



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en
Inligtingtegnologie / Lefapha la Boetšenere,
Tikologo ya Kago le Theknolotši ya Tshedimošo

RESEARCH SUMMARY 2017

DEPARTMENT OF MINING ENGINEERING

JULY 2018

Executive Summary

The use of industry experts to support lecturers, in doing full time lecturing, and the appointment of some of them on a part time basis to support undergraduate as well as postgraduate studies, was well received by the students. The industry specialists got involved within a number of designated academic programmes and specifically in research related activities. This is also of value to the research activities within the Research study module presented for postgraduate students. As part of a process to increase the quality of research projects, the department made a decision to include research methodology as part of all Masters' thesis registered students and where students have not done research methodology as a module before also include research methodology as a pre-requisite for PhD registration.

In the field of mining there are many collaborative and cross-cutting research initiatives. Mining related research by various departments in the Faculty of Engineering, Built Environment and Information Technology continues. These efforts are co-ordinated within the Mining Resilience Research Centre (MRRC) hosted within the Department. It is a strategic intent that more contract researchers will be appointed within the MRRC so as to increase research capacity and capability within the department. The department at this stage only has 6 permanently employed lecturers, which makes it imperative to have a contracted-in researcher strategy as part of the department's long strategy.

The support for the Chair in Rock Engineering by Harmony Gold continues in this programme as industry directed research into specific Rock Engineering problems and the associated solutions. The Harmony chair is in its second year of a three year contract ending in December 2019. The Department are already in discussions to extend this support for another three years, from 2020 to 2022. A new research chair, in innovative rock breaking technology, was also established within the department through the support of AEL Mining Services with its first active year of a three years contract that started in January 2018.

The department is also involved in the following research areas with industry leaders within each of the mentioned disciplines:

- Mechanisation and Automation
- Rock-breaking and Explosive engineering
- Rock cutting
- Management and Leadership
- Safety and Health
- Risk Management
- Mine Ventilation Engineering
- Rock Engineering.

There has been a slight increase in the number of publications compared to 2016 for the 2017 period. The pipeline for 2018 is however very healthy and indicates an increase compared to 2017. It must however be stated that with the small number of permanent employed lecturers (namely 6) will also be a challenge to increase research capacity on a year by year basis. Contract research appointments are no longer a nice to have but quite important in building up the

research capacity and capability in the department. The challenge to identify suitable, high impact journals within the mining research area remains a considerable challenge.

The Mining Resilience Research Centre (MRRC) has experienced growth through its success in obtaining new projects and successfully delivering quality work. Activities within the MRRC is managed under the leadership of the newly appointed Professor Francois Malan and supported by co-ordinated by two junior researchers as contract staff, namely Mr Jónatan Jacobs and Mr Eugene Preis. They function as project managers, tender process managers, stakeholder managers and engineers in project execution. After Prof Jan du Plessis' departure, Prof Francois Malan was appointed as the new Director of the MRRC. The appointment of Professor Malan brings great value to both the department for academic quality as well as for the MRRC through his experience and background in contract research.

The MRRC continued its excellent relationship with the Mine Health and Safety Council (MHSC), additional research projects were tendered for, and more tenders will be released in 2018 that will be evaluated for potential to tender for as well. At present there are 7 active research projects within the Centre of Excellence as well as within SIMRAC. To date, 3 projects have been completed successfully for the MHSC under the MRRC. External research funding through the MHSC undertaken under the MRRC will further assist in keeping the current research momentum. It is foreseen that the Department will again be successful in attracting external Research funding through SIMRAC and the CoE respectively even though the mining environment is extremely constrained. Attempts to source any additional funding to support the respective minimum research roles within the MRRC have not been successful. The sustainability of contract researcher appointments and its related compensation models still remains a risk to the success of the Centre to be content with.

The South African Mining Extraction Research Development and Innovation (SAMERDI) strategy built on the collaborative research proposals developed between the CSIR, UP, Wits and UJ. In this, UP (predominantly EBIT, through the MRRC) is involved to various degrees in the projects under SAMERDI. SAMERDI had a slow start in 2017 due in part to the collaborative nature hindering effective proposals that include the four mentioned entities in capacity and methodology to an agreeable extent, as well as delays in contracting between the CSIR that coordinates SAMERDI and the DST that provides the initial funding, and in turn delays in contracting between the CSIR and the universities. Once the contracting is in place (which is currently still underway in 2018), it is envisioned that UP can make a significant contribution to these projects and increase its presence in this collaborative network that not only includes the research bodies mentioned, but also the local (and international) equipment manufacturers, and the government entities such as DST and DTI.

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1 Introduction

Over the past years the use of industry experts that were appointed on a part time basis to help the department with postgraduate studies (project and research related work) has continued. This was very well received by the students as industry experts got involved with the academic programme (especially with regards to research related activities, required from the Guided Special Studies Module). Figure 1 shows a breakdown of the research capabilities and the environment in which postgraduate students can be assisted with in their studies within in the Department of Mining Engineering. It is also a strategic intent that all research projects will have as key objective visualisation as part of the implementation strategy of all research projects.

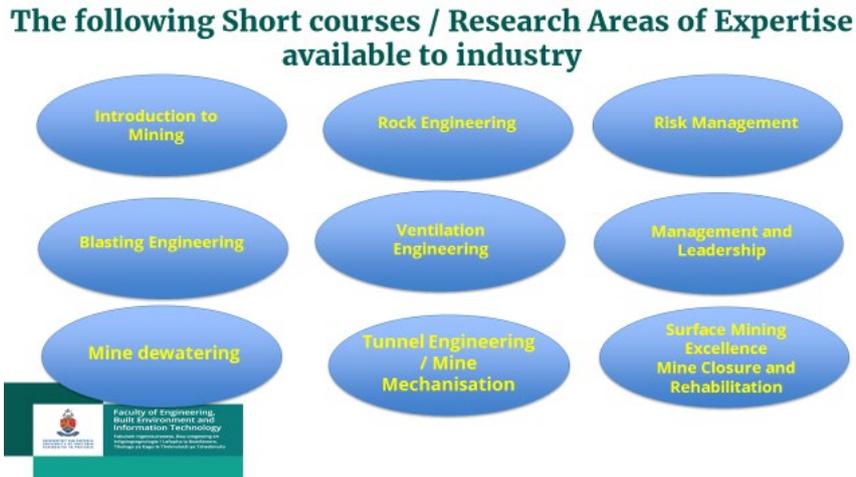


Figure 1: Post graduate research focus areas

The department as part of its industry collaboration process will also be involved with a safety officer qualification drive which is a Minerals Council South Africa initiative under the guidance of Mr Leigh McMaster. All four mining Universities form part of this initiative. Innovation and its related innovation process is a key initiative in the department and the role out thereof to be seen in 2018. It is also in the long run the intention to explore activities in marine and asteroid mining which would further enhance the department’s involvement in innovative research activities (Figure 2).

