# A History of Mine Wastes Rehabilitation Techniques in South Africa: a multi-disciplinary overview of mine waste rehabilitation and the non-scientific drivers for its implementation 1950s – 1980s

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## Introduction

This paper sets out the evolution of the South African mining industry's efforts to develop scientifically sound and replicable methods of gold mine waste rehabilitation between the 1930s and the mid-1980s, just before mine waste rehabilitation was formally legislated in South Africa. This paper[1], arose from the author's experience as the Corporate Environmental Manager of South Africa-based AngloGold Ltd., during which it became apparent that in the mid-1990s – nearly 50 years after the industry claimed to have begun systematic research into mine waste rehabilitation – only a general rehabilitation methodology existed in the South African mining sector.

This paper, focussing on the activities of the Chamber of Mines of South Africa Vegetation Unit during the years that the Unit was virtually the only industry authority on mine waste rehabilitation, seeks to chronicle events between the mid-1950s and mid-1980s with the objective to cover not only the scientific factors that drove the evolution of mine waste rehabilitation techniques, but also to high-light the political, social and financial factors that influenced how, if at all, the applied science of mine waste rehabilitation was practiced in the field. Drawing on the personal records of participants and the Chamber of Mines of South Africa Archive, it also considers the role of personalities and the organisational constraints within which they operated in implementing these techniques. One of the themes that emerges is that the advance of science, even applied science , is rarely a linear, logical process in which what works is applied. The reality is often far more subject to economic and political issues as well as beholden to the nature of key personalities involved.

## The Mechanics of the Problem

Gold was found intermittently in South Africa after 1868 but it was only with the discovery of the Witwatersrand gold field after 1884/5, that the industry could grow as a formal economic sector over the longer term.[2] The mining cycle established on the Witwatersrand and later extended to the East Rand, West Rand Welkom and Klerksdorp gold fields begins with the construction (sinking) of a shaft. Shaft sinking involves downward blasting and removal of blasted material as the shaft grows downward towards the ore body. Ore received from underground needs to be crushed and milled before extraction is possible.[3] During the early years of Witwatersrand mining the ore passed through a stamp mill, in which a weighted stamp was alternatively raised and dropped by an eccentric drive with the stamp breaking and pulverising the rock as it fell. The sands produced by the stamp mills were

passed over amalgam plates, where the gold was attached by mercury on the plates. The plates were periodically scraped and the amalgam was distilled to recover the gold.

When, barely ten years into the boom, the miners encountered un-oxidised, sulphidic ores, a crisis of confidence ensued but after this was eventually overcome through the cyanidation process which, combined with more intensive milling resulted a finer, smaller particle size, led to improved gold recoveries. [4] From 1904 rotating cylindrical mills were introduced which ground the stamp mill product even finer so that the slime content of the final product rose from between 16- 33% to over 75%, allowing for better gold recovery.[5] Initially the material crushed by stamp mills had been labelled as sand, while later refinements led to the material milled to smaller particle sizes being labelled as slimes or tailings. Over the decades the milling equipment was continuously refined to achieve an ever smaller, more homogenous particle size of around 30 microns before the material is sent for the gold extraction.[6]

The disposal of residues – waste rock, cyanided sand and slime, surplus mine water and discarded solutions – presented little difficulty in the early days of gold mining as there was no legislation constraining it.[7] As a result miners could reason that with "sufficient unused land in the vicinity of the reduction works to accommodate these residues and effluents, "[8] there was no limit on their deposition. Between the 1880s and the 1910s this changed only insofar as the growth of the residential and industrial zones of Johannesburg and its adjacent towns began to compete with mine waste deposits for access to land. While the miners preferred having the mine waste residue deposit sites as close as possible to the treatment plant to contain pumping costs, it increasingly became necessary for them "to move further afield either owing to lack of suitable terrain adjacent to the plant or to the proximity of townships, industrial zones , watercourses, railways or electric power lines." [9] When the industry resumed its growth after the lull caused by the First World War between 1914 and 1918, this increasing shortage of suitable deposition space heightened the risk that a collapse of a mine waste deposit would lead to loss of life or impact on other economic activity. This encouraged a formalisation of deposition techniques for the two main waste streams produced by the mines – waste rock and residual slime or tailings. As waste rock was always viewed by the industry and the Government, not only as a potential resource for the construction sector but as a generally non-polluting material, the focus here (in this paper) is on tailings or residue deposits.

Although early Chamber of Mines Handbooks, first published in 1898[10] and expanded in various forms during the interwar period, contributed to the formalisation of tailings dam construction and operational practice, as well as a range of associated non-technical issues such as health, personnel and safety, [11] it was not until the 1950s that some form of standardisation began to appear. Common to all tailings dams was the construction of an outer wall and the continued deposition of tailings into the dam area. In most cases water would be recovered from the facilities for re-sue in the plant. Beyond this however, great variation in the width of the walls, wall angles, rate of rise and final height could be found across the industry.[12] However, even though some of these handbooks would contain images of tailings dams with the dust blowing off them, mining and metallurgical engineering

graduates entering the industry in the period up to the mid 1960s would have received no guidance during their formal training period on how to deal with the nuisance dust from the tailings and sand dumps. Nor would the formal training have in any way alerted them to the issue.

The practice that evolved between the 1920s and the 1960s and was codified through industry research together with the Council for Scientific and Industrial Research (CSIR) broadly involved the setting aside of land, no land clearance prior to deposition, the construction of a system of storm water perimeter trenches and free-draining internal drainage pipes (called penstocks) the pipeline delivering the slime from the processing plant would terminate at an elevated point so as to allow the targeted deposition of tailings to ensure a horizontally level deposition of tailings across the facility, the recovery of water pumped with the tailings from the processing plant to the tailings dam where it would be directed into the various compartments of the tailings dams.[13]

From this practice, codified between 1960 and 1968, when the Chamber of Mines issued its first 'Code of Practice in respect of tailings dams',[14] a number of requirements for the safe operation of tailings dams arose. These would have a significant bearing on their grassing and closure. The recommended rate of rise for a tailings dam,[15] created a logical limit on the height of tailings dams as well as a preference for their shape to that of a square, or at least a rectangle. In addition it was recognised that due to the high sulphide content (up to 1.5% of $FeS_2$) of the tailings, the oxidisation of this pyrite would encourage the formation of a hard crust on the outer walls as the material gradually dried. During the operational life of the tailings dam, no grassing would take place as the dam would be deemed 'wet', and thus less likely to generate dust. Only once deposition had formally ceased would the facility be prepared/altered to be a self-draining structure – mainly via its penstock. A key part of this activity would involve the construction of contour walls to separate the surface area of the top of the tailings dam into different compartments so as to contain rain water falling on the dam within the structure. This would be done with the intention of allowing the rainwater to drain via the penstock to evaporation dams or evaporate on the surface of the dams.[16]

The end of deposition of material on a tailings (or sand) dam would be followed by its gradual drying out. Critical to facilitating, indeed speeding up this process, was the increasingly homogenous particle size of more then 75% smaller than 30 microns. Once the material has dried out, it was this homogeneity that makes it more susceptible to wind and water erosion in two separate ways;

- wind erosion of dry material would come in the form of rapidly moving air mobilising the loose particles on the long level surfaces of the slopes or tops of the structure leading to the generation of dust. Due to the small particle size and the large flat surface areas, tailings would be easily mobilised when compared with materials on natural, more heterogeneous surfaces.
- water erosion of tailings material would take two forms: first, physical mobilisation of material and its movement in accordance with gravity down the structures slopes as rainfall run-off would carry it along and potentially into the surrounding environment,

> or second, the mobilisation of soluble elements within the tailings material and their transport – in solution – in accordance with gravity downward on the structure's exterior or within its body into the receiving environment.

Both forms of erosion led to pollution during the operational and closed phase and thus required an industry response.

**The Experimental Years 1890s – 1940s**

In the early years the South African mining industry operated in a near legal vacuum, which first the agrarian Transvaal, and later the South African state gradually addressed as they sought to extract taxes from the sector. Nevertheless the communities affected by the wastes the mines generated did not wait for the development of legislation to exert pressure on the mining companies to address their environmental impacts. The most immediate of these impacts was dust pollution of the mine dumps and while the details of engagement between communities, local authorities and the mining companies do not appear to have been recorded by newspapers or in the Chamber of Mines' public correspondence files, they nevertheless must have taken place on a sufficiently large-scale for individual mining companies to begin experimenting various forms of dust suppression.[17] Indeed, the first reference to dust suppression has been found by Thatcher[18] who cites an extract from a letter dated 23 August 1894 the director of Kew Botanical Gardens in Britain which reads:

> I beg to return you my best thanks for the seeds received in two bags, as noted in yours of July 26. The *Ammophila* seed is very acceptable; as I wish to experiment with it and find if it will grow on, and bind together the sand, or tailings heaps, which are accumulating so fast along the Main Reef, and around this town. …. Blown about by the strong winds here, the sands cause serious eye complaints, and illness. The question is, will any vegetation grow on such poisonous mountains – for so the tailings heaps may well be called ."[19]

Due to the passage of the first regulation to prevent air-borne dust pollution which was gazetted in 1911, this date is generally cited as the beginning of pollution control methods on the Witwatersrand , for it gave the Government Inspector powers to require measures to prevent the dissemination of dust from the dumps, through the spraying of "a sludge of black soil or otherwise".[20] In the two decades following this "direct covering methods such as blanketing with rock, ashes, soil or any kind of suitable debris." were explored. [21] In addition the spraying of dump surfaces with various, more widely available substances such as, salt, molasses, 'night soil',[22] salt water and slime from reduction works was done, but on an ad hoc basis due to the erratic availability of such material. Only "night soil" (sewage sludge) , was consistently available and applied repeatedly. [23]

The dust challenge must have increased during the lull of the First World War and the subsequent cost inflation in the face of a fixed gold price squeezed many gold mines out of business. However first the 1923 devaluation of the British pound,[24] and subsequently the 1934 devaluation of the US dollar boosted the industry in a way that saw active deposition on most mine dumps, ensured that the scale of dust pollution from the dumps remained lower

than it had been between 1914 and 1923.[25] Equally significant in terms of potential regulatory pressure, Government Commissions and independent economist at this time generally accepted that the industry accounted for somewhere around 50% of state finances and that 50% of the population obtained its livelihoods directly or indirectly from the gold mines.[26]

