poikilitic textured pyroxenite (HW1A and B Units, 4–6 m thick), that hosts up to three chromitite 'leader' layers (collectively termed the UG2A chromitite layers). The HW1B pyroxenite underlies the UG2A2 chromitite layer and is only present where the UG2A2 is developed. This is a fine-grained feldspathic pyroxenite, with large, subhedral augite oikocrysts. The lowermost chromitite leader (UG2A2 chromitite layer, 5 cm thick) is present over the deep central and southern part of the farm. Borehole information indicates that this leader splits off from the top of the UG2 chromitite layer. The HW1A pyroxenite overlies the UG2A2 chromitite layer. It consists of a medium to coarse-grained feldspathic orthopyroxenite with occasional clinopyroxene oikocrysts. The second chromitite leader (UG2A1 chromitite layer) is invariably present, and is approximately 15 cm thick, comprising a massive chromitite layer, often with diffuse margins. The combined thickness of the UG2A1, UG2A2, and intervening pyroxenite layers is consistent where they

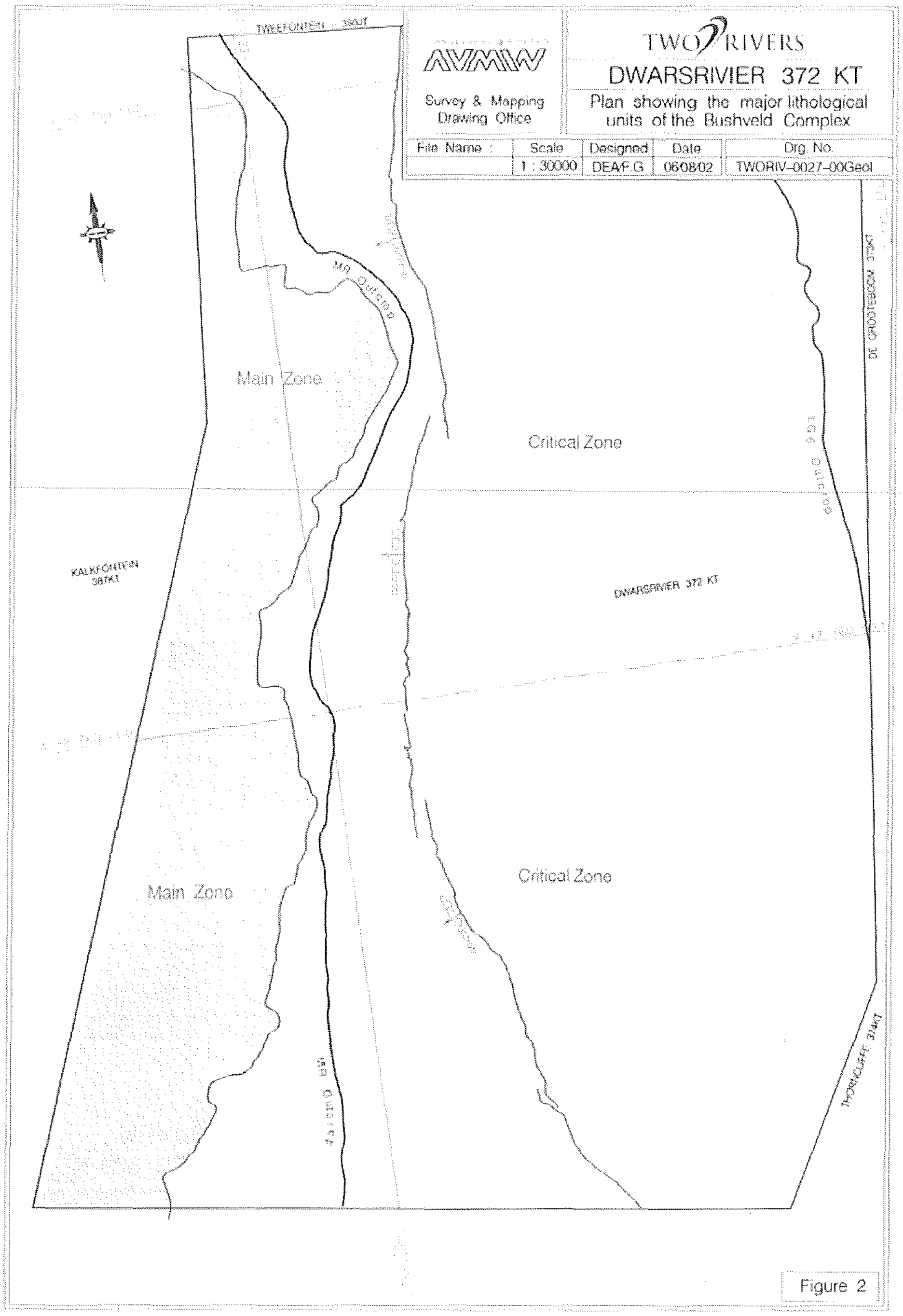


Figure 2

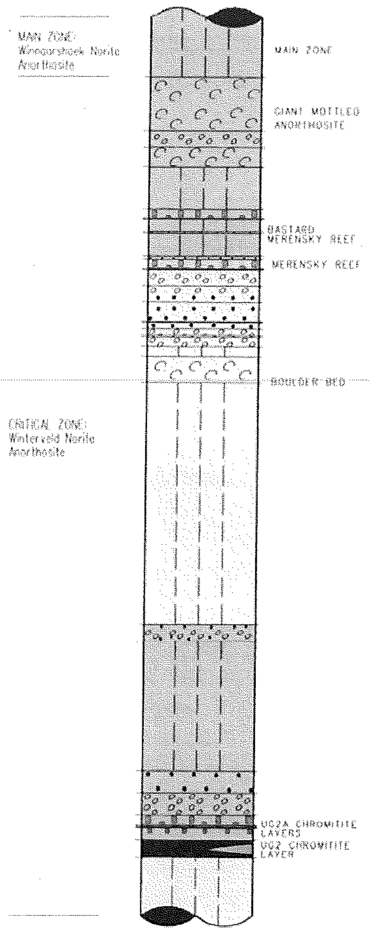
are all present. The uppermost chromitite leader is generally present, and comprises a millimetre-thick layer within pegmatoidal pyroxenite immediately overlying the second leader. The HW1 pyroxenite is overlain by a 6–15 m layer of mottled and spotted anorthosite (HW2 and 3 Units), followed by approximately 40 m of norite (HW4 Unit).

The UG2 chromitite layer at Dwarsrivier is distinct from that mined over much of the remainder of the Bushveld Complex in that it contains zones of internal pyroxenite and norite. The proposed trackless mining method will exploit different intervals of the UG2 sequence dependent on the PGE grade of the individual layers and the thicknesses of the intervening silicate layers. The definition of reef facies has been based on the number of chromitite layers present over a particular area.

Late stage features related to the intrusion of the Bushveld Complex