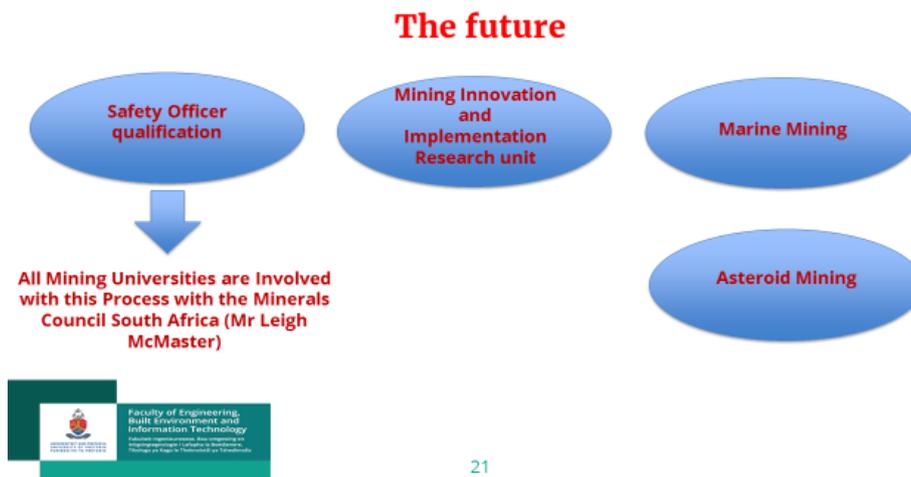


Figure 2: Future research and other interventions

Research Chair and other research activities are highlighted and discussed accordingly. Each of the initiatives is briefly discussed and an update for the 2017 activities is provided in the following sections.

2 Harmony Chair for Rock Engineering (Mr Johan Hanekom)

The support for a chair in Rock Engineering by Harmony Gold continued during 2017. Unfortunately Mr Hanekom resigned at the end of July 2018 and Prof Malan has been appointed as the acting Chair holder for the Harmony Chair. This tabled and approved at the last Chair Management committee that was held in May 2018. The following strategic issues have been included within the Harmony Chair in terms of research, funding and development.

- The development of a new mine design criterion as part of the mining rate research process is being promoted, marketed and applied within the research.
- Harmony staff or personnel providing rock engineering services to Harmony was approached to assist with research as part of their continued studies and include Mr P Couto, Dr J le Roux and Dr Michael du Plessis. Mr Couto has already formalised his contribution and talks are currently under way with Dr Le Roux and Dr du Plessis participation to be formalised.
- Mr B Okhuis is another Post Graduate student from the Industry that is involved with this research, currently enrolled for his MSc.
- Transfer of knowledge from researchers to subordinate rock engineers in the industry was formalised with a training session to Harmony Rock Engineers in 2017.

A summary of the research findings for 2017 is shown in Table 1.

Table 1: Summary of research outcomes reached

Nr	Date	Author	Topic	Summary
13	26-Jan-17	F Malan, J Napier	Calibration of numerical modelling	Utilised case study closure measurements to calibrate the code. Code is able to represent closure and closure rate profiles well and much better than traditional visco-elastic models (Burger). An exponential decay function is derived with two constants a & b that allowed good estimation of actual closure profiles. The numerical model is able to address stress and material related time dependent behaviours (creep) and other processes should be excluded. Thus, if large scale instability occurs, the resulting closure profile should not be applied to attempt numerical model calibration. A simplified geometry was used to illustrate code's behaviour and results correlated well with expected closure profiles and is thus an improvement on the historical visco-elastic models applied. However, grid size and sequential failure of elements in a row ahead of the face distorts results. Smaller grid sizes and non-decay of slope parameters provide better profiles. The half-life parameter was calibrated against actual closure profiles and allows for corresponding half-life and b constant to describe exponential closure profile. If only strength is decayed, the correlation is better than when the slope parameter is also decayed. The sequential activation of elements also leads to poor correlation of profiles and also indicate that a simple exponential model to describe the closure profile is also not appropriate. Calibration appears very difficult and will require more work.
14	25-Mar-17	B Okhuis	Sensitivity study	The work conducted in 2016 was extended to include the codes sensitivity to several other input parameters including cohesion, friction angles on bedding, position of bedding, Elastic constants, etc.
15	24-Mar-17	F Malan, J Napier	Grid size effects in simulating closure	Impact of grid size on closure profile results were confirmed and indicated that very small grids provided good results but large grid sizes create jumps in the closure profiles as elements yield / fail. A solution to this concern was addressed by investigating the fracture zone length ahead of the mining face which indicated dependency on the grid size and confirmation of jumps observed in the closure. It also shows near constant peak stress ahead of the face. An algorithm was developed to track the fracture zone development within coarse elements. The need for coarse elements in large scale mining problems are important, but the calibration indicated the need for smaller elements. This algorithm attempted to indicate fracture zone movement within large elements, so providing a more useful tool to larger mining problems.
16	11-Sep-17	F Malan, J Napier	Strategies to address numerical grid size effects in simulating time-dependant stope closure	Fracture front position cannot be located more accurately than the grid size. Due to this, near face closure in time-dependent fracturing is thus not smooth and becomes a larger problem when grid sizes are large. When the grid size is reduced, run-times become excessive. Lumping was used to improve run-times in Texan using kernel tables, but layouts are limited to 80,000 elements. Solutions exist that will require substantial research (Napier, Malan, 2007) but a interim solution was trialled, called partial element failure. Since time dependent closure is sensitive to the strength drop from the initial to limit strength values, the partial fracturing was trialled for zero and non-zero strength drops. Texan command CrushX refers to discrete element failure and CrushF to partial failure. For zero strength drop, discrete failure shows much smaller fracture zones for coarse than for fine grid sizes. The partial failure runs at larger grid sizes correlated well with fine grid, discrete element failures for failed region and closure profile, but not for fracture zone depth as a discrepancy appears when the grid size edge is passed. When allowing a strength drop to occur, failed region, closure profile and fracture zone depth correlate well.

Table 2: Summary of research outcomes reached continued

Nr	Date	Author	Topic	Summary
19	15-Jan-18	F Malan, J Napier	Evaluation of proposed partial element fracturing algorithm	Spurious variations in time-dependant closure profiles indicated in previous report addressed via partial fracturing scheme. Random distribution of rock strength properties also investigated as a solution. Impact of element size on energy release also evaluated. Closure response appears to be smoothed if random strength properties are applied. The impact on the fracture front shape and energy release in currently unknown. Property variation should be offset against actual space and value variations in-situ as this may be a way to consider varying actual properties in rock mass. Discrete vs partial fracturing of elements indicates small increase in fracture front with partial element failure. A reduction in grid size from 1m to 0.2, provide a larger fracture zone at discrete with coarse grid random properties and a smooth fracture front for partial element failure and random properties to fine grid elements. This smoothed fracture zone approaches that of uniform property runs. Energy release for partial failure at a larger grid size is similar to discrete failure at smaller grid sizes when random strengths on a 1.0m grid is applied. Random strengths do not require random to be on fine grid as it does not impact substantially on energy. Fracture zone size is affected by grid size for discrete element failures and fine grids are similar to partial failure at larger grids. Using partial, grids can be made larger and get similar results to finer grids on discrete, affecting running times substantially. Closure profile not substantially affected by partial, discrete and grid size. Variable strengths lead to larger variation in energy release, but shows slow mining has lower energy release than fast mining, where 0.5m per day per panel indicates lower energy release on each face than 1.0m per 2 panels per day (i.e. similar overall production).