Nevertheless the industry must have faced sufficient public concern in the interwar years to continue individual dust suppression experiments, some of them longer-term: Thurlow in 1937 suggested that one experiment was monitored for a period of possibly 6 years, with some of annual species being reseeded for up to 5 times after successive failures. Indeed these early trials were scoped scientifically in the case of the tree trials, where similar-sized seedlings were planted in nearby favourable soil conditions and monitored to enable comparisons to be made of relative growth.[27]. The results of these experiments were presented by J.R. Thurlow Chief Metallurgist of the Corner House Group in 1937, and did however suggest three significant trends: grasses tended to be the most sensitive to the harsh and acid conditions on the dumps, requiring significant soil amelioration for their survival. By contrast, larger woody species appeared to fare better requiring less long term support. Furthermore, the spraying or deposition of heterogenous materials on the dumps did suppress dust on a temporary basis. In short, using grasses would necessitate a larger investment in ameliorants, [28] even though they offered the prospect of quick establishment and a bias towards their usage would gradually pull the rehabilitation industry towards ever-more costly and input-intensive amelioration techniques. By contrast woody species appeared to offer a better 'plant return on investment' both in terms of plant survival and subsequent assistance required.[29] These benefits, however, could only be realised over the longer-term and it is likely that for this reason this key conclusion was not spelt out by the key person who presented this research in a scientific journal at the behest of the mining industry – Professor John F. V. Phillips, then Head of the Department of Botany at the University of the Witwatersrand.[30]

No matter how progressive the commissioning of the Phillips study and its subsequent publication in a reputable scientific journal in the mid-1930s was at the time, - there was no effective legal sanction compelling miners to take steps to prevent dust pollution - Phillip's focus on grasslands ecology as a specialisation led to this becoming a lost opportunity. Ignoring the potential of woody plant species which Thurlow highlighted, the grassland specialist Philips - who cited Thurlow as the key source in his article - argued that only acid- and drought tolerant grass species offered the best opportunity to establish vegetation on the dumps that might suppress dust for the longer term.[31] He then however negated his own recommendations by conducting his cultivation experiments for suitable grass species such as the acid tolerant *Cynodon dactylon* in much less acid soil pot trials.[32] His subsequent departure from South Africa and the subsequent direction of botanical investigation at the University of the Witwatersrand ensured that for the moment the mining industry made no more use of the scientific capacity available. Phillips' article did much to discourage further experimentation with vegetation cover on dumps until the aftermath of the Second World War. Lacking a permanent solution to the problem many mines continued to rely on the spraying of sludge pumped from the underground workings over the dump surfaces. For the

remainder of the 1930s and early 1940s that was a viable option as the industry went into expansion mode utilising and thereby keeping moist, most mine waste deposits. However, it would be this expansion and the sheer increase in mine wastes and their associated acidic water pollution that in the post war years would force the industry to continue and escalate its search for a pollution-reducing technique capable of large-scale application. By the early 1950s approximately 9000 hectares of land were occupied by mining wastes, the time for tinkering was over.[33]

**The Formative Years: 1955-1963**

As long as the tailings dams stayed operational, public pressure remained low despite increasing proximity of urban areas and tailings dams as the expanding mines and the secondary industry that grew along with it, occupied the limited area. Some enterprising souls saw opportunity where others saw challenges and in the early 1950s, a R Horowitz was responsible for the development of Benrose, a business and industrial area, on the top of two flattened sand dumps.[34]

But by the early 1950s things began to change: while urban expansion and industrial sprawl continued unabated, many of the slimes dams of the Central Rand came to the end of their operational life and began to dry out as dust-suppressant spraying was increasingly discontinued. While the abandonment of such mine residue deposits was legal at this time, the resultant nuisance from dust must have increasingly impacted Witwatersrand residents. Curiously this development is not chronicled anywhere in the popular or scientific press but rather asserted by authors of grey literature as conventional wisdom without reference to any original sources. These authors, many of them members of the Chamber of Mines of South Africa Vegetation Unit, cite this dust as a key source of public pressure on mining companies to address pollution emanating from dumps but a newspaper survey conducted as part of this research for the period of 1910 – 1960 has failed to bring to light any references to dust nuisance among Johannesburg-based publications.[35] Similarly a series of files kept in the Chamber Archive containing newspaper clippings of matters relevant to the industry does not contain any articles mentioning dust nuisance. Nevertheless subsequent actions on the part of the Chamber suggest growing public complaints, lending credence to the argument, put forward by some of the Vegetation Unit field staff that complaints tended to be made telephonically.[36] The only newspaper references to dust nuisance for this period can be found in the Pretoria News of 29th September and the Johannesburg Star of the 28th of September 1954 when the then Director of Johannesburg Housing, A J Archibald was cited as making ‘exaggerated claims about erosion from mine dumps’ in a paper delivered at the Annual Conference of the South African Institution of municipal Engineers held in Bulawayo, Rhodesia that year.[37]

But while the public may have relied on verbal pressure to address mine dust, the regulator was formally moving on the issue of water pollution from mine dumps. Despite its name, ‘white water ridge’, the Witwatersrand is not particularly water-rich and within a few years of human settlement around what is today Johannesburg, public and collective action was required to secure the local water supply both for human and industrial use. In the early days

water on the Rand was scarce and in 1896 a water supply scheme sourcing water from the Klipspruit area was put in place but even this provided only temporary relief.[38] Between 1905 and 1911 water was sourced from local sources and water supply received the first legal framework in the form of the Irrigation Act No 27 of 1908.[39] By 1911, the mines were taking 45% of the total water supplied by the system and in times of drought were forced to cut back production drastically. [40] Growing demand forced the sourcing of water from the Vaal River where a barrage was constructed between 1916 and 1922. But the rising cost of water as well as access to underground water as the mines deepened meant that by 1925 the industry refused to contribute to funding additional water supply infrastructure.[41]

The infrastructure for the abstraction of water from the Vaal included a plant for the treatment of water and from 1923 onwards, systematic chemical analyses of the quality of the Vaal River were undertaken to monitor drinking water quality. Over time these analyses revealed a steady deterioration in the water quality so that by 1948 the Water Board's chief engineer, J.P. Leslie, stated that "Experts are now gravely concerned at the quantities of obnoxious effluents entering the Vaal barrage … the most objectionable feature being the addition of sulphates"[42] Sulphates shift the pH of the solution in which they dissolve, leading to the release additional metals and the break-up of organic compounds, inhibiting biological processes.[43] Gold mine tailings deposits were implicated as the most likely source from which "accumulated" mineral loads of the magnitude involved could derive. [44] Iron pyrites are the most common and widely distributed mineral which leads to the formation of acid mine water.[45] In 1951,the Rand Water Board began monitoring some tributary streams flowing to the Vaal Barrage. Practically all the Witwatersrand goldmines were located in the upstream catchments of these three streams – the upper Klip River at Jackson's Drift, the Natalspruit above the confluence with the Klip River, and the Blesbokspruit at Heidelberg. And in all the rivers, rising dissolved mineral loads as well as rising acidification began to manifest. [46]

The 1948 Report of the Departmental Committee of Enquiry on the Bacteriological and Chemical Pollution of Water Supplies, had recommended to Parliament that legislation to protect water resources from industrial and mining pollution be significantly tightened, as this could be done without imposing material costs on industry. [47] By 1950 a Commission to review and revise water had been appointed and it delivered its report which singled out mining and industry as key users and sources of pollution. National Party protection of its key constituency – agriculture – delayed the passage of legislation until 1956.[48] The Water Act would be the central legislation to drive the mining industry's pollution prevention measures for the next 40 years. Fully aware of the implications of the Act, the Chamber at the time commented that "the new legislation has brought about far-reaching changes in a number of matters of particular interest to the mining industry such as the use of water for industrial purposes, the purification and disposal of industrial effluent, the use and disposal of water from an underground source, and the establishment of water boards."[49] In other words, it could have been worse. Although air quality legislation was not passed in the 1950s, the commissions that were set up indicated clearly to industry that this would only be a matter of time. Correspondingly and to its credit, the Chamber of Mines sought to address the problem

at source, exploring first mechanical means of tailings stabilization in conjunction with third party research institutes, before returning to vegetation establishment as a means of controlling water and dust pollution from the mine dumps.[50] Although the Phillips study of the 1930s had been pessimistic about the value of using vegetation, personal observations by key decision-makers of self-establishing vegetation on mine dumps being linked to the presence of suitable soil conditions (often created by the dumping of household wastes or other materials) proved the key driver.[51]Personal experience outweighed science at this junction and in 1955, just before the passage of the Water Act, the Chamber formally returned to vegetation as the most promising technology. [52]

Having chosen vegetation as a method, the industry had two options: the use of plants naturally adapted to arid, acidic environments and thus more likely to cope with the adverse conditions on the dumps, or to explore methods of ameliorating the surface area sufficiently for less hardy plants to establish themselves. In its search for suitable plant species the Chamber of Mines originally adopted an open approach, seeking to let itself be guided by experts, i.e. botanists. James claims that South African and overseas authorities on semi-desert vegetation were consulted on what species had proved successful in stabilizing such environments.[53] But no specifics were provided and since this was still a relatively low priority for the Chamber of Mines, it is unlikely that more than some informal correspondence with overseas (probably UK botanists) and a general literature search – possibly via Wits Botany – was ever done. Chamber archives contain no references to any formal interaction with, or commissioning of, experts, other than commissioning of Witwatersrand University Botany Department into desert plants usage for this purpose in 1957.[54] Between 1958 and 1959, the Chamber explored the adaptive plants option but abandoned this option largely due to cost considerations, and possibly also due to lack of in-house skills and familiarity with the botanical issues.[55] This was a critical decision as it fundamentally narrowed down the search for rehabilitation technology to a single avenue – the amelioration of the surface layer of tailings for purposes of modification of the growing environment for commercially available seed of a single plant group grasses. Since tree species are generally absent from the desert environment, the input of the Witwatersrand University study further emphasised the focus on grasses and smaller woody species.

This trend was further amplified by the work done independently by Gold Fields (GFSA) which at the initiative of its then CEO Adriaan Louw, in 1956 appointed its Chief Horticulturalist, W. B Cook, to initiate a dust control programme. [56] Cook, who was British-born with a horticultural diploma from Cambridge, had during the Second World War worked for the 100th Aerodrome Maintenance Unit where his duties focussed on keeping the runways and their surroundings serviceable by maintaining the grass C*ynodon dactylon* as the dominant ground cover. To achieve this Cook solved the challenge of ensuring regular and large-scale germination for the grass by feeding it to sheep.[57] GFSA combined Cook's forceful personality with that of the publicity-hungry General Manager of its West Rand Luipaartdsvlei Gold Mine, D. Chernik, also known as 'photo-chernik'. [58] It is critical to high-light the importance that cost played in shaping this research agenda for GFSA's experiments were designed to "examine various possible means of consolidating the surfaces of mine

dumps, with a view to reducing the run-off of polluted rain water and eliminating, if possible, the blowing of dust, " the purpose was "directed at obviating the costly procedure of introducing soil to slimes as a surface cover." [59] Based on years of observation by various Chamber member officials it was taken as a given that covering mine waste dumps with soil or other organic matter was a largely proven method of establishing vegetation on mine dumps. This 'proven' method – even supported back in the 1930s by Phillips as economical[60] - would not be contemplated due to cost, even though no actual business evaluation of this method was ever done.[61] Cook's work therefore was really about finding a cheaper method, even though exactly what cheaper would be was never spelled out.