These include potholes and the emplacement of Fe and Mg-enriched replacement pegmatoid into the cumulate stratigraphy. Potholes are broadly circular to oval areas within which a layer sharply transgresses its footwall units. Generally, thinning of the layer coupled with the steep and erratic dips around the pothole, result in a total ground loss during underground mining operations. Potholes are present on varying scales, from the large regional potholes affecting the Merensky stratigraphy of the Northwestern Bushveld to smaller circular areas of less than 10 m in diameter[1]. Current information based on borehole intersections of potholed Merensky and UG2 layers and limited

Figure 3



Thickness (metres)	Lithology
> 250	Gabbronorite with anorthosite layers
35	Mottled and spotted anorthosite
5	Mottled anorthosite
6	Mottled anorthosite
13	Norite
3	Pyroxenite
4	Norite
0.1-0.5	Pyroxenite
7	Mottled anorthosite
1	Spotted anorthosite
2-3	Pyroxenite
0-0.3	Pyroxenitic pegmatoid
0-5	Mottled anorthosite
5	Spotted and mottled anorthosite
6	Spotted anorthosite and norite
0.3	Mottled anorthosite
2	Spotted anorthosite
2	Mottled anorthosite
0.5	Spotted anorthosite
3	Mottled anorthosite
3	Norite
8	Mottled and spotted anorthosite, pyroxenite 'boulders'
65-75	Norite
5	Spotted and mottled anorthosite
30-40	Norite
7	Spotted anorthosite
7	Mottled anorthosite
3	Pyroxenite (medium grained)
0.2	Chromitite
0.3-0.5	Pyroxenite (medium grained)
0.1	Chromitite
0-2	Pyroxenite (fine grained)
0.4	Chromitite
0-6	Pyroxenite / norite
0.8	Chromitite
0-2.5	Pegmatoid
>10	Norite / pyroxenite

ANGLOVAAL MINING
Survey & Mapping Drawing Office

TWO RIVERS
DWARSRIVIER 372 KT
Type Section of the Upper Critical Zone from the Merensky Pyroxenite to the UG2 Chromitite Layer

File Name :	Compiled	Designed	Date	Drg. No.
		DEA/FG	06/08/02	TWORIV-0010-00Geol

Figure 3

underground and surface mapping from Dwarsrivier suggests that potholes affect the Merensky pyroxenite and UG2 chromitite layers. 'Replacement pegmatoid' comprises a suite of Fe or Mg-rich pyroxenite bodies or dunite pipe-like features that appear to result from the generation and movement of Fe-enriched fluids during the fractional crystallization of the intrusion[2]. At Dwarsrivier, there is limited emplacement of replacement pegmatoid. These comprise a series of pipe-like features striking linearly E-NE across the farm.