3 AEL Mining Services Chair for Innovative Rock Breaking Technology (Prof. William Spiteri)

The AEL Mining Services research chair for Innovative Rock Breaking, a position held by Prof. William Spiteri, was established in 2017 and implemented in January 2018 due to the late start of the agreement. During 2017, the first research study was initiated after the University was approached by the General Manager of Glencore's Goedgevonden Mine regarding the safe clearance distance implemented at the mine.

A summary of the research findings for 2017 is shown in Table 2.

Table 3: AELMS Chair Summary of research outcomes reached

Topic	Summary	Future research required
<p>Determination of safe blast clearance radii for blasting operations at Glencore coal mines in the Witbank area.</p>	<p>Flyrock remains a significant side-effect of surface blasting practices in mining and presents substantial risk along with high penalties if damages and/or injuries occur. This investigation was conducted at Glencore’s Goedgevonden mine near Ogies in Mpumalanga province. The main objective of this investigation was to review the mines current clearance distance and make recommendations following a literature review and field investigation.</p> <p>The flyrock causative factors that were identified by the literature study as geology, burden, stemming, charge mass per hole, blast design layout and timing sequence. Moreover, during the literature study, two predictive models were identified, namely the SveDeFo equation and the Scaled Depth of Burial (SDOB) approach. However, comparing the causative factors to the predictive models’ factors, an obvious disconnect was observed; resulting in the conclusion that additional research and investigation is necessary with regards to flyrock.</p> <p>The field investigation and GAP analysis yielded evidence that some blast parameters were not always designed according to the formulae and/or rules-of-thumb. This could potentially cause flyrock. Stemming was identified to significantly influence the calculated clearance distance and an exponential relationship was illustrated between the stemming length and the clearance distance (based on the SDOB approach).</p> <p>The main recommendation for this project was that the Scaled Depth of Burial approach should be used for calculating each blast in order to calculate an accurate clearance distance based on a specific blast design. This clearance distance will then dictate the clearance plan that always accompanies the blast design/plan. For a standardised clearance distance, if preferred for SOP’s, the minimum clearance distance of 800m was recommended for people.</p>	<p>The literature reviewed during the study yielded significant evidence that very little work have been conducted in the field of flyrock and that the overall concept is rarely fully understood.</p> <p>In order to satisfy the mine’s need for evidence to support the safe clearance distance currently implemented, a quantitative analysis is required. As such, accurate, quantitative recording of flyrock during a blast is required.</p>

It is therefore proposed to research and develop a methodology of accurately measuring and recording fly rock during a blast, in order to gain a sufficient sample size or data set to make additional and more reliable recommendations to the mine. In addition to delivering an adequate dataset for the mine, the methodology should also be applicable to measuring the effect of the various drilling and blasting parameters on fly rock and can therefore ultimately assist in developing a new and accurate predictive model to improve blasting performance and eliminate the risk of fly rock.

The importance of developing local post graduate students was identified and Ms Jennifer Sapsford was involved in 2017. Her responsibility included conducting the research and field investigation for the study summarised in Table 2 and to continue with the required future research relating to this topic in 2018.

4 Mining Resilience Research Centre

Professor Jan du Plessis' resigned in July 2017 and Professor Ronny Webber-Youngman was appointed as the interim Director of the MRRC until December 2017. Professor Francois Malan was officially appointed as the Director of the MRRC as from the 1st of January 2018. The department continued without interruption in its efforts to develop the research offering through the Mining Resilience Research Centre (MRRC). The MRRC activities have been co-ordinated by the two junior researchers in the department Mr Jónatan Jacobs and Mr Eugene Preis. They functioned as project managers, tender process managers, stakeholder managers and engineers in project execution. Through these efforts, it is envisaged that the MRRC will further grow our footprint in the mining research industry globally. This initiative will have as part of its strategy teaching, research and consulting activities to be further explored. It is further proposed industry leaders in their related research topics needs to be recruited and appointed as contract researchers within the MRRC as a sustainable solution towards establishing capacity and capability within the Centre. This includes the appointment of full time postgraduate students are researchers in the MRRC.

As part of the development, it was planned that all the Mine Health and Safety Council (MHSC) Research within UP, be conducted through the MRRC, as the coordinator of the Centre of Excellence (CoE) under the Memorandum of Understanding between the MHSC and UP.

Numerous proposals were prepared and submitted to the MHSC since the establishment of UP as a CoE, and UP was successful in securing a number of research contracts that were still in execution in 2017. This involved a number of departments within EBIT and within UP, namely:

1. Upgrading of sound analysis facilities with the addition of an Acoustic Camera – Mechanical Engineering.
2. Establishing a Test and Simulation Capability and Standard Verification Methods to Evaluate Collision Management Systems – Mechanical Engineering.
3. Underground and Surface Communication System – Electric, Electronic and Computer Engineering
4. Rock mass condition assessment tools – Mechanical Engineering.
5. Assess the feasibility of reducing diesel particulate matter (DPM) exposure through replacement and/or conversion of all Tier 0 with Tier 2 or Tier 3 engines – Mining Engineering.
6. Developing mining illumination standards for mobile equipment operating in open pit and underground mines in the South African mining industry – Mining Engineering.

In 2017, UP also became involved in the South African Mining Engineering Research Development, and Innovation (SAMERDI) Strategy. SAMERDI is a collaborative initiative, between the CSIR, UP, Wits and UJ, which is coordinated by the Mining Precinct (a division of the CSIR). SAMERDI is funded by government, currently by the DST and with planned funding by DTI once the research projects reach sufficient technology readiness levels for commercialisation. The MRRC spearheaded the engagements and coordination of UP within SAMERDI and greatly contributed to the collaborative project planning and proposal development. The projects UP were involved in (primarily the departments within EBIT), for 2017, included (these were investigations at risk, awaiting approval of the contractual agreement between UP and the CSIR Mining precinct:

1. Mechanisation of Gold and PGM mines using drilling and blasting.
2. Non-explosive rock breaking of Gold and PGM mines.
3. Real-time information management systems.
4. Longevity of current mining through best practice analysis.
5. Real-time information management systems for underground mining.

Various researchers from UP have been contacted and indicated interest and further involvement within these themes, with continued and increasing involvement planned post the finalisation of contracting between UP and the CSIR for work under SAMERDI.

Other potential upcoming research projects for 2018 tendered for, include:

1. The issuing of self-contained self-rescuers – MHSC.
2. Research and development for technology transfer of the missing person locator system project - MHSC

Continued involved in projects under SAMERDI:

1. Mechanisation of Gold and PGM mines using drilling and blasting.
2. Non-explosive rock breaking of Gold and PGM mines.
3. Real-time information management systems.
4. Longevity of current mining through best practice analysis.
5. Real-time information management systems for underground mining.