In spite of this limitation, Cook's research was done with an energy and on a scale that made it credible. He was the first to systematically approach potentially relevant experts across the Union and the region for advice. Furthermore the scale of his trials – 1500 experimental plots over three years investigating over 100 mainly grass species under different conditions of soil amelioration - was undoubtedly significant.[62] Chernik's publicity helped move the Chamber along: the Timber Laboratory was renamed the Biological and Chemical Research Laboratory, and the Chamber, in its annual report announced that "vegetation on Slimes Dams and Sand Dumps investigations commenced on the screening of likely plants by attempting to establish them at test sites. Various trees shrubs herbs and grasses are being tested."[63] Nevertheless cost was something constantly affecting his work as his co-author Chernik stated at the outset of the 1960 article in which they released the preliminary results of Cook's work.[64] Cost considerations also played a role in shifting Cook's focus towards grasses as opposed to more woody species for the simple reason that they grew faster and needed smaller, less expensive windbreaks.[65]

While the publicity that the publication of the initial trial results in the 1960 edition of the Journal of South African Mining and Metallurgy generated certainly helped raise awareness of the issue among peers, its greater significance lay in the performance pressure it implicitly exerted on the more modest Chamber of Mines vegetation research. The May 1960 Chernik paper was well received.[66] More significantly it prompted A L James, newly-appointed Research Advisor to the Chamber of Mines at the time, to respond with a quick summary of the work he was supervising for the Chamber in July 1960, thus further raising the profile of the topic within industry.[67] With both programs seemingly generating similar results, the industry, eager for a solution to the growing public concern about mine waste pollution, found the logic of placing both initiatives under the supervision of Cook, compelling. In March 1959, after just one year of conducting their own trials, Gold Fields agreed to work with the Chamber of Mines Research Laboratory.[68] Happy to consolidate the credit, the Chamber recorded in its Annual Report that "the investigations started in 1958 into the choice of suitable plant types for establishment on tailings dumps were continued and experimental plantings have been made on a mine on the central Rand. This work was co-ordinated with investigations being carried out by individual mines."[69] However placing Cook's work under Chamber auspices had one indirect long-term drawback: as the industry research effort his work gradually became subject to the more general public pressures on the mining sector to be seen to be 'doing something' about dust. The May 1960 paper by Cook and Chernik had

still clearly stated that "it would be most foolhardy to draw positive conclusions after a period of only 20 months of experimental work".[70] However, their January 1963 paper, in its introduction contained the curious claim that based upon the progress made "this field of experimentation can now safely be left to its own devices."[71] This statement came at a time when Cook himself had cautioned against regarding conclusions reached so far as 'all-embracing and far-reaching."[72] But in 1963, with an Air Quality Act finally on the way, the industry needed to be seen to do something.[73] Had Cook still been under GFSA auspices only, this pressure could have been deflected. But as an industry initiative this was not as easy.

As newly-appointed Chamber of Mines Research Advisor, A L James, in 1962 encouraged Cook's growing prominence among the mining companies. For the industry, traditionally a price-taker for its product that limited management actions to cost-control, was increasingly taking a co-operative approach to research and this would eventually lead to the formation of the Chamber of Mines Research Organisation (COMRO).[74] The need for a common rehabilitation technique fitted well into this approach. Previously many of the technologies that changed the Witwatersrand gold mining industry had been developed by individual mining houses, but in the post-war period some of the traditional technology leaders had diversified out of deep-level gold mining. This had prompted the Chamber of Mines to become an increasingly active player in the research activities of the industry.[75] Early in 1960 the Chamber member companies agreed to the formation of a Research Advisory Committee (RAC) tasked with the organisation, direction and control of all research conducted by the Chamber. The creation of a Chamber of Mines Vegetation Unit, although it only happened formally in January 1964, fit neatly into this development.

Although Cook made it very clear that until the mid-1960s, he regarded his research as 'work-in-progress', the demand for solutions grew.[76] In 1963 the Chamber already described his work as "a pilot plant, [established] to throw light on problems and difficulties not encountered to date …and pave the way for larger-scale plantings."[77] 'Technical details' such as the reality that only the vegetation of dump tops was truly matured, could be ignored at an industry policy level.[78] By adopting the public position that Cook's work had by 1963 reached a stage where mere 'refinement of the technique' remained to be done, the Chamber mislead itself and its non-specialist members into thinking that no new avenues of research would need to be explored. In the 1963 JSAIMM article Cook still maintained that it would be inadvisable to regard any conclusions reached as far-reaching and all-embracing, especially when the work [was] so largely dependent on circumstances beyond human control;" such as climate and the variable materials conditions on site.[79] However, with the pending air quality legislation in mind, the Chamber proclaimed that "Based upon these findings an attempt was made to provide a standardised procedure for vegetating the tops of slimes dams on a large scale, at a rate and cost suited to the magnitude of the task."[80] Under increasing pressure to be seen to be doing something, the Chamber would between 1963 and 1966 fundamentally shift Cook's focus away from further research towards applying the 'matured' method, in a way that his experimental plots would be pushed aside by the sheer volume of work generated by the large-scale application of 'the formula'.[81] This large-scale

activity which saw the Unit sometimes working on over a dozen sites, formed a key element in the Chamber's campaign for self-regulation on the basis that it was 'getting its house in order'.[82]

**Applying the Formula and Recognizing its Limitations 1964- 1969**

The industry's sensitivity to regulation was intricately connected to its traditional obsession with cost control. Since the price of gold remained fixed, cost control remained the single most important management tool to affect profitability. As a result, the industry's reluctance to acknowledge its environmental responsibilities was sometimes out of all proportions to the actual costs associated of addressing these.[83] When in 1963 Chamber made the first systematic effort to quantify the scale of the mine dump challenge so as base its approach on data rather than assumptions, its numbers suggested that for an industry generating an annual gross revenue in excess of R 600 million, the overall dust suppression liability stood at approximately R 1 million. This figure, which would have covered all dumps and could have been spent over many years, could hardly be described as crippling.[84] Nevertheless such was the obsession with cost control that even in the run-up to the passage of the Air Pollution Prevention Act, the Chamber denied Cook's Unit the resources to fill all approved staff positions, while at the same time expanding the scale of his work and holding up his Unit's activities as a success obviating the need for further legislation.[85]

It appears that the need to talk up the degree of success of the Unit necessitated a certain level of self-deception for the Chamber whose officials would argue that "we have the necessary knowledge to enable us to grow vegetation on *all aspects* of the slimes dams and sand dumps on the Witwatersrand and Far West Rand" and that all that remained was the development of mechanised methods ...[to]reduce the cost per acre of the operations." [86]. In any case Chamber officials would make clear, the method was being "widely applied to mines"[87] While there is no doubt that Cook by 1963 had developed a generally successful method for the establishment of vegetation on tailings dams tops and less acidic slopes, the sand dumps and highly acidic conditions still defied him over the medium term.[88] More significantly he had not solved the challenges associated with ensuring the longer term survival of the established vegetation on these dumps.[89] Internally the Chamber of Mines recognized that "the establishment of a permanent cover of vegetation involves not merely growing plants. It necessitates [establishing] a plant community that will maintain itself indefinitely without further attention or artificial aid such as irrigation."[90] This suggests that although a formal ecological conceptualization of the rehabilitation challenge had not yet been formulated, the men working on the ground were beginning to understand that their work and research would need to go significantly beyond their current level of knowledge.[91] Irrespective of this, the Chamber in the mid-1960s would repeatedly seek to create the impression that all challenges associated with "grassing the dumps had been solved and it now only remained for the industry to find a means of reducing the costs of this work through mechanisation.[92]

While this led the Chamber to push Cook's Unit to ever-growing levels of activity, the 1965 passage of the Air Pollution Prevention Act (APPA) created a new challenge: During negotiations in the run-up to the passage of the Act, the Chamber had been forced to concede

that "it was not at present possible to estimate with any degree of accuracy the cost of establishing vegetation on a mine dump until it had lain fallow for about a year, while a mine was required to make suitable provision before it would be allowed to close."[93] As a possible solution, the Chamber proposed "the establishment of some form of trust fund, either in each Group or in the Chamber."[94] The trust fund model was in a way a child of necessity for the Chamber recognised that "dust prevention measures by means of vegetation on sand dumps and slimes dams can in general only be taken when the dumps or dams are no longer in use and the surface layers are in a state of oxidized condition."[95] Since surface layer oxidization was generally not achieved until "some time after a mining company has ceased active mining operations and possibly only after the company has been finally wound up, … the funds required to meet pollution prevention measures to be undertaken at the time when the company [had] ceased active mining operations [could] only come from past revenues."[96] However, in terms of the tax legislation appropriations from current revenue can only deducted as working costs for income tax purposes in the year the expense is incurred. To overcome this difficulty the Chamber developed the idea of establishing a special trust fund to which contributions would be made by each existing company, such contributions being allowed as working costs for income tax purposes in the year in which they are made."[97] At the time, New State Areas Ltd was about to close and planned to follow the lead of Anglo's Springs Mine which had retained its Chamber membership despite closure "only for the purpose of the establishment of vegetation on the dumps."[98] The Chamber understood that this problem would recur frequently and moved to put forward the trust fund model as a possible solution to the Government.[99] The trust fund model was attractive to Chamber members as they felt that such contributions, could in terms of the Income Tax Act's section 10(1)(e) be made to be tax deductible. And in negotiations subsequent to the passage of the Act, the Government conceded this, [100] agreeing to "recognize Group funds and would allow the contributions to such funds by individual companies as working costs."[101] Out of this necessity the trust fund model, which to this date governs financial provisioning for post-mine closure environmental liabilities, was born.