Structure

The Two Rivers Project area is subject to dykes and faults, which appear to be a result of the breakup of the eastern margin of Gondwanaland from approximately 200 to 150 Ma[3]. Two sets of dykes are apparent, with the major set aligned N-NE, and a lesser set aligned S-SE (Figure 6).

The Two Rivers project

The Two Rivers Project is a feasibility study into the establishment of an underground mine to exploit the UG2 chromitite layer. The mine will be accessed via a decline and will utilize a trackless bord-and-pillar mining layout. The ore will be transported to surface by a system of strike conveyors on the reef plane, and a dip conveyor situated in the UG2 footwall. The ROM ore tonnage will be approximately 175,000 tpm. The plant will produce a concentrate for toll refining at Impala Refining Services, Rustenburg. Approximately 175,000 oz pa PGE in concentrate will be produced.

Two main factors, the initial capital outlay, and the desire to exploit the current favourable PGE price and supply/demand scenario influenced the project mandate that was given. The bidding process was considered to comprise

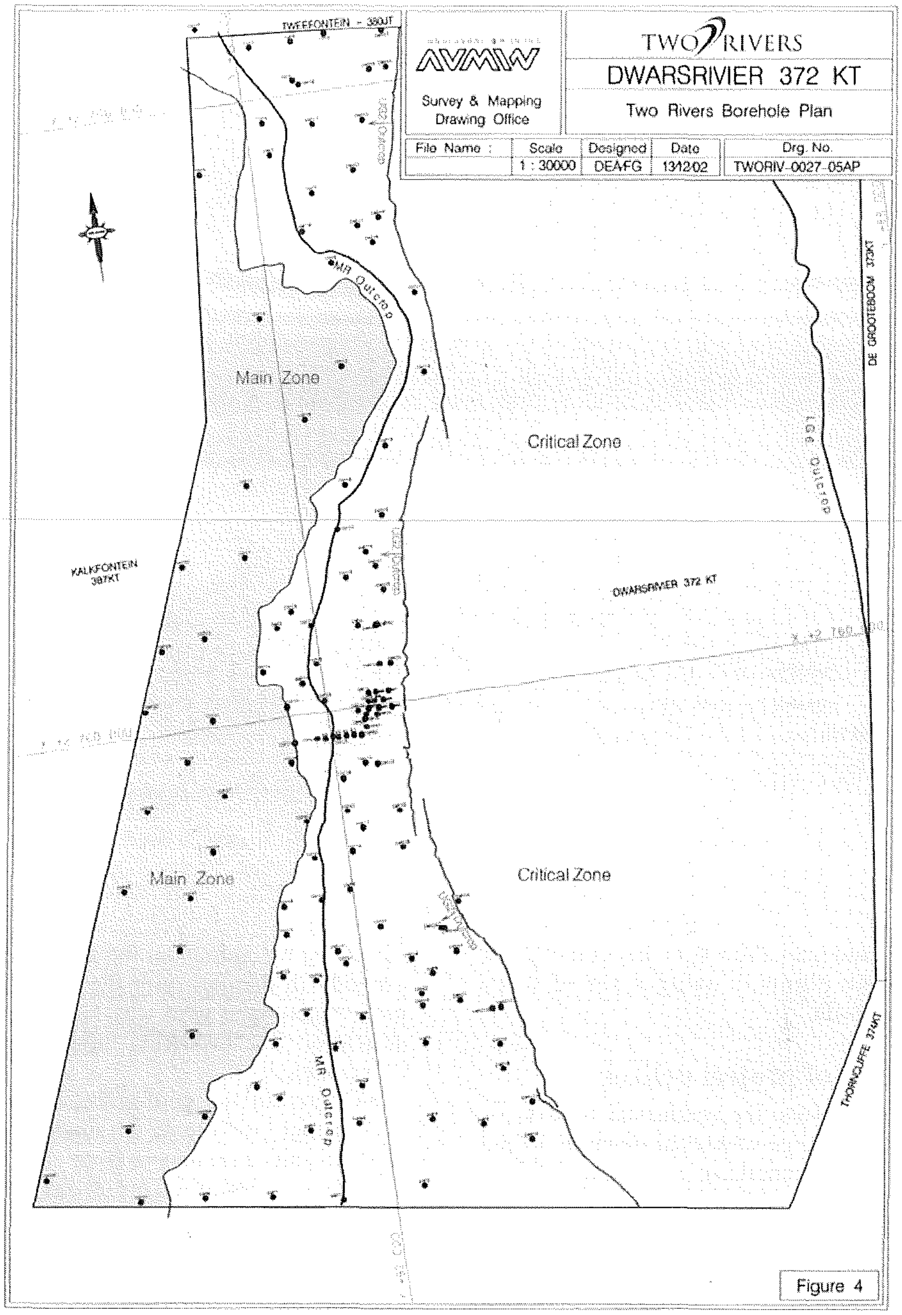


Figure 4

a pre-feasibility study; therefore a feasibility study to 90% accuracy was requested. The deadline was that the project should be ready for submittal to the management boards by the end of 2002 to receive a go-ahead decision in early 2003. To achieve this, all project disciplines would run their schedules in parallel to provide the base case for the study. Prior to finalization of the study, the initial work was checked and verified. Project go-ahead was formally given in August 2001.

The requirements for the geological work programme were outlined during the pre-feasibility phase of work. Due to topographical constraints, the borehole coverage was limited to a narrow area along the Klein Dwarsrivier valley. The programme therefore mainly focused on the completion of borehole coverage and the creation of a Datamine geological model for geostatistical evaluation and a comprehensive mine planning process using Mine 2–4D. Despite the desire to optimize the programme by using computerized methods to their maximum effect, the audit requirement both from the JV partner and the financier perspective led to the requirement that a full information audit trail be maintained.

As outlined above, the geology of the UG2 at Two Rivers is somewhat unique within the Bushveld Complex, due to the presence of the various reef facies. This leads to a 3-dimensional planning requirement that is distinct from that normally used, where a 2-dimensional approach may be adopted. In particular, the location of the boundaries between the various reef types affects the potential tonnage of the orebody, and the mining method or reef cut that will be employed. The creation of a robust geological model is required, where all the individual layers are modelled and