Other potential projects to become involved in under SAMERDI in 2018:

1. Advanced orebody knowledge.
2. The successful adoption of technologies (a map).

External research funding through contract research work within SAMERDI and for the MHSC, undertaken under the MRRC, will further assist in keeping the current research momentum. It is foreseen that the Department will again be successful in attracting external Research funding through SIMRAC and the CoE respectively (under MHSC) even though the mining environment is extremely constrained. Attempts to source any additional funding to support the respective minimum research roles within the MRRC have not been successful. The full time/part time appointment of contract researchers and project leader needs to be investigated and implemented as a long terms sustainable solution. This is a risk identified that needs to be addressed. Currently the MRRC under the leadership of Professor Malan is coordinated and operated predominantly by contract staff who secure external project funds through proposal and tendering efforts as well as the majority of the required project execution work within the Department, this is not sustainable.

5 Contract Research activities

Below is a short list of contract research activities concluded within the department in 2017:

1. Develop feasible methodologies to aid escape in poor visibility in underground mining environments (SIM 140701). This project was concluded in 2016 and final close-out completed in 2017.
2. Missing Person Locator System (CoE 150904) – Mining Engineering.
3. Developing testing specifications for netting and the dynamic testing of tendons; and assess the feasibility of establishing an independent accredited support testing facility (CoE 150202) – Mining Engineering.
4. Dissemination and commercialisation function of the research Centre of Excellence (CoE 170904) – GSTM, Mining Engineering.
5. Impact of technology on people in mining sector (CoE 150901) – Shared Services, Mining Engineering, Lead Compass
6. Critical (Gap) Analysis on SIMRAC Occupational Health Handbook of 2001 for the South African Mining Industry – The Guild, Mining Engineering.

Table 4: Summary of research themes within SAMERDI

Advanced Orebody Knowledge	
Contact Person from UP	Mr. Jannie Maritz (Jannie.Maritz@up.ac.za)
MRRC interest in participation and the role of individual members	<p>Mine planning</p> <p>Analysis of data outputs</p> <p>Geo modelling (Metallurgical Engineering Department)</p> <p>Geotechnical Data and Seismic Risk (Geotechnical Engineering under MRRC)</p> <p>Systems approach to the project from a mining engineering and systems engineering perspective</p>
Mechanisation of Gold	
Contact Persons from UP	Dr. Bertie Meyer (Bertie.Meyer@up.ac.za)
MRRC interest in participation and the role of individual members	<p>Rock Engineering fundamental research, and design of support systems (Prof Francois Malan, Jannie Maritz)</p> <p>Rock removal systems (Mechanical Engineering at UP)</p> <p>Best practices (Dr. Bertie Meyer, Prof Jan du Plessis)</p> <p>Longhole Stopping (Dr. Bertie Meyer, Prof Jan du Plessis)</p> <p>Remote operating systems (Electronic Engineering Department)</p> <p>Systems approach to mechanisation (Sezer Uludag, Bertie Meyer, Jan du Plessis, Jónatan Jacobs)</p> <p>Lab funding requirements for Engineering 4 lab for rock breaking, mechanisation, explosive testing etc.</p> <p>MRRC can source students for literature studies</p>
Mechanisation of PGM	
Contact Person from UP	Dr. Bertie Meyer (Bertie.Meyer@up.ac.za)
MRRC interest in participation and the role of individual members	<p>Rock Engineering fundamental research, and design of support systems (Prof Francois Malan, Jannie Maritz)</p> <p>Rock removal systems (Mechanical Engineering at UP)</p> <p>Best practices (Dr. Bertie Meyer, Prof Jan du Plessis)</p> <p>Longhole Stopping (Dr. Bertie Meyer, Prof Jan du Plessis)</p> <p>Remote operating systems (Electronic Engineering Department) – Review of current standards and regulations regarding (UG) communications, for systems and frequencies etc.</p> <p>Systems approach to mechanisation (Sezer Uludag, Bertie Meyer, Jan du Plessis, Jónatan Jacobs)</p> <p>Lab funding requirements for Engineering 4 lab for rock breaking, mechanisation, explosive testing etc.</p> <p>MRRC can source students for literature studies</p>
Modernisation of Current Mining	
Contact Person from UP	Mr. Jónatan Jacobs (Jonatan.Jacobs@up.ac.za)
MRRC interest in participation and the role of individual members	<p>MRRC can source students for literature studies</p> <p>Leveraging work done in MHSC quick-win projects under UP (Contact persons:</p>

	<p>Eugene.Preis@up.ac.za, Jonatan.Jacobs@up.ac.za, Investigate new technologies (Jónatan Jacobs, Dr. Bertie Meyer, Prof. Jan du Plessis) Change management initiatives (Dr. Johan Uys and Eugene Preis) Automation of mining operations (Sezer Uludag)</p>
Non-Explosive Rock Breaking	
Contact Persons from UP	<p>Prof William Spiteri (William.spiteri@up.ac.za) Dr. Bertie Meyer (Bertie.Meyer@up.ac.za) Mr. Wolter de Graaf (Wolter.DeGraaf@up.ac.za) Mrs. Sezer Uludag (Sezer.Uludag@up.ac.za)</p>
MRRC interest in participation and the role of individual members	<p>MRRC can source students for literature studies + work comparison on global OEMs (Jan du Plessis) Mining layouts and requirements (Prof Francois Malan) Geotech assessments Previous work assessment (Prof Francois Malan, Dr Bertie Meyer) Assessment of rock breaking mechanisms (Bertie Meyer, Wolter de Graaf, Sezer Uludag) Systems design methodology (Sezer Uludag, Jónatan Jacobs) Change management (Johan Uys)</p>
Real-Time Information Management Systems	
Contact Person from UP	Mr. Eugene Preis (eugene.preis@up.ac.za)
MRRC interest in participation and the role of individual members	<p>Modelling capabilities (Metallurgical and Mechanical Engineering Departments) General project interest (Electronic Engineering Department, Eugene Preis, Jónatan Jacobs) Review of current standards and regulations regarding (UG) communications, for systems and frequencies etc. (Electronic Engineering Department) Sensors, data acquisition, data transfer, communication systems, tracking (Electronic Engineering Department)</p>
Human Factors	
Contact Persons from UP	<p>Dr. Johann Uys (joeuys@lantic.net) Mr. Eugene Preis (Eugene.Preis@up.ac.za)</p>
MRRC interest in participation and the role of individual members	Across the board interest
All Geotechnical based work	
Contact Person from UP	Mr. Johan W. Hanekom (jhanekom@middindi.co.za)
All Mechanical Engineering based work	
Contact Persons from UP	<p>Prof Stephan Heyns (Stephan.Heyns@up.ac.za) Mr. Abrie Oberholster (Abrie.Oberholster@up.ac.za) Mr. Rudi Kroch (Rudi.Kroch@up.ac.za) Prof Schalk Els (schalk.els@up.ac.za)</p>

All Electronic Engineering based work	
Contact Persons from UP	Dr. Kahesh Dhuness (Kahesh.Dhuness@up.ac.za) Dr. Herman Myburgh (Herman.Myburgh@up.ac.za)
Metallurgical Engineering based work	
Contact Persons from UP	Mr. Nigel Phuti (u29205337@tuks.co.za) Mr. Jónatan Jacobs (Jonatan.Jacobs@up.ac.za)

6 Internal staff development

As was mentioned with last year's report it must be that the department has a number of contracted in staff is still considered to be junior in terms of academic development and their associated academic profile (when one considers it from a pure research prospective). There are also only 6 full time appointed lecturers in the department (which includes the HoD). This is in stark contrast to the department's staff complement and their associated mining experience. Most of the staff members are busy with advancing their academic careers. One of the staff members (lecturers), converted his honours degree into master's degrees and one staff member is registered for his master's degree in mining engineering, one with a master's degree is registered for a PhD. There is also currently 2 Associate Professors in the Department and the remaining senior lecturer (PhD) has more than 30 years of mining experience.