Having staked so much political capital on avoiding a tighter regulatory air quality framework, the industry in the wake of the passage of the APPA Act, the Chamber now concentrated its energies on focussing Cook's Unit on large-scale grassing of dumps, while at the same time keeping a tight reign on his costs.[102] 1967 was the first year in which the Vegetation Unit warranted a separate heading in the Chamber's annual report. Seeking to re-assure the Government Mining Engineer (GME), the report stressed the numbers:

> "the Chamber's Vegetation Unit continued to increase the scale of its activities. During the year grass was planted on 125 acres of sand dump surfaces, 708 acres of the flat tops of slimes dams and 219 acres of their sloping sides. The total area covered during the year was 1052 acres, an increase of almost 50 per cent on the area covered during 1966. Since it commenced operations, the unit has successfully established vegetation on 2513 acres of dump surface…on the properties of 15 gold mines."[103]

This was as detailed and open as the Chamber would get about the Unit's activities. The next year, 1968 the annual report used exactly the same format merely updating the figures to show that during the year a total of 1160 acres had been grassed an increase on the previous year which brought the Vegetation Unit's total since establishment "to 3673 acres of dump surface."[104] This amounted to approximately 12% of total dump surfaces on the Witwatersrand (assuming an original 9840 hectares in total). Cook's Unit would maintain this elevated level of activity into the 1970s at the expense of further research into the very real challenges associated with ensuring the survival of the established vegetation due to the "the area of tops of slimes dams at mines ceasing operations each year [exceeding] the rate of grassing for some years to come."[105] This alone forced the primacy of grassing over research in the Unit's efforts would persist, as it was reduced to a single research site. [106]

This would assume increasing significance as from 1966 onwards Cook began to observe that the vegetation kept failing increasingly as it aged. In a report on the condition of vegetation on 'completed projects' (older than 3 years) as at September 1968, he noted that on eight out of 56 grassed sites vegetation was failing or stagnating, in other words a failure rate of 15%, but his analysis also showed that a further 8 sites were receiving follow-up fertilization. Thus the real failure rate closer to 18% an unacceptably high level given that the vegetation was supposed to sustain itself over long periods of time and these failure rates were already manifesting over the short-term.[107] Over the following years these failure rates edge upward to where a full third of sites on which Vegetation Unit worked in late 1970 were in need of repair and maintenance. Clearly the promise of long-term stabilization was in question.[108]

Nevertheless, in 1968 Cook co-operated with the Chamber's Effluent Officer, H T Claussen in drafting a preliminary codification of the rehabilitation methodology. [109] The process allowed the Chamber to recognize the limited nature of technically qualified personnel driving this initiative, leading it to briefly seek to contract in academic support in 1969 but reject the external specialist recommendations due to cost implications. [110] But Cook had in many respects become the bottleneck: Although he had a second horticulturalist in W Smith, Cook's style of leadership was not a consultative one, meaning that decisions concerning site-specific adaptations of the general methodology were generally decided by him alone.[111] By centralizing the decision-making process Cook overcame the challenge of working with staff not formally trained in horticultural practices, but effectively limited the development of the methodology to himself as he could not discuss any site results with similarly qualified colleagues.[112] Since his field notes were lost and the progress reports tended to be monosyllabic and filled with general, unscientific descriptions regarding the status and progress of vegetation, there is little opportunity for exploring the motivation for the various adjustments he continued to make to his methodology on a site by site basis.

**Tracking Cook's progress – some problems[113]**

From the start Cook was required to submit monthly management reports to the Committee of Management Vegetation Unit. Initially these followed no set format and Cook was soon steered in the direction of standardised reporting. By 1966, however, his format had been set with him submitting the following

- Monthly staff report showing strength, absenteeism, leave, etc.
- Value of his stores at the end of the month
- His capital inventory and the rainfall for the month at key sites.
- This would be followed by a progress report in which some descriptive detail for each site being worked by the Unit was given.
- From 1967/8 this would be followed by a water report listing water pumping and leaching infrastructure on a site basis and recording whether the water was supplied by the mine or not.
- There would then follow three tables listing 'active' sites and in the context of running totals provide the monthly acres 'worked'. This would be accounted for separately for slimes dams tops and slopes and as well as sand dumps.

Although on the surface offering comprehensive information of his Unit's activity Cook's information suffered from two structural problems for researchers seeking to assess his activities: In the first instance it was prepared by different members of his team and thus came in a series of formats. Secondly and most significantly the qualitative data provided in his Progress report was generally vague dominated by comments such as 'vegetation on all sand dumps and Slimes dams is in good condition' or 'all in good condition'. When referring to work activity he would comment that 'work is proceeding at a good pace' or 'satisfactory progress made'. While such comments will have deemed appropriate language for a Committee dominated by engineers and generally unable to understand botanical terminology, Cook missed a critical opportunity to use these reports as an on-going record of his work. Only very rarely would he record specifics such as the hand-planting of specific species or the completion of key elements of site preparation work. To compound this issue Cook's qualitative progress reports do not match his quantitative reports. Sites, such as Randfontein which Cook might list as having six slimes dams (1/L/29-30, 1/L/36-37, 1/L/40-41) and five sand dumps(1/A/15-18, 20) as active sites would receive a single sentence, 'Vegetation on all slimes dams and sand dumps in good condition' commentary. Only laborious comparison between his three quantitative progress sheets would reveal to a reader that for the month in which this comment was made, that only 4.5 acres were established on two sites although his report would list all as 'active.' Compounding this is that Cook tended to report only by exception, leaving the reader unclear whether the acres listed in the tables referred to in the statistics had been established, had received follow-up treatment or whether any other activity had taken place. Administratively his acreage accounting and his lists of active sites was also made more difficult by his retaining a site on his list until the unit had removed all of its equipment, including the leaching piping from site. Although it is certain that Cook's verbal report back was more detailed, it surprising that the Committee accepted this feedback, until one considers that nature of the audience: Cook was speaking invariably to individuals with an engineering background and who saw the world in engineering terms. These were people who were inherently not comfortable with the legitimacy of his work and consequently not that interested in it.

**Moving towards Acceptance of a new strategic research effort 1970-1975**

By the late 1960s, the issues that would continue to dog grassing in the 1970s began to emerge.[114] Principal among them was the Unit's inability to understand and manage fluctuating acidity which threatened the long-term survival of vegetation on the dumps. Cook's response was mechanistic – the addition of additional lime.[115] Increasingly he had to confront that he had developed a methodology for the establishment of vegetation on dumps rather than plant survival on mine wastes.[116] Despite their sensitivity to costs and their lack of specialist botanical expertise, the members of the Chamber Committee overseeing Cook's Unit could understand the risk associated with this. Although the curt style of the committee minutes and of Cook's monthly reports do not reveal the specific sequence of events, it is clear that by 1968/9 obsessions with cost containment was giving way to a deeper recognition that more research remained to be funded to ensure that this dust control method remained an acceptable form of legal compliance. This was made more urgent by Government actions at this time which also demonstrated that the industry had indeed let the leadership position, derived from its pro-active formation of the Vegetation Unit in the late 1950s, lapse. Although a series of closure certificates had been successfully obtained in the mid and late 1960s, the realisation that the vegetation might not be as sustainable as originally thought, seemingly forced a grudging acceptance of the need for more research. 1969 would begin with a real shock for the industry, as for the first time the Department of Water Affairs would exercise its longstanding powers (under the revised 1956 Act) to deny a closure certificate to a mine. The industry realised that regulator acceptance of its practices could no longer be taken for granted.[117] And while at the same time, the pace of national and even international attention picked up,[118] the country's fluctuating economic fortunes, during the early 1970s would ensure that the dedicated research required to address issues of long-term plant survival and fluctuating acidity would be delayed time and again. And in a similar development, the coal and platinum miners would, although formally Chamber members, time and again refuse to engage the Vegetation Unit's despite growing pressure from the regulator to improve performance, especially in respect of water pollution.[119]

Parallel to this, the Government Mining Engineer (GME) with his responsibility for abandoned or closed mine dumps, developed into a significant customer for the Vegetation Unit. While the cost conscious Chamber members welcomed this sharing of overheads, they were also painfully aware that as custodian of mine waste facilities for which there was no longer a responsible or solvent owner, the GME had, since 1965, (when it acquired this responsibility) also experienced the reality of progressive vegetation failures on sites grassed by the Vegetation Unit. Thus the growth of this new customer was a direct function of the growing concerns raised around the viability of the Vegetation Unit's core methodology. The more the GME grew in prominence as a customer, the more the Chamber had to confront that the regulator understood the short-comings of the current 'tailings dam closure recipe', which in the 1960s it had accepted as 'best available technology'.

Having failed to develop the coal and platinum sectors as new customers, the Chamber's Vegetation Unit briefly had the opportunity to branch into dust control on operational, rather than closed dumps, when in October 1971, Vaal Reefs, the largest of the Klerksdorp mines, sought his assistance, stating that "during the windy months, a great deal of dust [had] been

blowing off one of the discussed dams causing concern to the local authorities."[120] This was the first record in which a mining company explicitly acknowledged stakeholder and regulatory pressure as the motivation for grassing dams and it should have been the beginning of many more such requests, thus transforming the business of the Vegetation Unit away from dealing with closing or closed dumps only. A month later GFSA sought Cook's help when the construction of Rand Airport necessitated the implementation of dust control measures on the Group's Elandsfontein Slimes Dam (4/L/5)[121] Ultimately, however, these requests proved the exception for neither the South African authorities nor the public were able to create or sustain such pressure. Thus the Vegetation Unit's business gradually atrophied in its focus on closing or closed dumps; in view of its inability to guarantee permanent vegetative cover. This was unsustainable business model which affected staff morale and led to the loss of the few skilled staff of the unit in 1971/2.[122] Cook's labour shortage was also made structural by the continued need for major repairs on the sites that the Vegetation Unit moved onto. Despite the requirements of the Chambers Code of Practice on how mines should prepare dams and dumps for closure, virtually no operation devoted significant effort to this, leaving Cook and his team either to conduct often significant engineering earthworks or to engage contractors such as Fraser Alexander for this purpose. Both options imposed considerable delays and administrative burdens on the Unit. [123]

In 1971 the Chamber once again went through the motions of contracting external specialists to investigate the reasons for vegetation failure only to discard once more any recommendations it saw as too costly. [124]At the same time the Chamber Committee's members took the first implicit step in accepting that Cook's methodology would require more fundamental research in 1971/2 when they permanently included financial provision for follow-up treatment as part of the Unit's standardized quotations. [125] They also – for reasons of long-term cost containment – authorised the expenditure associated with the establishment of the Vegetation Unit's own laboratory and the appointment of a new Technical Assistant and Soil Scientist, John Easton-Groves in October 1972.[126]

Substantially the inability of the Chamber members to commit to spending significant new resources was driven by external economic factors: In the 1960s manufacturing had overtaken mining as the pre-eminent sector on the back of a growing current account deficit, which had brought not only reduced growth but also inflation. Having averaged 3.3% throughout the 1960s, inflation, particularly food inflation, took off in 1970, leading to black wages falling further and further behind. Combining with this growing economic desperation was a fading of the memory of the harsh repression of the Sharpeville Uprising. Together this created a renewed sense of opposition, one that expressed itself in a rapidly escalating strike movement across South Africa's urban centres from 1972 onwards.[127] Employers therefore swiftly moved to increase African salaries to contain the unrest,[128] but the real solution came from gold, whose de facto price began to rise for the first time in 1969, when the speculation led to US and European currency devaluations and in August 1971, the United States abandoned the gold standard, sending the gold price upwards. By May 1973, the gold price had reached US $ 100, solving the Republic's balance of payments problems and bestowing massive profits on the gold mining companies.[129]

Bolstered by such good fortune, 1972/3 saw a gradual loosening of the Vegetation Unit's purse strings as the Chamber Committee members could increasingly afford to concede the argument for additional fundamental research, made by their own and external specialists. [130] They were also facing a far more politically adept individual in the form of the laboratory manager – John Easton-Groves – who understood how to present some of the difficult challenges in a manner the practical Cook could not. Supported by the far-sighted, but ageing Claussen, they began assembling the scope for a large-scale research program from late 1973. Although it went through many permutations, it was aimed at revisiting various issues of managing soil fertility during and after vegetation establishment, alternative sources of plant nutrients, fertiliser application options, issues around plant succession, and the use of acid tolerant plants. [131] Their efforts suffered a setback in December 1974 when Cook, after 15 years at the helm of the Vegetation Unit was forced to retire. His replacement, to whom he did not transfer any skills, was an administrator who, lacking technical skills, did not last. The next two successors went the same way, so that by 1976 Easton-Groves and Claussen effectively control the Unit. [132]

Throughout 1975 Claussen and Easton-Groves remained positive that their proposal for large-scale, fundamental research had not only not been rejected, but was actually successfully working its way up the Chamber hierarchy of committees. Due to the scale of the field research - expected to be about R 4 million in total - and the desire by Clausen and Easton-Groves to retain in-house control over much of the work, the funding of additional vegetation-related research by the Chamber of Mines, rather than by the Vegetation Unit's clients became a matter of political debate. To defuse it, the Claussen lobbied for the consolidation of the various environmentally focussed resources to be consolidated into an Environmental Section, later called the Pollution Control Section was established on July 1st, 1975. The establishment coincided with the formal decision to proceed with the overall research initiative which would cost approximately R 4.2 million over 5 years.[133] The logjam of cost-aversion appeared broken.