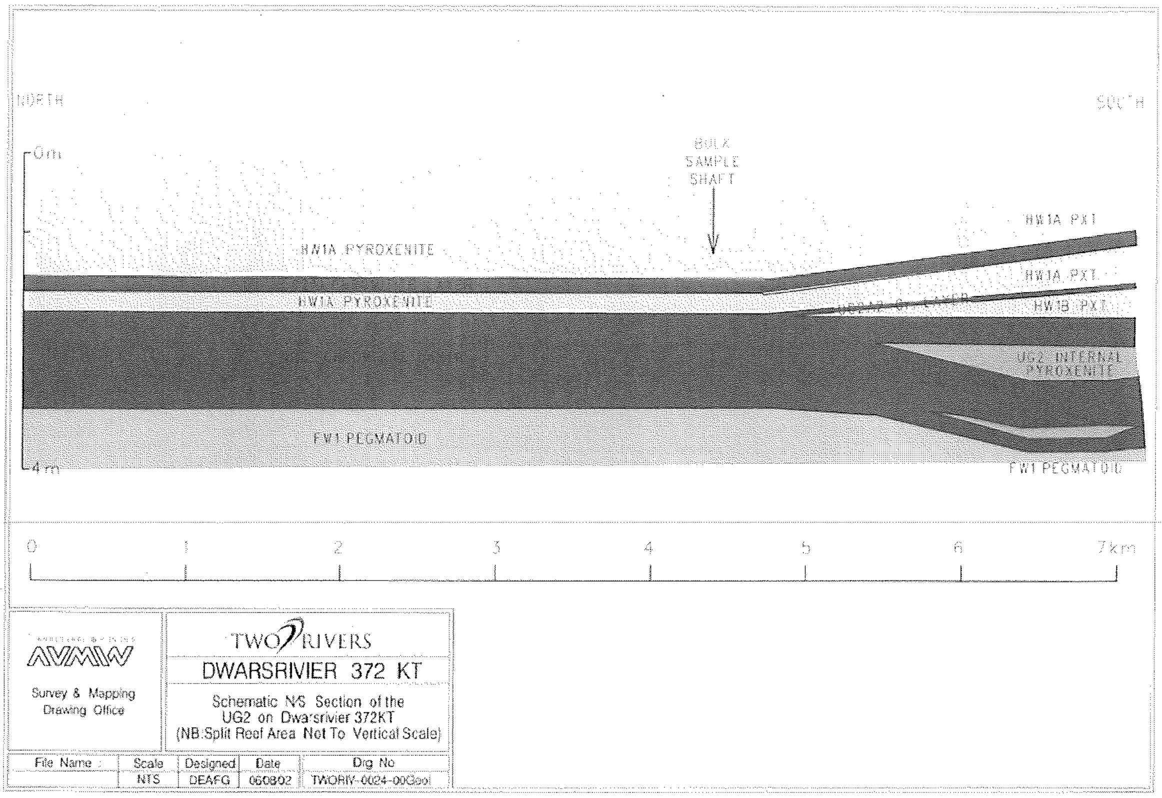


Figure 5

coded individually, and can therefore be considered separately by the mine planners using a set of rules developed within Mine 2-4D.

Optimization of project delivery

Under normal time constraints, the traditional process of performing the geological and geostatistical functions of the feasibility study would have comprised;

- Completing the geological drilling, core logging, assay and data capture
- Drafting the geological facies and structure plans
- Handing over to the Datamine geological modeller (either in-house or external consultant)
- Completing the geostatistical modelling following the completion of the geological model.

This process is linear, with the commencement of one activity following the completion of the previous activity. Using the real timeframes from the project, as well as estimated activity timeframes from other projects, the above process would have taken approximately 16–18 months to complete. This timeframe was not acceptable to the project sponsors, who required a timeous return on the initial investment.

Examination of the above process identifies two major constraints that could not be significantly optimized. The most significant is the actual drilling programme. In the Two Rivers case, the topographical constraints limited the number of rigs that could be employed. The geostatistical modelling process also comprised a less serious constraint, in that a complete geological model was required prior to the commencement of any meaningful resource evaluation work. The remaining scope to optimize the programme lay in the shortening of the time to complete the geological modelling by cutting out the drafting step, and modeling the orebody in parallel with the drilling programme using a project geologist who was familiar with the geology and structure. The following modified process was therefore implemented;

- Carry out the geological drilling and modelling in parallel, performing the modelling directly in Datamine as results became available
- Perform as much up-front geostatistical work as possible, including the development of macros, prototype block models, interim semi-variograms, etc.
- Complete the final geostatistical resource calculations immediately following the receipt of the final assay data.

The limiting factors on delivery in this case became the drilling time, and the assay turnaround time. These were optimized as far as possible by the efforts of the geological team on site, who liaised closely with the drill contractors regarding borehole management, to minimize excess drilling and contractor standing time. The analytical laboratory (Genalysis, Perth) and the sample shippers were kept appraised of the project schedule and informed in advance of sample batch timing and quantities.

The final schedule of project deliverables was:

- Geological drilling and modelling (9 months)
- Geostatistical modelling (3 months).

This comprised a potential time saving of 4–6 months on this section of the project.

Modelling methodology

Having made the decision to model all the layers within the UG2 sequence, certain potential problems became apparent, including:

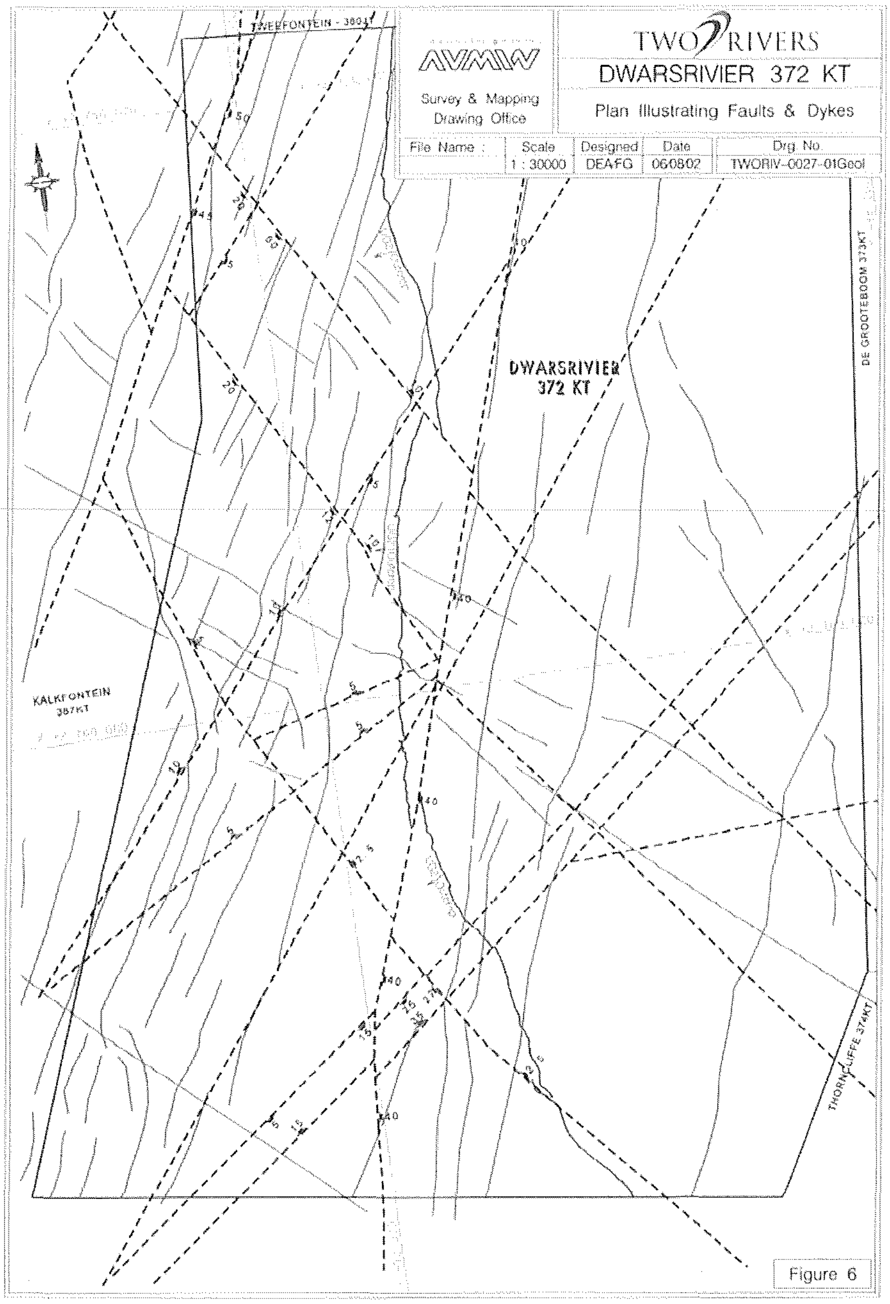


Figure 6

- Due to the topographical constraints, as well as the different generations of drilling, regular borehole grid spacing was not achieved
- The individual layers that were to be modelled were extremely thin. For example the UG2A2 chromitite layer averages 4–5 cm in thickness
- Due to the need to accurately model the boundaries between reef facies a macro-driven modelling method was not possible.

The decision was eventually taken to model the layers by creating digital terrain models (dtms) of each layer's lower and upper surfaces (Figure 7). These surfaces were then linked to create a 3D wireframe. The definition of facies boundaries and the presence of internal pyroxenite lenses was guided by ongoing geological interpretation as borehole data became available.

In line with the overall project methodology, a modular approach was adopted, whereby modelling progressed in discrete blocks defined by faults. The ongoing interpretation of geological facies boundaries was used to ascertain whether lateral movement had occurred on faults. If this had occurred, appropriate modelling adjustments were made.

Due to the inherent impossibility of modelling geological losses due to potholes, replacement pegmatoid, dykes, and faults in the Bushveld Complex, no losses were modelled in Datamine. Abnormal intersections were used for stratigraphic or structural purposes only. Geological losses were accounted using global numbers derived from local study (dykes and faults), or industry averages (potholes and replacement pegmatoid).

The output from this exercise was a geological model in which all individual layers comprising the stratigraphic