We have four extraordinary professors to further enhance the academic profile and research related activities in the department, they are Professors Jan du Plessis, William Spiteri, Johan Napier and Bharath Belle. This forms the building blocks for the foundation for establishing an academic team that would be in a position to enhance the research output of the department in the future (with specific reference to Masters and PhD registered students).

Historically the department was not known to deliver a high number of research outputs annually (because of the low number of permanently employed staff members, of whom only 3 have PhD qualifications (the remaining three, 2 Masters and 1 Honours degree qualifications). As from 2014 there has been a slow and steady increase in the number of publications from permanent employed staff members. The strategic intent in appointing more contract researchers within the department is to increase the overall research output in the department. The MQA continued its support by sponsoring 4 assistant lecturer positions per year for Historically Disadvantaged South Africans (HDSA's), which is to continue in 2018. Two of the current 4 assistant lecturers have been registered for their Masters' studies and the other two for their Honours' degrees in mining engineering. Once these students complete their Masters' degrees they will be considered for appointment as junior researchers, something that the department fully supports.

7 Postgraduate studies

In addition to all of the above mentioned, the department has also put in place a further new requirement for graduation of our B.Eng. (Hons) Mining Engineering students and BSc Applied Science Mining (Honours), that all registered students submits an article for publication with their respective department supervisors as art of the assessment process. It is then based on this article presented that the supervisor and student agrees to submit the article for publication. It has also been decided that for all Masters and PhD registrations, that all candidates needs to provide evidence of research methodology experience. For all Masters' degree registration all potential candidates will be registered Masters in progress with pre-requisite of the successful completion of the Research Methodology module presented at the University of Pretoria.

In 2017 the number of postgraduate students that graduated from the department, namely 3 B.Eng (Hons) Mining, 3 BSc Applied Science Mining. The department has made the strategic decision to reduce its undergraduate number intake and to increase its postgraduate intake numbers so as to support its research drive objectives as indicated in Figure 3.

The intention is to have 70 students registered for an Honours degree in Mining Engineering, 20 students as Masters' degree students and 10 students as PhD candidates (100 postgraduate students in total). This will represent 33% of the total Mining Engineering student body (undergraduate student numbers target set to be 200 students). Achieving the

expected postgraduate number of 100 students will only be possible through strategic alliances with international Universities' staff members to act as supervisors as well and also industry involvement and South African University collaboration strategies to further emphasise the importance of postgraduate research as part of the strategy to make mining safer, healthier and more profitable.

The establishment of the Mining Resilience Research Centre at the University of Pretoria and the current Mine Health and Safety Council and SAMERDI innovation solutions drive funded by DST are great initiatives that will stimulate the increase in research activities in the mining industry even further. The next generation mining drive will be completely different than before.

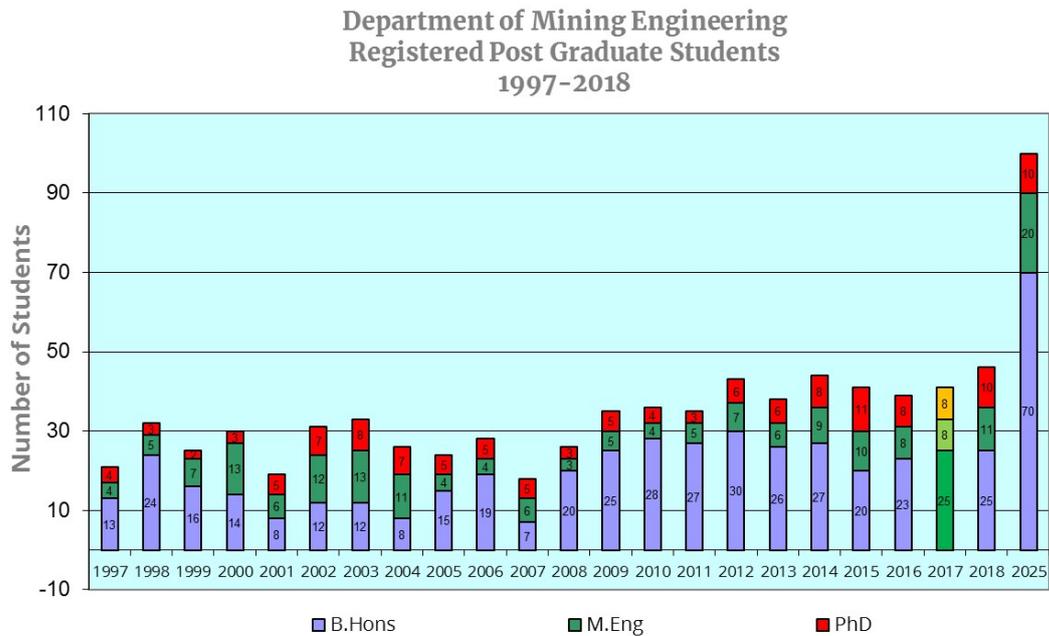


Figure 3: Post graduate students intake in Mining Engineering (history to date)

[Table 3](#) shows a breakdown of the research related topics and progress with regards our PhD and in [Table 4](#) our Master's students.