In fact 1975 marked the high point in terms of the volume of the Vegetation Unit's work. From 1967 onwards about 400 hectares per annum either being grassed or received post-grassing care on annually. [134] By 1976, about 4 190 out of a total estimated 8 500 hectares of abandoned tailings deposits of various kinds on the Witwatersrand had been grassed.[135] But from 1975/6 onwards work both from the Group companies and from the GME began to decline. In part this was due to a significant proportion of the problematic sites having been grassed, but also because the price of gold settled in comfortably above the US $ 100 fundamentally transforming the economics of gold extraction.[136] Whereas previously the gold miners had been price takers focussing on cost control almost to exclusion of all else, they now had a product nearly four-times as valuable as before (if you discounted inflation) 1969. With this the economics not just of marginal ore underground were transformed, but also the retreatment of gold-bearing tailings already on surface became commercially viable. Tailings, especially from early mining activities, still contained residual gold often at levels of 0.5 to 1.5 grams of gold per ton. Moreover the advantage of tailings deposited on surface was that there were no mining, hoisting or crushing costs and thus even low-grade tailings

containing as little as 0.05 grams per ton could technically be made to yield some of their gold. As the levels of confidence of a permanently higher gold price rose, the tailings looked increasingly prospective and the miner's appetite for rehabilitation of tailings dams had begun to dwindle.

In late 1973, just after the gold price punched through the US $ 100 barrier, both Rand Mines and Anglo American initiated research projects to consider the large-scale re-treatment of the gold tailings on the Rand. But it was only in early 1976 when the gold price appeared to stabilize comfortably above US $ 100 that the Anglo American Board formally approved the project, designed to re-treat 19 gold tailings dams containing 384 million tons of material across the East and Central Rand - naming it East Rand Gold and Uranium Company (ERGO).[137] ERGO's technology was designed to extract three commercial products from the tailings – gold, uranium, and sulphuric acid. Using sulphuric acid the uranium content of the tailings would be extracted by leaching from the pyrite concentrate, after which the pyrite would be fed into the 'acid plants' oxidization in the acid plants, besides producing acid would improve gold recovery from the tailings by releasing the gold otherwise locked into the sulphide matrix that would have resisted conventional extraction by cyanidation. Calcine from both acid plants be treated in the normal cyanidation circuit for further gold recovery.[138] It was the production of the three commercial products that made ERGO significant for the rehabilitation context. When Anglo announced the project go-ahead in January 1976 the press release stated, "A significant feature of the project will be the reclamation of large areas of land, presently overlain by slimes dams, for industrial and residential development by the owners of the surface rights. In addition, the removal of sulphur from the slime will eliminate a potential source of pollution (acid mine drainage) from the tailings."[139] Construction began in July 1976 and the operation came online in early 1978. ERGO, for which Anglo American issued an uncommonly optimistic profitability prediction when it listed the company in 1977, captured the public's imagination. While the Group did not over-emphasize the sulphur removal aspect too heavily, it was well-known and could have played a role in improving public perceptions of the mining industry. [140] At the same time a degree of complacency crept into the miners discussion about water pollution on the Rand. For ERGO was only the largest of two such projects brought into operation around this period: Anglo's ERGO which would treat 378 million tons of slimes from 19 slimes dams over a 20-year period at the rate of 1 million tons per month, and the Rand Mines and Milling operation at Crown mines which planned to treat 52 million tons of sand and 18 million tons of slimes from three large problem sites. As both operations would be recovering between 70 and 85% of the sulphur contained in the dumps, the argument ran that "this would almost eliminate pollution potential of the new slimes dams [built with retreated material] … treated slimes …will therefore not contribute much additional seepage."[141] In addition, the coal miners would alleviate the pollution problems associated with their slurry dams where previously all coal fines – a by-product of coal beneficiation – would be deposited. Now that coal fines had found an export market this material was scheduled to be reclaimed for sale.[142] Thus the industry argued, time and capitalism would take care of the water pollution problem. Management Magazine commented wryly at the time that the coal mines "serious water and air pollution problems have not yet been tackled on the same scale." [143]

Around the time Anglo's Board approved ERGO, Easton-Groves and Claussen, flush from the approval of the massive long-term research budget were busy adding additional trial plots to the research scope and setting up the first experimental sites.[144] Almost immediately they encountered manpower constraints. 1975 had been a high-rainfall and stormy year which led to damage at a few sites and despite having received funds for research, Easton-Groves and Claussen found that no additional labour was allocated to the Unit.[145] In response they shifted to contractors to advance the trial plots only to discover significant quality issues in the exact execution of the scopes.[146]

By mid-1976 the mood was changing. Aware that tailings dam retreatment was being considered as a large-scale option across the Rand, the research timeframes set by Easton-Groves and Claussen began to shorten. They had initially scoped 3-5 year trials,[147] but in mid-1976 Easton-Groves reported to the Chamber Research Advisor, G H Grange, preliminary results of liming and leaching trials on the basis of which he argued that leaching should be discontinued.[148] Once again the need for quick results was appeared sufficient to warrant changes to methodology. Beyond this, however, the Unit's work seemed to loose focus; and although Easton-Groves generated an interim report on the trials, there does not appear to have been significant interest shown by the Committee in the results of these experiments from late 1976 onwards. Politics, in the form of the 1975 independence of Portugal's former African colonies Angola, Guinea-Bissau and Mozambique, and the events that led to the Soweto riots, it seems once again served to distract them. Collectively these events moved the gold miners to switch from foreign migrant labour to migrants from Lesotho and rural South Africa.[149] This brought the mining industry into direct competition with South African farmers, the National Party Government's most powerful constituency.[150] In addition timid efforts to move stabilize the African workforce and relax job reservation brought it into conflict with another pillar of National party support, the white mineworkers union.[151] These worsening industry-Government relations would set the tone for engagement over the issue of mine dump rehabilitation for the remainder of the decade and beyond.

The most immediate effect was felt in the Vegetation Unit's cash flow because by 1975 the diversion of much of the Unit's resources towards remedial and research work meant that the Government Mining Engineer (GME) assumed increasingly greater significance as a client when seven significant contracts were awarded.[152] As 1975 turned into 1976, these contracts became problematic as the GME increasingly delayed payments. While this proved a constant irritation and distraction, in terms of the Unit's reputation, the decision by Rand Mines to go its own way in tailings dam rehabilitation was perhaps the most severe blow.[153] Rand Mines was widely known as the one of the most progressive of the Chamber mining companies and its departure, and employment of the retired W B Cook as a rehabilitation consultant, sent a clear, if unspoken message that the Chamber's Vegetation Unit was no longer the only authority on matters of tailings dam rehabilitation.[154]

One individual who fervently believed that the Vegetation unit remained best placed to address tailings dam rehabilitation was Easton-Groves in his capacity as Scientific Officer. Aware that "the absence of government pressure and legal enforcement remained the single biggest factor holding back progress in South African tailings rehabilitation work,"[155] he was

determined to build up scientific data as a base for a more scientific future approach, continued to motivate for individual trails and to push for continued sampling and analysis of vegetated and un-vegetated sites. The 1976/7 growing season proved to be difficult with rainfall concentrated in short, heavy downpours between long dry spells, as a result many experiments were impacted and some grassed sites established by the Unit as part of its regular contract work damaged by floods in February 1977.[156] Easton-Groves was also concerned that a steady drop in the number of new soil samples sent to his laboratory indicated a drop-off in new work.[157] By September 1977, one of the members of the Pollution Control Committee, also noted that the Vegetation Unit was "in an unhappy state."[158] Part of the problem lay with the irregular nature of the GME work, which hindered the Unit's ability to plan due to erratic cash flow. At the same time, Easton-Groves efforts, including those using the retired Cook as a consultant, to drum up work from among non-Chamber members as well as coal mining members of the Chamber over 1976/7 yielded virtually no income.[159] The resultant uncertainty, coupled with the lack of focus that accompanied the trials of the major research initiative are likely to have played a major, if un-recordable role in the gradual petering –out of the Chamber's research effort. In part this may have been due to the new manager, MacVicar, carrying on the vague, unscientific reporting style of his predecessor when communicating with his managing committee. No consistent record survives – if it even existed in the first place – that suggests that the Unit systematically tracked the results of its various trials, or that the results were at some stage summarized for discussion. Nevertheless, the minutes of the Committee of Management of the Vegetation Unit suggest that the significance of any trial findings were further reduced due to the habit of individual results being discussed without much reference to previous results or wider context, whenever they became available. Easton-Groves would repeatedly argue "it has been suspected for some years that this micro-biological activity or lack of it, is limiting soil development on spoil. Without soil development, particularly humus formation which is a microbiological process, vegetation aftercare is likely to be a protracted process."[160] However, this meant little to engineers. The Vegetation Unit also co-operated with F Thatchter, a PhD student from Witwatersrand University doing a seminal study on a single tailings dam complex, in the hope of creating a template for more structured, scientific research of sites slated for rehabilitation.[161] But these were longer term research projects to which the members of the PCC, according to the minutes, reacted with limited interest. [162]

Thus by 1977, the Vegetation Unit was being hemmed in by three related factors: it had grassed 30 of the 80 sq km mine dump surfaces on the Witwatersrand at a cost to the mining industry of R 12 million,[163] and thus reduced the public nuisance and in this context the growing realisation that the GME understood the limitations of the existing rehabilitation methodology meant that the industry had to accept that obtaining mine closure certificates would in future be challenging. In 1978 the Chamber had to formally concede to the GME that "the costs lay not in the initial care but in the aftercare of mines."[164] The major research initiative launched at the time could have offered a way forward had members been serious about the matter and not starved the initiative of scientific capacity to fulfil its mandate. But with most Chamber members contemplating the re-working of their dumps, the prospect of investing in additional grassing research was hardly attractive. The modern dump retreatment

technology appeared to offer a potential way out of the environmental dilemma due to its removal of sulphur from the tailings, and so investing in grassing, which would make future re-treatment more difficult, was hardly attractive. Since the members of the relevant committee remained, with one exception engineers representing companies who did not at the time employ any environmental managers, they failed to consider the information that became available from the various trials in any systematic manner. Even in the face of continuous tightening of legislation on pollution issues, this left the Vegetation Unit reduced to tinkering with its methodology. Nevertheless globally and locally environmentalism as a movement had proved itself a durable force, leaving the Chamber with little alternative but to continue its support for the Unit's activities under the guidance of the Pollution Control Committee.