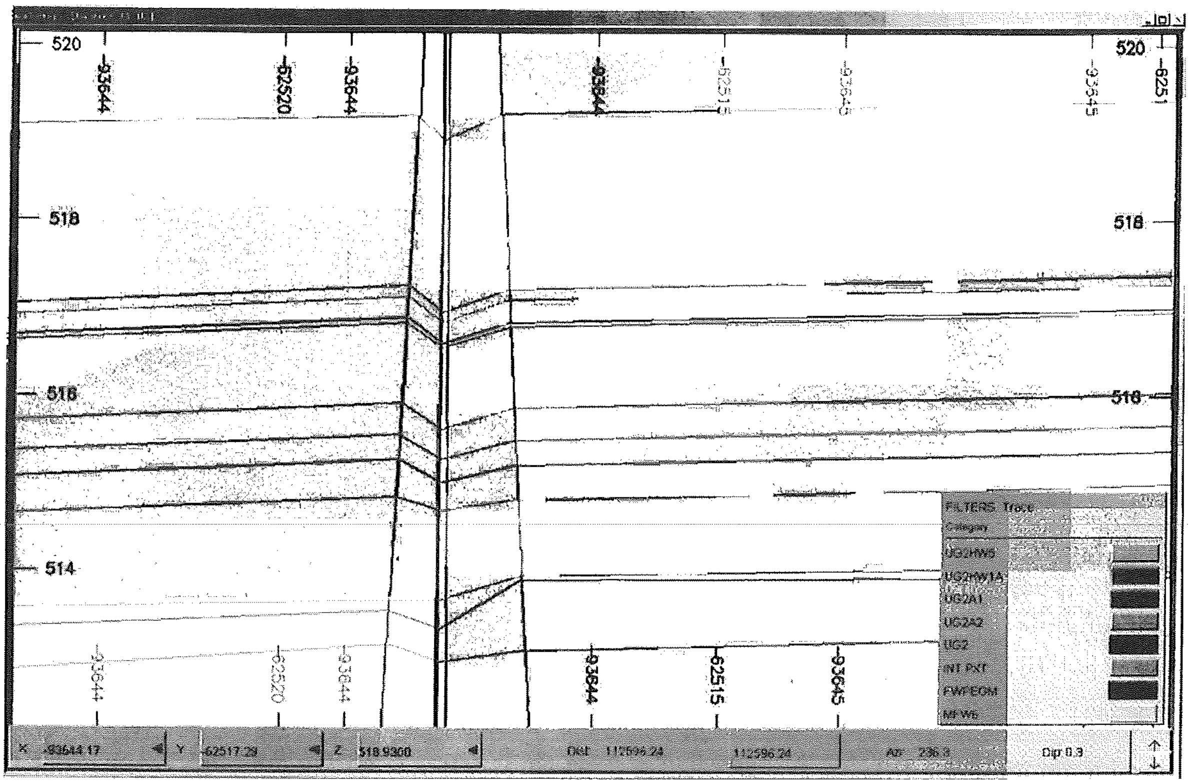


Figure 7. UG2 intersection to the south of Dwarsrivier illustrating the dtm surfaces modelled on the individual stratigraphic units of the UGs chromitite sequence

interval from the top of the HW1 unit to the base of FW1 were individually modelled.

Concurrently with the above work, the statistical and geostatistical investigation started by converting the old Pb-collection assay values to NiS-collection data by means of the 'Least-Squares' correlation-line technique. This was done in order to make use of as many of the previously drilled boreholes as possible. This entailed the re-assay of some of the older holes by the NiS-collection method.

For modelling purposes the UG2 was divided into three units comprising the top, middle and lower sections of the chromitite layer. The resulting 9 individual lithological wireframes were filled with 50*50*5 m blocks to create block models for the individual fault blocks. Within each of the wireframes, samples were composited over the wireframe thickness.

Histograms and probability plots were generated. Following analysis of the data distribution a normal distribution was employed throughout.

Eight semivariograms (5PGEs, Au, Thickness and Density) were generated on the accumulations (cmg/t) of the different elements, using all the data across the property. This was done for each geological unit. The UG2, when considered as a whole, generated a 'pure nugget effect' semivariogram. Improved UG2 semivariograms were obtained following splitting into the 3 separate units as described above (Figure 8).

Ordinary kriging was utilized for the evaluation using the improved semivariograms for the UG2. The differential between the mean of the borehole grades and the mean of the kriged grades for the combined 5 PGE + Au (6E) is less than 2%, which is considered acceptable.

Based on 250 m drillhole spacing, 20% of the UG2 mineral resource on the property was classified as Measured with the rest falling in the Indicated category.

Cost benefit of optimization

A value may be assigned to the time saving through the use of Datamine to perform modelling in conjunction with the drilling programme. This comprises several components. Firstly the opportunity, or interest cost of the initial purchase price (R5,000,000/month, based on R600 million, 10% interest rate); secondly the cost of maintaining the project personnel and equipment for the additional time period (R250,000/month); and finally the cost of delaying the project on the overall NPV (not quantified herein).

These costs amount to R20–30 million, and reflect a direct saving to the Two Rivers Project that was achieved by optimization of the work sequence and the use of the appropriate technology.