Table 3: PhD Research in progress (completed 2017 and continuing 2018)

	Title (PhD research)	Name	Program	Status	Supervisor
1	An Enterprise Development Business Model for Small Mining Partnerships in the 2015 South African Socio Economic Environment	HJ Kriel	PhD: Mining	In progress	Prof. R Webber-Youngman Prof. Con Fauconnier
2	Pillar Design Aspects related to South African Underground Manganese Mines	Johan Hanekom	PhD: Mining	In progress	Prof. F. Malan Prof. J. Napier
3	Active Suppression of Methane in Coal Mines	Arend Späth	PhD: Mining Engineering	In progress	Prof. JJL du Plessis
4	Development of Systematic Support Rules for Underground Mines in Namibia	Michael Jethro	PhD: Mining Engineering	In progress	Dr. Bertie Meyer
5	Measuring the Efficacy of RFID Technology Being Integrated into Existing Mine Operational and Management Systems	Sezer Uludag	PhD: Mining Engineering	In progress	Prof. Leon Pretorius
6	Not yet finalised	Vernon Anfield	PhD: Mining Engineering	In progress	Prof R Webber-Youngman
7	Not yet finalised	Yolande Jooste	PhD: Mining Engineering	In progress	Prof. F. Malan
8	Not yet finalised	Eugene Preiss	PhD: Mining Engineering	In progress	Prof. R Webber-Youngman
9	Not yet finalised	Jannie Maritz	PhD: Mining Engineering	In progress	Prof. F. Malan
10	Determining an efficient underground mine production schedule	Tshisekedi Ngalamulume, J	PhD: Mining Engineering	In progress	Dr Bertie Meyer
11	An Investigation of the suitability of South African support structures for small scale mining as an engine for Socio Economic development	Thabo Gazi	PhD: Mining Engineering	In progress	Prof R Webber-Youngman

Table 4: Masters Research progress (completed 2017 and continuing 2018)

	Title (M.Eng/MSc research)	Name	Program	Status	Supervisor
1	Mechanical Rock Breaking in Hard Rock Narrow Reef Stopes	Wolter de Graaf	M.Eng: Mining Engineering Publication 2013	Planned completion 2017 but still in progress	Prof. William Spiteri
2	Optimization of Load and Haul System for Surface Mining Operation Using Simulation and Linear Programming	Phumudzo Ramashau	M.Eng: Mining Engineering	In progress	Me. S. Uludag
3	Opencast Coal Mining Integrated Rehabilitation	Refilwe Mabapa	M.Eng: Mining Engineering	Registration pending	Mr Brian Hayes
4	Developing minimum illumination standards for mobile machinery for underground and surface mining operations in the South African mining industry	Johannes Scholtz	M.Eng: Mining Engineering	Registration pending	Prof. J. du Plessis
5	Not yet finalised	Dirk Botha	M.Eng: Mining Engineering	In progress	Prof. J. du Plessis
6	The implementation of people tracking systems across the South African mining industry for enhanced safety	PL Ngwenyama	M.Eng: Mining Engineering	In progress	Prof R Webber-Youngman
7	Alignment of mining method and equipment with expected geology during the initial mine planning phase	Danisa Boloji	M.Eng: Mining Engineering	In progress	Dr Bertie Meyer
8	Calibration of TEXAN 3D	Brandon Okhuis	M.Eng: Mining Engineering	Registration pending	Mr Johan Hanekom; Prof Francois Malan
9	The Eye in the Sky - Drone Investigation	Alton Bester	M.Eng: Mining Engineering	In progress	Prof William Spiteri
10	A Critical Investigation into value adding principles for conducting an open pit conceptual study	Ockert Buys	M.Eng: Mining Engineering	Graduate	Prof RCW Webber-Youngman
11	Influence of geology on pillar stability	AG Hartzenberg	MSc (App SC)	In progress	Prof. F. Malan;Michael du Plessis

12	Not yet finalised	LJ Scheepers	MSc (App SC)	In progress	Prof. F. Malan
13	Mine Digital Nervous System	Mulisha Mukheli	M.Eng: Mining Engineering	In progress	Prof. F. Malan
14	Not yet finalised	Michael Arthur Neale	M.Eng: Mining Engineering	In progress	Prof. R Webber-Youngman
15	Developing a methodology for accurately and efficiently measuring fly rock with the intention of eventually optimising fly rock prediction models	Jennifer Sapsford	M.Eng: Mining Engineering	In progress	Prof Wiliam Spiteri

[Table 5](#) shows a summary of the 2017 honours degree topics that were successfully concluded and Table 6 the 2018 applied research topics and their relevant students and supervisors.

As mentioned before, a further requirement for this year is that all B.Eng (Hons) mining students (as compulsory) will have to provide proof of publication with their respective supervisors, which will definitely have a major impact on the publication output of the department. It has also been suggested that BSc (Hons) Applied Sciences Mining selected students will be considered and chosen for research publications as well.

Table 5: Honours degrees thesis completed in 2017

	Title	Last Name	Name Initials	Program and Plan	Supervisor
1.	Cladding Strategy at Grootegeluk Mine	Hugo	DW (de Wahl)	BSc (App Sc) Hons	Mr T Gazi
2.	An evaluation of a conveyor system as an alternative transport system to articulated dump trucks for a chrome ore mine in a koppie	Moen	HC (Hendrik)	BSc (App Sc) Hons	Dr B Meyer
3	A comparison between the operation of autonomous and manual drilling at an iron-ore open pit mine	Motjopi	TK (Tsebisio)	BEng (Hons) Mining	Mr W de Graaf
4	Implementation of blast assessment in underground narrow tabular mines	Mukheli	M (Mulisa)	BEng (Hons) Mining	Mr R Irvine
5	Determination of safe blast clearance distance for blasting operations at Glencore	Sapsford	J (Jennifer)	BEng (Hons) Mining	Mr W de Graaf
6	Access infrastructure establishment methodology comparison	Thompson	WR (William)	BEng (Hons) Mining	Dr B Meyer

Table 6: Honours degree students (BSc and B.Eng) and Research topics 2018

No	Last Name	Initials (Name)	Research title	Supervisor	Programme
1	Ahlers	JE (Juan)	Factors influencing penetration rates of handheld drilling equipment	Prof R Webber-Youngman	BEng (Hons) Mining
2	Gae	PY (Pelonomi)	Shaft pillar evaluation on Nchwaning liat black rock mine operation	Prof F Malan	BSc (App Sc) Hons
3	Gouws	HH (Hermanus)	An investigation into the suitability of battery powered LHDs at Dwarsrivier chrome mine	Dr B Meyer	BSc (App Sc) Hons
4	Habile	TS (Thokozani)	A critical evaluation of the new support unit at Palabora Copper (Pty) Ltd.	Mr J Maritz	BSc (App Sc) Hons
5	Langa	LN (Lindokuhle)	Applicability of muon geotomography in South African mines	Mr P Couto	BEng (Hons) Mining
6	Maselela	TA (Tumelo Arnold)	A guideline to improve safety in surface mining	Prof F Malan	BSc (App Sc) Hons
7	Maswanganne	S (Samuel)	Not yet available	Mr J Maritz	BSc (App Sc) Hons
8	Mokonyane	SC (Shadikie)	Noise induced hearing loss in South African mines	Prof R Webber-Youngman	BEng (Hons) Mining
9	Moseamedi	TF (Tokologo)	How poor fragmentation affects load & haul process	Mr W de Graaf	BSc (App Sc) Hons
10	Nyathi	N (Njabula)	Integrated planning and mining matrix	Dr B Meyer	BSc (App Sc) Hons
11	Phago	TC (Tshwarelo)	Safety, health and environmental management at penumbra coal mine	Mr W de Graaf	BEng (Hons) Mining
12	Philo	KG (Keaton)	Investigating disruptive technological productivity solutions within the mining value chain.	Prof R Webber-Youngman	BEng (Hons) Mining
13	Suliman	MAM (Mohammed)	Environment and Waste recycling	Prof J du Plessis	BSc (App Sc) Hons
14	Titisi	TI (Thabiso)	Tyre condition monitoring	Prof W Spiteri	BEng (Hons) Industrial
15	Tshivule	RJ (Rendani)	Optimization for quarries	Ms S Uludag	BSc (App Sc) Hons
16	Tshuma	M (Mthabisi)	An investigation on what leading practices are available for mining applications of real time information systems and the digitisation of mining operations	MS S Uludag	BEng (Hons) Mining
17	Tsiku	K (Khumbelo)	Open pit mining compliance as per plan and design: case study of Tharisa Minerals	Ms S Uludag	BSc (App Sc) Hons
18	van Wyk	FB (Frede)	Calculation of the breakeven commodity price of new mining rights.	Mr T Gazi	BSc (App Sc) Hons
19	Venter	DL (Dirk)	Delineating the behaviour of brittle rock using a tri-linear strength criterion approach	Mr J Maritz	BSc (App Sc) Hons