**The Promise of a cheaper alternative: The Chamber of Mines Erosion Tester (COMET) 1978-1983**

In 1978, the Chamber employed a former senior bureaucrat from the Department of Water Affairs and groomed him as a successor to now 74-year-old Claussen. Fred Cartwright, an engineer by training, had been selected on the basis of his 'good contacts within Government' and his forceful personality, but above all his fervently held view that there had to be cheaper alternatives to grassing.[165] Upon joining the Chamber he almost immediately began campaigning for resources to be devoted into research for non-grassing alternatives, methods he referred to physical. [166] He also motivated for the relocation of the Vegetation Unit's Pollution Control Section and its laboratory facilities at Carlow Road, although rental was being paid for said offices.[167] Cartwright argued that since 1976 the Vegetation Unit's function had been changed by legislative developments. The Vegetation Unit would "now have to conform to the changing requirements of all relevant Government Departments the concept of which is not within the orbit of the Vegetation Unit per se."[168] He did not explain what 'the changing requirements of all relevant Government Departments' amounted to in respect of the Vegetation Unit's activities. Nevertheless, he argued, the "circumstance requires that the Vegetation Unit ceases to be an entity and becomes an arm of the Pollution Control Section" because it was "necessary to merge all the anti-pollution activities into the Pollution Control section in order to better serve the Industry and the State and so reduce the cost of anti-pollution measures." Against the formal opposition and some behind the scenes lobbying of the Vegetation Unit staff this was approved in November 1978. Once approved Cartwright pushed the matter relentlessly even though the new central facility at 16 Shaft to where the laboratory, all Vegetation Unit equipment and other PCC equipment and infrastructure was moved required a significant capital outlay. In a move that would come to symbolize his *modus operandi*, he also fended off all criticism when the cost of this move exceeded the initial approved budget. [169] One of the savings he did 'conceed' was to delay the re-assembly of the laboratory equipment once it had been moved. It would never again be assembled. [170] A key pillar of the grassing capability had been neutralised.

Cartwright's succession of Claussen came at a time of significant industry uncertainty, for the South African Government had taken the better part of 1977 to put down the aftershocks of the Soweto Uprising and in the process begun the militarisation of the public sector which led

to Defence Minister P W Botha assuming the Premiership in September 1978. However the ever growing military expenditure, the cost of creating the Bantustans and the continuously rising costs of oil imports, created a structural balance of payments crisis which the government could not offset against surging revenue from gold exports as the price of gold stabilised in the mid-1970s. Already committed to raising mineworkers wages to the levels of parity with industrial wages, South African gold miners now had found inflation driving labour costs even further. With mechanisation efforts not yielding much savings, labour costs continued to soar, particularly in respect of unskilled labour – something the industry needed in great numbers.[171] Although the ensuing recession, briefly eased the mines labour shortage labour costs in line with all other costs continued to rise. [172] While nothing could change the fact that gold was worth at least 10 times what it had been worth in 1969, the cost of grassing the mine dumps had increased twenty-fold between 1972 and 1979.[173] The key driver here was the cost of labour, particularly black labour, as the Vegetation Unit experienced a series of work stoppages over working conditions in 1978 which forced it to increase wages, add medical benefits and invest in improving the living conditions in the compounds housing its black staff.[174]

Cartwright knew exactly where to apply pressure. Aware of the potentially open-ended cost associated with the maintenance of vegetation , companies such as Witwatersrand Gold Mining Company Ltd corresponded with the Chamber in late 1978 primarily in order to establish which dumps it actually was responsible for, but secondarily to explore the possibility of "growing fruit and … other kinds of food plants" as a commercially viable alternative to grassing.[175] They did so in the knowledge that the labour costs of the Vegetation Unit's African workforce, "including accommodation of field-workers in non-mine facilities and the cost of fertilizer…had risen substantially in price, adding heavily to the cost of grassing and [distorting] the figures of ten years ago out of all proportion.[176] Thus the Vegetation Unit increasingly found that the contracts it sent out to prospective client mines would go unsigned or be returned over issues of long-term cost. [177]

This disagreement over method between Cartwright and the Vegetation Unit management affected Unit morale, which then suffered even further when the proposed move to 16 Shaft and then 4 Shaft at Crown mines did not materialise and instead even more costly premises at City Deep were proposed, while wages and salaries were not raised.[178] In his efforts Cartwright also proved adept at interpreting previously published research to support his argument in a way that was not always in line with the intentions of the authors. All previous aspects of vegetation experiments, he argued, showed that vegetation was not the solution in view of the substantial ameliorative inputs (such as soil, fertilizer and leaching) it required for long-term survival. By summarily asserting that these ameliorative input methodologies would be too expensive, especially during the open-ended after care phase, he reversed the authors arguments into 'evidence' for the unviable nature of grassing. [179] Instead the engineer Cartwright, looked to an engineering solution for the answer to the management of dust on tailings dams. While he was forced to accept that in nearly half a century of experimentation none of these 'physical methods' had yielded 'entirely satisfactory results', he believed that

these physical as opposed to vegetative efforts were likely to yield better results if further researched.[180]

Before assuming the post of Pollution Control Manager, Cartwright had come across erosion testing equipment and he pushed hard for its assessment by the Chamber. Immediately upon joining, in August 1978 he proposed the purchase of a prototype erosion tester from South African manufacturer Thorn M I based in Johannesburg, and also included the use of the system in the draft Handbook of Guidelines on tailings dam management whose preparation he oversaw.[181] Thus the device, called Chamber of Mines Erosion Tester (COMET), entered into the Guideline even before the first prototype was tested in October/November 1978. The Department of Agricultural Technical Services participated in the early tests which led to modifications to the design which were begun in December 1978.[182] The next trials had to wait until March 1979.[183] In his work Cartwright found intellectual support from two key sources, Oskar Steffen, one of the founding partners of a young but flourishing mining consultancy – SRK – and G E 'Jeff' Blight, then Professor of Civil Engineering at the University of the Witwatersrand as well as a special advisor to SRK.[184]

The COMET device supported by a tripod and designed to direct a jet of fluid, usually water, to the deposit surface from an orifice 0,8mm in diameter, located at a fixed distance away from the surface. The pressure of the jet is increased at a constant rate from zero until dislodgement of the surface material occurs. The jet pressure in kPa at which dislodgement first occurs is noted as a numerical value as the Comet Erosion Index of the surface. A sufficient number of tests should be made at a reseaonably practicable number of locations on the dam or dump in order to fully define the mean and range of the values and also to define any zones which may require special or less treatment because of a greater or lesser tendency to erode. [185] In short the surface hardening effect of the tailings was to be randomly measured by this device to determine its resistance against rainfall erosion. If it was shown to be resistant to rainfall, Cartwright reasoned, it would be resistant to all other natural erosive forces. If need be this resistance could be artificially achieved by mixing cement into the surface layer. In early 1979 when his first survey of COMET values on various tailings dams indicated that quite a few could possibly be declared naturally self-sealing, he reduced Vegetation Unit field staff from 81 at the end of April to 40 at 30th June 1979.[186] The Vegetation Unit staff, reduced to GME work and a few remaining experimental trials could hardly object.[187]

By early 1979, Cartwright's single minded pursuit of the COMET solution was leading to serious friction with the staff in the Pollution Control function. At this time he also killed off a project Easton-Groves had been championing for some time: the establishment of a soil fertility database to assist in predicting vegetation behaviour.[188] Cartwright saw no need for this and starved the project of funding. In the internal debate which was for obvious reasons not committed to paper, [189] Cartwright soon emerged as the clear victor due to his ability to muster the support of the Pollution Control Sub-Committee members with his promises of a cheap, effective and most significantly permanent solution to the problem of dust on tailings dams. Unable to put forward the scientific merits of the case at the Chamber's Technical Advisory Committee, all John Easton-Groves, as Scientific Officer of

the Pollution Control Section, could offer was a repeated minuting of his opinion that "the Chamber of Mines leads the world in suppressing dust by means of grassing and that there was at present no adequate substitute for grassing dams and dumps."[190] In early May 1979 matters came to a head when John Easton wrote a last forceful memorandum to Cartwright in which he argued that:

> "The only methods for mine dump reclamation which have demonstrated any success, and with which we have any experience to date are vegetation of the tops, vegetation of the sides and rock cladding of the sides with associated toe-paddocks. The success of any other method is as yet only possible not probable, especially … methods such as covering with soil, cement and plastic sheets or organic binders have already been tested, and proved unsuccessful for various reasons."[191]

Easton was adamant that while "failures of grass had occurred due to absence of continuing research in the late 1960s" and "random departures from the standard method as outlined within the 1979 Handbook of Guidelines for Environmental Protection's section on grassing, it remained that only grassing is presently viable." Easton's memorandum was as much a last argument against Cartwright's single-minded vision as it was a note for the record, for attached to the memorandum was his letter of resignation in which he condemned the "hasty" pursuit and adoption of an unproven technology. Easton's resignation was a matter of principle and it cost him dearly; at the time there were was only one other organization looking for an environmental officer in the resources sector; ESKOM. Unable to secure other work Easton-Groves eventually relocated to Australia to continue his career.[192] Cartwright did not replace the position left vacant by Easton-Groves' departure and instead recommended that "any project which might arise from the work of the Vegetation Unit, could be done by the University of Natal" and Professor D de V. Booysen of that University's Department of Botany, who specialised in grasslands. [193] Implicitly he suggested the Unit's dissolution.

With Easton-Groves's departure the controversy over dust suppression methods could no longer be ignored by Chamber members who were left with the impression that "the future of the Vegetation Unit is not altogether clear, …[and] that the results of the review of present methods of combating air and water pollution from residue deposits by the Chamber's Research Organization, as recommended by the Pollution Control Sub-Committee on 30th May 1979, should first be obtained."[194] Only Anglo American Corporation's D J Bosman came out strongly in favour of continued grassing, which the DME still supported."[195] Cartwright also found that in some open forums, his argument that surface stabilization was preferable to grassing as the latter risked sterilizing the resources contained in the tailings, came under fire. In a public debate, Professor P de V Booysen of the University of Natal, dismissed Cartwright's argument as "just postponing the eventual time as the problem would still be there and would eventually have to be solved."[196] Nevertheless Cartwright continued to press ahead with the sale of 'surplus equipment' from the Vegetation Unit, including 7

tractors and two trailers.[197] The Chambers members allowed him to do this even though it was not until May 1980 that they were given a first- hand demonstration of the single prototype device. Cartwright it must be emphasised was betting the industry's reputation in respect of rehabilitation on a single prototype with no track record anywhere in the world.