Potential downside

There are several dangers inherent in the application of 'black box' methodology to the geological modelling process. If taken too far, the audit trail of the project may be compromised. The temptation is to capture all information directly into an electronic database, whereby it then becomes extremely difficult to check if omissions are present, or if a problem is identified, to track it back to source. Version control may be a problem, especially if several people are working on the project simultaneously. Standardization of the project database is critical from the start of the project. It is therefore important to maintain continuity of project personnel, or ensure that efficient hand-over procedures are in place. The 'black box' approach does not lend itself to non-specialist verification or input, and therefore the onus lies with the user to ensure that the modelling process is clearly explained and justified to all project members. Finally, as in all specialized fields, there are limited personnel with the requisite computer

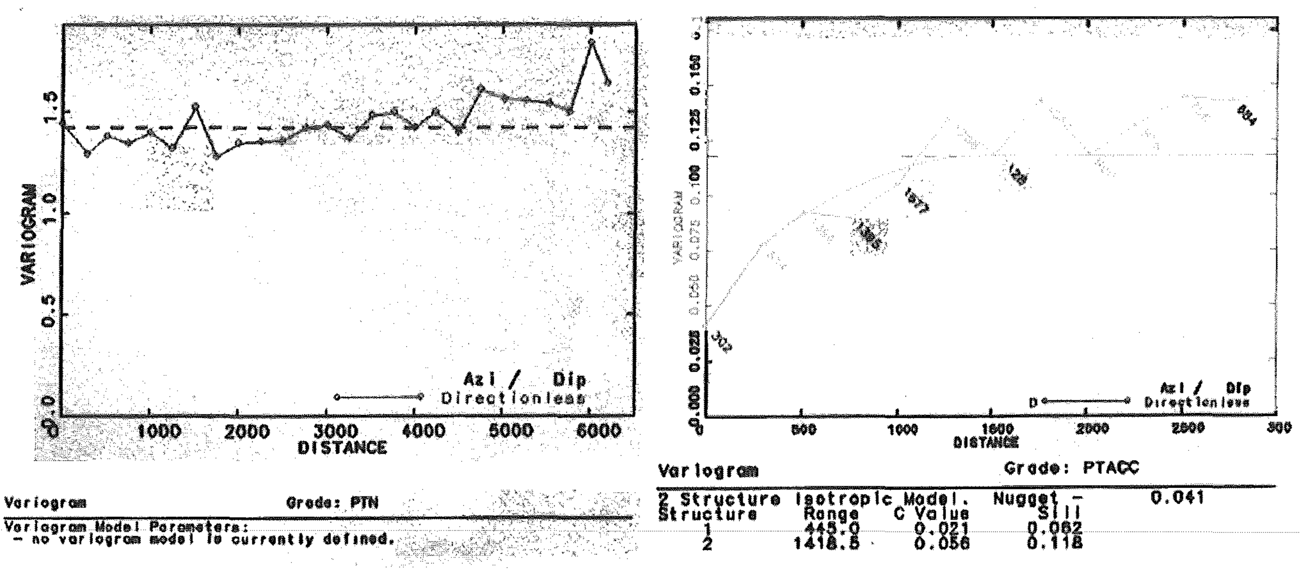


Figure 8. Semivariograms obtained for Pt accumulation at Two Rivers illustrating the UG2 chromitite layer considered as a whole unit (left), and the improved semivariogram obtained following splitting of the layer into top (illustrated), middle and lower zones

skills, coupled with the geological knowledge to add real value to a project by optimizing the schedule as at Two Rivers. In a similar vein, not all orebodies are as consistent in their geology as the UG2 chromitite layer; therefore the success of this process is orebody-dependent.

The applicability of this approach at Two Rivers has been proven by independent audit of the project by SRK Consulting (South Africa). Their audit was done less than a month following the completion of the work programme, and no material concerns were identified with the quality of the geological and geostatistical work.

Conclusions

The delivery time of the Two Rivers feasibility study was shortened by 4–6 months through the use of appropriate technology, combined with process optimization. This has been achieved by:

- Performing the geological modelling of the orebody in Datamine in parallel with the drilling programme
- Performing as much up-front geostatistical work as possible.

The major time constraints to the programme were the drilling programme (9 months), and the geostatistical modelling (3 months) following the completion of the geological model and receipt of assay data. Performing the geological modelling directly within Datamine in parallel with the drilling programme resulted in a time saving of approximately 4–6 months on delivery of this section of the feasibility study. The estimated cost saving to the project is R20–30 million (excluding NPV considerations on the future capital expenditure programme). Despite the drive to optimize the programme, a full audit trail was maintained. The success of this project methodology was facilitated by the consistent geology of the UG2 chromitite layer. A more complex orebody may not be amenable to the use of this project methodology.

Acknowledgements

The success of the methodology employed at the Two Rivers Project is a direct result of the focus and effort of the site project team in delivering the geological section of the project on time and within budget. The authors express their thanks to these personnel for a job well done.

Two Rivers management are thanked for their permission to publish this paper, and for their continual support during the period of the project.

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