8 Journal and/or Conference proceedings Department of Mining Engineering in 2017

In 2017 we had less publications when compared to 2016, but the department has a very strong pipeline for 2018 (example shown in Table 7 and 8 of this report). Below is a list of published papers in refereed journals and conferences for 2017. A total of 5 papers were published in journals with departmental contribution of 3,75. A total of 11 papers were presented at conferences of which all were submitted to the DOE, with a departmental contribution of 5,92, which shows a significant contribution by mainly our full time postgraduate students.

A list of the journal and conference articles/papers follows.

Journal Articles

Gomes-Sebatiao, G. & De Graaf, W. 2017. An investigation into the fragmentation of blasted rock at Gomes Sand. *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 117, no. 4, pp. 321-328.

Grobler, H. & Maritz, J. 2017, Status of the phasing out of the Chamber of Mines of South Africa Certificate of Competency. *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 117, no. 8, pp. 793-802.

Jacobs, J. & Webber-Youngman, R. 2017, A technology map to facilitate the process of mine modernization throughout the mining cycle, *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 117, no. 7, pp. 637-648.

Malan, D., Alejano, L. R., Arzua, J. & Castro-Filgueira, U. 2017, Strapping of pillars with cables to enhance pillar stability. *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 117, no. 6, pp. 527-540.

Ngwenyama, P., Preis, E. & De Graaf, W. 2017, Factors and challenges affecting coal recovery by opencast pillar mining in the Witbank coalfield. *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 117, no. 3, pp. 215-222.

Conference papers

De Graaf, W. & Ngwenyama, P. 2017, The application opencast pillar mining for the secondary extraction of pillars from previously mined bord-and-pillar operations, , *3rd You Professionals Conference*, 9-10 March, Pretoria, South Africa, The South African Institute of Mining and Metallurgy, pp. 277-292.

Du Plessis, M. & Malan, D. 2017, Mining with crush pillars, *AfriRock 2017 ISRM International Symposium "Rock Mechanics for Africa"*, 3-5 October, Cape Town, South Africa, The Southern Arica Institute of Mining and Metallurgy, pp. 109-121.

Essrich, F., Hanekom, J. & Bouwer, J. 2017, Technology transfer for minimizing seismic risk in South Africa's platinum mines, *AfriRock 2017 ISRM International Symposium "Rock Mechanics for Africa"*, 3-5 October, Cape Town, South Africa, The Southern Arica Institute of Mining and Metallurgy, pp. 377-389.

Esterhuyse, J. C. & Malan, D. 2017, A study of multi-reef pillar extraction in the Ventersdorp Contact Reef, *AfriRock 2017 ISRM International Symposium "Rock Mechanics for Africa"*, 3-5 October, Cape Town, South Africa, The Southern Arica Institute of Mining and Metallurgy, pp. 471-483.

Hanekom, J. & Okhuis, B. 2017, Is face-bursting imminent in deeper South African mines? , *3rd You Professionals Conference*, 9-10 March, Pretoria, South Africa, The South African Institute of Mining and Metallurgy, pp. 253-262.

Hanekom, J. & Okhuis, B. 2017, Numerical model calibration: process of luck? *AfriRock 2017 ISRM International Symposium "Rock Mechanics for Africa"*, 3-5 October, Cape Town, South Africa, The Southern Arica Institute of Mining and Metallurgy, pp. 753-767.

Hanekom, J. & Rajpal, Y. 2017, An empirical and numerical approach to quantifying raisebore-hole stability, *AfriRock 2017 ISRM International Symposium "Rock Mechanics for Africa"*, 3-5 October, Cape Town, South Africa, The Southern Arica Institute of Mining and Metallurgy, pp. 427-438.

Hanekom, J. 2017, Fundamental understanding of underground pillar design processes and methods, *AfriRock 2017 ISRM International Symposium "Rock Mechanics for Africa"*, 3-5 October, Cape Town, South Africa, The Southern Arica Institute of Mining and Metallurgy, pp. 1081-1093.

Malan, D. & Napier, J. 2017, Reassessing continuous stope closure data using a limit equilibrium displacement discontinuity model, *AfriRock 2017 ISRM International Symposium "Rock Mechanics for Africa"*, 3-5 October, Cape Town, South Africa, The Southern Arica Institute of Mining and Metallurgy, pp. 441-454.

Maritz, J. 2017, Preliminary investigation of the effect of a real shape on pillar strength, *AfriRock 2017 ISRM International Symposium "Rock Mechanics for Africa"*, 3-5 October, Cape Town, South Africa, The Southern Arica Institute of Mining and Metallurgy, pp. 143-154.

Preis, E. & Webber-Youngman, R. 2017, Identification of cost factors relating to mining incidents, *3rd Youth Professionals Conference*, 9-10 March, Pretoria, South Africa, The South African Institute of Mining and Metallurgy, pp. 89-105.

5 Publication outlook - 2018

The outlook for 2018 is indicating a very healthy pipeline of publications with a potential of 38 papers of which 32 are Journal papers (abstracts submitted and in referee process), 6 Journal articles published which is already 1 more than last year, the number of conference papers already published thus far this year is 3. The challenge to identify suitable, high impact journals within the mining research area remains a considerable challenge. Table 7 and 8 show the respective pipelines for Journals and conferences for 2018.