Cartwright also injected the COMET concept as the potential magic bullet into a serious confrontation between the GME and the industry. Since then 1965 requirement arising from the Air Pollution Prevention Act, that companies set aside funds to provide for dust pollution prevention measures after closure of the tailings dams, gold mining companies had gone to extraordinary lengths to avoid making such provisions or in any way standardising the methodology of calculating the amounts for these trust funds.[198] By 1979 matter had deteriorated to the point where the industry was openly defying the GME by refusing to update their dust control funds in the manner required by the regulator. What emerges from the correspondence between the Department of Mines and the Chamber on this issue during 1977-1979 was the fear of companies being stuck with open-ended liabilities to maintain vegetation on dumps for an indefinite period of time. In a letter to the GME, dated 10th May 1978, the Chamber emphatically stated that "the uncertainty of the liability is thus the main issue."[199] For despite promises from Cartwright, the GME refused to commit himself to a fixed timeline of vegetation maintenance after which a closure certificate would be issued and the state would assume the responsibility. As a solution Cartwright suggested that the COMET be agreed upon as the technology that would determine the length of time members would be obliged to cover post-closure dust suppression.[200] Cartwright argued that once the COMET was accepted by the Department of Mines, the device offered the prospect of drastically reducing the need for the dust funds. [201] With the GME still pushing the issue of standardised dust funds, he argued that, companies should further stall with respect to obtaining the annually required quotations on which to base their financial contributions to the dust funds, until the Department of Mines had formally agreed to the use of the COMET[202]; a remarkable proposal given the fact that the COMET concept rested on a prototype which the GME had yet to see. [203]

The Chamber also used the rising gold price as a reason to stall on the updated dust funds issue, citing uncertainty "as to whether certain residue deposits should be covered or reprocessed."[204] As a result "there has been a fall-off in the demand for services of the Vegetation Unit … making it difficult for the small staff which remains to cope with their normal day-to-day duties and process quotations [for dust funds]."[205] Cartwright who wrote the letter, was being somewhat disingenuous in this respect, for while it was true that work had declined, he had, as responsible official, not replaced departing staff.[206] The GME was not intimidated by the letter of March 10th and pointed out that even according to Chamber correspondence "the proposed cut-off point of 60 with the Comet is still being investigated by the Vegetation Unit and will be decided upon as soon as the tests have been completed." [207]In short, he had no intention of supporting unproven technology.

Nonetheless Cartwright from the May 1980 demonstration of the COMET to the Chamber members, kept promising the imminent acceptance of the device by the regulator. [208] And in the meantime he blocked reports submitted by members the Vegetation Unit that did not fit

his view, even going as far as withholding the full correspondence from rand Mines for common approaches to vegetation-related issues from Committee members. [209]

In part Cartwright's focus on the COMET was a function of the cost-consciousness that swept through the Chamber during 1978 and 1979 when the South African economy was gradually recovering from the economic shocks of the early and mid-1970s. However inflationary pressures and a perceived shortage of oil had shaken the confidence of the captains of industry.[210] Thus even vehicle fuel bills came up for extensive debate in the PCC meetings as members worried that due to the declining work load, the Vegetation unit was loss-making. The Vegetation Unit's work for 1980 essentially had been reduced to GME work as members held back, pending the formal acceptance of the COMET concept.[211] A meeting on November 4th 1980 also made it clear that all that stood between "the disposal of Vegetation Unit tractors, trailers and equipment [was] … the Government Mining Engineer's acceptance of the Guidelines."[212] In other word,s even before the COMET trials had been completed, the disposal of all non-COMET capital items in the Vegetation Unit's possession was being planned.

When in late 1980 Cartwright was repeatedly again pushed about the finalization of the COMET methodology specifications, he stalled but concluded his prognosis with the statement that once the GME had accepted the COMET cut-off points "it would be possible to assess the amount of money required by the Group Dust Control Trust Funds.[213] Another source of member anxiety was the pending formation of the Department of Water Affairs, Forestry and Environmental Conservation and the looming passage of the Environmental Conservation Bill(which became the Environmental Conservation Act in 1980), which for the first time would provide a general framework for pollution control legislation, including the polluter pays principle and the requirement for an Environmental Impact Assessment (EIA) study to be done prior to the commencement of a new business. Cartwright noted "in my opinion there are far too many people set on improving the environment."[214]

Curiously the combination of these pressures allowed Cartwright to fast-track the acceptance of the unproven COMET even further, despite still only having a single COMET prototype to work with. In his 1981 budget vote he asserted that the instrument had been developed and that "by the first quarter the second instrument will have been made, the working drawing will have been completed, the production costs will have been determined, an instruction pamphlet[215] will have been produced, and the instrument will be commercially available.". Never tiring of reminding the Committee members of why they were backing this unproven concept he reiterated that "resulting from the COMET Instrument, the mining industry will be relieved of shrouding some parts of residue deposits, such as sides of gold slime dams, resulting in a considerable saving."[216] The unreality of the situation can be gleaned from the fact that as late as 1981 Cartwright does not appear to have arrived at a final decision regarding the optimal sealant as he continued to explore all possible materials – including bitumen – as potential sealant candidates for the dumps.[217]

1981 began well for Cartwright's strategy against the dust funds, when in February when the Department of Mines "provisionally accepted his COMET cut-off point value of 60." [218] A great ambiguity would arise over the next few years as Cartwright or others persistently failed to include the word 'provisional' in the references to the GME's acceptance of the COMET values, leading to some Chamber members operating under false impressions. This ambiguity would be a source of great confusion, mistaken assumptions and dashed hopes. As late as October 1983 when Cartwright had left the Chamber, the organization would in its patent application correspondence for the Comet still refer to the acceptance of the technology by the GME without any reference to the word 'provisional'.[219]

With the provisional acceptance of the COMET cut-off points, Cartwright moved more purposefully to wind down the grassing aspects of the Vegetation Units work. When the Assistant Field Manager left in February 1981, he did not replace him although officially he reported to the PCC that "the position of the Vegetation Unit would remain static until it was decided whether vegetation or other methods of controlling pollution should be adopted."[220] But Committee members were not prepared to go along with everything he did and Cartwright came in for considerable criticism in early 1981 for providing inadequate detail on the work done and the costs thereof. [221] By late 1981 this criticism would mount as members tired of Cartwright un-met deadlines and his consistent inability to deliver formal acceptance of the COMET by the GME. Also in August 1981, J D Greig of the Chamber of Mines Research Organisation (COMRO) Metallurgy Laboratory, formally presented his review of dust prevention methods on mine residue deposits. This was the research whose progress the Chamber had used to delay responding to the GME's request to update the dust funds, in the hope that it would indicate cheaper, non-grassing methods. Greig firmly came out in favour of grassing which "still appears to be the 'best practicable means' of stabilizing the surfaces of sand dumps and the top surfaces of slimes dams."[222] Cartwright managed to temporarily deflect the weight of Greig's research work by arguing (incorrectly) that "grassing was done for dust suppression and not for water or land pollution."[223] Thus while seemingly accepting that grassing could work in some cases, but not on slopes, he was preparing the ground for the slopes to be the place where the COMET would find its role.

However two things events gave the Greig Report considerable significance; it was formally circulated to the GME[224] and shortly afterwards Cartwright seemingly overstepped the mark in promoting the COMET as a GME accepted technology in March at a public conference. [225] Having just given the concept renewed credibility through its inclusion in the Chamber of Mines Guidelines on Tailings Dam management he also pushed the Chamber into beginning the (expensive) process of patent applications across the world.[226]

However by late 1982 things were changing as Cartwright remained unable to deliver his promise of GME acceptance of the COMET. In late 1982 he overstepped the mark when in a Committee meeting he asserted that the COMET devic, had it been commercially available, would have averted the high profile collapse of a large cooling chimney at Matla Power station. [227] After having been formally forced to retract that statement, the deathknell came when shortly afterwards the GME responded to the Greig Report. The Department of Mines response, dated August 17th, conceded Greig's points about grassing but pointed that due to

the vegetation's "inability to become self-sustaining, together with subsequent exorbitant maintenance costs, have prompted this department to reconsider and/or re-examine the long-term merits of vegetation as the 'best practicable means' for this purpose."[228] Without even mentioning the COMET, it went on to say that "under the above circumstances it is therefore not possible to provide an answer at present to the question of the period for which mines should be held responsible in discharging their duties in terms of the above Act." [229] The Chamber members who had skirted the law with delaying dust fund updates in the hope that the COMET would close the issue saw their hopes evaporate. This failure to gain the support of G P Badenhorst in his capacity as GME to agree to an acceptance of the COMET and thus a definite timeframe for the transfer of responsibility for the maintenance of pollution prevention measures on the dumps, proved a turning point in Cartwright's fortunes. Although nothing was recorded in writing, things moved rapidly from there and by the time the PCC met again – on November 16th – D.D Marsden attended in his position as Environmental Protection Officer designate, and Cartwright's retirement at the end of the calendar year was formally noted.[230].

Two issues stand out: Just as the Chamber had relied on a single individual – W B Cook – to develop a methodology and implement on a large-scale, so in 1978 they had backed another strong personality - Cartwright. Unfortunately for the Chamber Cartwright's unshakable belief in surface sealants and the COMET device – which he acquired even before the first test results came in – made this a flawed strategy. Once again the Committee members found themselves at the mercy of a single individual reporting upward, only that this time, the capacity for dissenting voices within the Unit was lost as Cartwright refused to replace any of the senior staff positions as scientists such as Easton-Groves left. A cynic could argue that Cartwright knowingly misled the Chamber in the hope of profiting commercially from the eventual mass application of the COMET. But the evidence ultimately does not support this. Rather it is likely that Cartwright was simply the wrong person for the line function he occupied. That it got this far however lies in the unwillingness (or lack of interest) of the Committee members for Cartwright never once is recorded as having to explain the 'science' behind his COMET values to the members. And herein lay the systemic fundamental failure of this period, Cartwright's claims were never put to the test of third party scrutiny, most probably because the Chamber members wanted to believe his promise of a cheaper alternative to grassing.

**In the Shadow of the COMET: the Vegetation Unit in the mid-1980s**

The new manager, D Marsden – a chemist by training - took over the remnants of the Vegetation Unit which at the time of his predecessor's arrival had had something approaching 100 sites (either being grassed, or monitored following grassing); in 1983 it had none, beyond sites it worked for Government departments. The Unit's Manager Report for January 1983, contain the Motor vehicle report and the staffing and stores report, but no information on site activity as there was none. At the time it still had 71 staff, six of them white foremen and administrators.[231] Incongruously that year for the first time, an image of a grassed tailings dam appeared in the Chamber of Mines annual report.[232] Nevertheless the

Unit, for 15 years a regular feature in the Chamber's annual report, would not be mentioned again for another five years.