Table 7: Journals publication pipeline 2018

Associate Name	Type [C / J]	Title	N° of Authors	Co-Author(s)	Potential Contribution value	Draft Paper/Article prepared	Paper/Article/Abstract submitted	Paper/Article Reviewed & Re-submitted	Paper/Article approved & Forthcoming	Paper/Article Published / Presented
B Meyer	J	An Evaluation of a Conveyor system as an Alternative Transport system to Articulate Dump Trucks for Chrome Ore Mined in a Koppie	2	Henk Moen	0,50		1			
F Malan	J	A limit equilibrium fracture zone model to investigate coal bumps	2	J Napier	0,50				1	
F Malan	J	Assessing pillar strenght in the Bushveld Complex	2	M du Plessis						
F Malan	J	Mining with crush pillars	2	Michael du Plessis	0,50					1
F Malan	J	Reassessing continuous slope closure data using a limit equilibrium displacement discontinuity model	2	J Napier	0,50					1
F Malan	J	Simulation of tabular mine face advance rates using a simplified fracture zone model	2	J Napier	0,50					1
F Malan	J	Some rock engineering aspects of multi-reef pillar extraction on the Ventersdorp ContactReef	2	J Esterhuysen	0,50				1	
F Malan	J	Rockburst support in deep tabular stopes	2	J Napier	0,50		1			
Doctoral	J	Identifying Cost Factors Relating to Mining Incidents	2	RCW Webber- Youngman	0,50		1			
Doctoral	J	Investigating the Stage-Gate Model as a Research and Development Implementation Process in Modernising the South African Mining Industry	2	RCW Webber- Youngman	0,50		1			
Doctoral	J	The Potential Applications of Augmented Reality in the Mining Industry	3	E van Wyk RCW Webber-Youngman	0,33	1				
Other Associate	J	"The impact of Forensic Laser Scanning Technology on Incident Investigations in the Mining Industry"	5	Hennie Grobler, Francois Stroh, RCW Webber-Youngman, Albert vd Vyver	0,20	1				
Other Associate	J	A 4D Leadership Model Postulation in the 4th Industrial Revolution relating to the South African Mining Industry	2	RCW Webber- Youngman	0,50		1			
Other Associate	J	A Critical Investigation into Spontaneous Combustion in Coal Storage Bunkers	3	M Govender, RCW Webber-Youngman	0,33			1		
Other Associate	J	Optimization of load and haul operation at an open cast colliery	2	S Uludag						
Other Associate	J	A Preliminary Qualitative Evaluation of a Hydraulic Splitting Cylinder for Breaking of the Solid in Deep Level Mining to Determine Possible Equipment Modifications and Applications	2	W de Graaf	0,50				1	
Other Associate	J	An investigation into fragmentation size reduction below 120 level, at Mponeng Mine.	2	W de Graaf	0,50		1			
Other Associate	J	The application of opencast pillar mining for the extraction of pillars from previously mined bord-and-pillar operations	2	W de Graaf	0,50		1			
Other Associate	J	Face bursting imminent on platinum - mines ?	2	B Okhuis	0,50		1			
Other Associate	J	Rock mass strength properties - pitfalls	1		1,00	1				
Other Associate	J	A limit equilibrium fracture zone model to investigate coal bumps	2	F Malan	0,50				1	
Other Associate	J	Reassessing continuous slope closure data using a limit equilibrium displacement discontinuity model	2	F Malan	0,50					1
Other Associate	J	Simulation of tabular mine face advance rates using a simplified fracture zone model	2	F Malan	0,50					1
R Webber-Youngman	J	"The impact of Forensic Laser Scanning Technology on Incident Investigations in the Mining Industry"	5	Hennie Grobler, Francois Stroh, Thabo Gazi, Albert vd Vyver	0,20			1		
R Webber-Youngman	J	A 4D Leadership Model Postulation in the 4th Industrial Revolution relating to the South African Mining Industry	2	J Uys	0,50			1		
R Webber-Youngman	J	A Critical Investigation into Spontaneous Combustion in Coal Storage Bunkers	3	M Govender, J du Plessis	0,33			1		
R Webber-Youngman	J	A critical investigation into value adding principles for conducting an open pit conceptual study.	3	H Buys, B Botha	0,33		1			
R Webber-Youngman	J	Creating a Technology Map to Facilitate the Process of Modernisation throughout the Mining Cycle	2	J Jacobs	0,50		1			
R Webber-Youngman	J	Engineering education: An integrated problem solving framework for discipline-specific professional development in Mining Engineering	2	G Haupt	0,50					1
R Webber-Youngman	J	Identifying Cost Factors Relating to Mining Incidents	2	E Preis	0,50		1			
R Webber-Youngman	J	Investigating the Stage-Gate Model as a Research and Development Implementation Process in Modernising the South African Mining Industry	2	E Preis	0,50		1			
R Webber-Youngman	J	The Potential Applications of Augmented Reality in the Mining Industry	3	J Jacobs, E van Wyk	0,33		1			
R Webber-Youngman	J	Creating a Technology Map to Facilitate the Process of Modernisation throughout the Mining Cycle	2	RCW Webber- Youngman	0,50		1			
S Uludag	J	Optimization of load and haul operation at an open cast colliery	2	O Pasch	0,50				1	
W de Graaf	J	A Preliminary Qualitative Evaluation of a Hydraulic Splitting Cylinder for Breaking of the Solid in Deep Level Mining to Determine Possible Equipment Modifications and Applications	2	W Spiteri	0,50				1	
W de Graaf	J	An investigation into fragmentation size reduction below 120 level, at Mponeng Mine.	2	S Mthembu	0,50		1			
W de Graaf	J	The application of opencast pillar mining for the extraction of pillars from previously mined bord-and-pillar operations	2	L Ngwenyama	0,50		1			

Table 8: Conference publication pipeline 2018

Associate Name	Type [C/J]	Title	N° of Authors	Co-Author(s)	Potential Contribution value	Draft Paper/Article prepared	Paper/Article/Abstract submitted	Paper/Article Reviewed & Re-submitted	Paper/Article approved & Forthcoming	Paper/Article Published / Presented
B Meyer	C	New Shift arrangements for Stoping	1		1,00		1			
B Meyer	C	Half-level optimization	1		1,00	1				
F Malan	C	The effect of rock mass stiffness on crush pillar behaviour	2	M du Plessis	0,50					1
F Malan	C	Time dependent coal pillar scaling	2	B Okhuis	0,50	1				
J Maritz	C	Using games to teach Support Design	2	K be Beer	0,50			1		
J Maritz	C	The need for formal rock engineering expertise in deep mining	2	H Wagner	0,50					1
Other Associate	C	Time dependent coal pillar scaling	2	F Malan	0,50	1				
Other Associate	C	Investigating the mechanism contributing to large scale structural driven hangingwall instability on the UG2 reef horizon	2	M du Plessis	0,50					1
W de Graaf	C	Training for Underground Tunnel Drilling and Blasting in the VR Space	1		1,00		1			

9 Conclusions

Further progress in growing research activities within the Mining Department continues. This is spearheaded through the establishment of the MRRC in 2016 as well as through continued research activities within the department.

A number of staff continued their personal research activities, and this led to an improvement in the research outcomes as measured against published papers. A number of staff members also completed their post graduate studies and a number will start and continue their PhD studies in 2018. Furthermore, a target of at least some International journal publications is a pre-requirement for success in 2018.

External research funding through the MHSC undertaken under the MRRC will further assist in keeping the current research momentum. It is foreseen that the Department will again be successful in attracting external Research funding through SIMRAC and the COE (through the MHSC) respectively even though the mining environment is extremely constrained.

The SAMERDI research drive that is currently in its establishing phase will further assist the Departments research efforts. This research initiative is a focussed three years start-up with R150m budget allocated from DST to it.