Marsden was however readily accepted by the remaining team members as he, mindful of his technological limitations, came to rely heavily upon the technical inputs of his specialist team members. Brian Cook, estates manager at Rand Mines Properties took an active role in familiarizing him with the sites at which the Unit had worked the past years and getting to know his client base, the mine managers of the gold fields. [233] Marsden was acutely aware of the controversy around the COMET but for some reason felt duty-bound to state publicly for some time to come that "the development of the COMET erosion tester, has eliminated the need to vegetate gold mine slimes deposits".[234] Interestingly out of 247 slimes dams and 95 sand dumps on the Witwatersrand, only 45 dumps had been surveyed for COMET readings by the time he took over, the bulk of which had been surveyed in 1981.[235] Nevertheless Marsden could not find any clients among Chamber member companies were willing to utilize the Unit's services, thus threatening its *raison d'étre*. Behind closed doors conservative Chamber members could state that it performed "no service to the mines, but rather was servicing the Government, and as such should be disbanded."[236]

Politics were also distracting members when following a few years of timid reform of petty apartheid and the introduction of the Tri-Cameral Parliament, the townships erupted in revolt. [237] Much of the Government's reform had been funded on the assumption of a permanently higher gold price. Although the gold price retreated rather dramatically and consistently from its 1980 highs over the next three years, it remained at sufficiently high levels to encourage further expansion in the gold sector.[238] However, the tightening of international sanctions against Pretoria which raised the cost of (foreign) borrowing for the country, together with rising state security and expenditure on the 'homelands' brought on inflation which in 1982/3 was amplified by drought. Caught by global stagnant demand for its products due to a poor global economic climate, the South African economy overall slid into recession in 1983.[239] By 1984 the country was in its most serious economic crisis since the Great Depression and continued political unrest and a volatile gold price made for an unsettling period for the sector. Distracted by political and economic uncertainty Chamber members made no real effort to rebuild the Unit, but in mid 1984 they could only agree that "for public relations reasons it was agreed that to disband the Vegetation Unit would be damaging to the industry and that the Vegetation Unit remain intact for the present."[240]

Shorn of all scientific expertise, the Unit was unable to provide new scientific or technological impulses to the sector in which it operated. Thereby the space was created not only for competitors to grow, but also for the Chamber's reliance on external specialists in this and related fields to rise. The most significant of these was an entrepreneurial academic, Professor Koos van Wyk based at Potchefstroom University. Van Wyk, had built up experience in roadside rehabilitation during the 1970s and in 1980 formalized his relationship with the Department of Transport into a longer-term research project. Working on various sites across the country, van Wyk's rehabilitation experiments were to reconfirm many of Cook's assumptions concerning the ability of grasses to establish and survive in disturbed soils and issues of erosion management. Based upon these experiments, van Wyk

championed a form of dryland rehabilitation which he came to believe would be of assistance to the mines. [241]

Marsden was nevertheless cautious when Koos van Wyk made an approach in mid-1983.[242] On November 15th 1983, a delegation from the Chamber visited the IEN at Potchefstroom "with a view to ascertaining whether the Chamber should commission the Institute to undertake research in the field of revegetation on its behalf."[243] After some discussion Marsden and van Wyk agreed that a pooling of knowledge would be beneficial and by the end of the year "a mutually agreed investigational programme was drawn up for implementation."[244] Of particular interest to Marsden's team was the prospect of better, more drought-tolerant *Eragrostis* varieties, which Brian Dawson was researching. Van Wyk's motivation in approaching the Chamber lay in the legal constraints he faced with respect to the 320 new *Eragrostis* varieties he claimed to have isolated, which he could not market commercially until they had been registered – a process likely to take a few years. By using these varieties in research trials commissioned by the Chamber, IEN could get around these restrictions in the short-term.[245] In 1984 the annual site visit by PCC and the Vegetation Unit Management Committee members was organised to visit the Potchefstroom grass trials as well as Chamber work, something that had not been done before.[246] The pilot trials began in January 1984 and from June 1984 van Wyk was also included on the circulation list for some papers to the PCC Sub-Committee and the Committee of Management of the Vegetation Unit.[247]

In the meantime, the mining industry was encountering some of the first hard questions about rehabilitation standards from regulators. 1983 had seen controversy over the closure and inadequate rehabilitation at Gencor subsidiary, asbestos miner Gefco, groundwater issues at Iscor and closure related queries at Phalaborwa. GP Badenhorst – was asking difficult questions to which the industry outside the Chamber of Mines had no clear answers. Then in 1984 the Maziska Slate Quarries closure attracted unfavourable attention from DME which approached consultants such as IEN for answers to these challenges.

Looking ahead Marsden also realised that with the rising gold price and operation of Anglo American's ERGO dump-retreatment company on the East Rand, the likelihood that tailings dumps (including the GME dumps) might be re-processed was steadily rising. Companies and the GME would therefore increasingly be less inclined to spend resources establishing vegetation on dumps whose removal could in the event of retreatment impose additional costs on their tailings retreatment operations. [248] Nevertheless the dump retreatment was not entirely without opportunity as various groups around such sites began to complain of the dust generated by the re-treatment operations.[249] Sadly for the Vegetation Unit, only Rand Mines owned up to one of its retreated dumps being a point source of dust and its Environmental Manager J D Wells was not about to let the Vegetation Unit conduct work on his sites.[250]

With the commercial fortunes of the Vegetation Unit in this difficult situation, the PCC focus shifted to water, where the Department proposed a series of amendments to the Water Act.[251] At the same time, research from the Water Research Commission showed very clearly the

total load of dissolved salts to the country's river systems from the gold mines exceeded that of the coal sector, with ERPM, ERGO and Sallies alone accounting for 150 000 tons of dissolved material per annum compared to about 100 000 for the total coal sector.[252] The industry also found itself worrying that the polluter pays principle – a by then widely applied concept in European environmental law – was being adopted by the South African authorities, particularly in respect to water. Unable to fault the principle, the PCC members after repeated debate accepted that "it was their responsibility to do something about it."[253]

In the meantime van Wyk, who was better at publicity than Marsden, was gaining some publicity from the collaboration and some of the Afrikaans mining houses and the parastatals such as Iscor had approached him about advice on the rehabilitation of sites. Iscor in early 1985 informed the Chamber that it would "draw up its own plans for rehabilitation which would be submitted to the Inspectorate for approval."[254] Concerned that this would create a difficult situation between himself and the Vegetation Unit, van Wyk suggested to Marsden "that mining houses should co-ordinate work of this nature through this Sub-Committee."[255] This approach stirred up a bee's nest; suddenly the PCC members were concerned that "the mining houses were overlooking the Chamber's expertise … [and recommended that] the Vegetation Unit consider establishing a consulting service to enable more use to be made of its expertise."[256] In the end there was little they could do, Iscor for political-ethnic reasons retained van Wyk's services for their Grootegeluk and Sishen operations[257]

By 1985, the relationship between the IEN and the Chamber's Vegetation Unit had evolved to a situation where van Wyk felt comfortable leveraging off the relationship by organizing a conference on rehabilitation of disturbed land. He was now receiving some financial support from his own University for the research project whose objectives he described as ascertaining whether a greater assortment of plant varieties could be established on mine dumps than is the case at present. If so, he argued, then through the identification and adaptation of more indigenous plants, a more sustainable solution could be arrived at.[258] The timing of the conference was critical to IEN's subsequent work, under the leadership of Marsden, the Vegetation Unit was still effectively limited to GME and Water Affairs work.[259]. Into the gap created had stepped individuals and a number of contractor/consulting firms such as Fraser Alexander and SRK had also begun to investigate the market opportunities. Tougher environmental legislation was winding its way through the legislative development process. Van Wyk was thus able to get 163 representatives of the Department of Mines, research institutions, mining companies and mining industry bodies to attend.[260]

For van Wyk and the IEN, the event would prove a great marketing success as M Marsden, with his taciturn nature, did not utilize the conference as a means of re-asserting the Vegetation Unit's prominence. Instead he sent conflicting messages, asserting one the one hand that "the development of the ETCOM erosion tester, has eliminated the need to vegetate gold mine slime deposit slopes," at a time when the Chamber itself was already moving away from the technology. At the same time he set out "for completeness, the procedure previously employed for grassing." He further weakened his case by stating that "the basic research on re-vegetation of sand and slimes residue deposits was undertaken by the Chamber of Mines

between 15 and 25 years ago," and "since then only relatively minor changes have been made in the techniques developed.[261]

Koos van Wyk, however, believed he could change this by developing a competitive edge over the Vegetation Unit technique. [262] Building on the roadside rehabilitation experience across the country van Wyk was able to convince the management of Anglo's Gold & Uranium Division Western Deep Levels Mine near Carletonville to allow him to trial his dryland method on the NW slope of the WDL #3 dump near the northwestern border of the mine lease. Unfortunately a misunderstanding during this first trial in mid-1988 led to a fundamental deterioration in relations between IEN and Vegetation Unit, with van Wyk being accused –most likely incorrectly – of helping himself to Vegetation Unit consumables from a neighbouring site. [263] The incident escalated and permanently poisoned the relationship between the two individuals in charge of the respective organizations. As a result co-operation between the two organizations dwindled.[264] The Vegetation Unit, while larger at the labourer level was left with its focus on Government work while Chamber member companies looked to its competitors or began building in-house expertise.

By the close of the 1980s, the Chamber of Mines Vegetation unit had implicitly conceded its loss of pre-eminence and Chamber members seeking to trim Chamber budgets began exploring privatisation options for the Unit which would be realised in the early 1990s. By the late 1980s it was clear that the Vegetation Unit had become just one of a group, its key competitive advantage the association with the Chamber itself. For its managers the decline must have been doubly hard due to the increasingly rapid advances of environmental legislation during the decade, as manifested by the formation of a Department of Environmental Affairs and the rising tide of pro-environmental sentiment among the South African public at large. As the Botha administration gave way to De Klerk and politics and the economy began opening up, a new force in mine waste rehabilitation in the form of global environmental consultancies began establishing itself in South Africa. By the early 1990s, IEN had itself spawned a number of new operators. Within two years of the passage of the Minerals Act of 1991, the Chamber of Mines Vegetation Unit was privatised and just one of many private concerns seeking to sell expertise for the management of dust- and water-borne pollution off the mine waste residues of the South African gold mining sector

**Summary and Conclusion**

For most of its existence the South African mining industry and the Chamber of Mines of South Africa had remained ahead of legislative requirements in their initially ad hoc , and later more formal dust control efforts with respect to their tailings dams. When following decades of ad hoc experimentation, the mining companies, in the 1950s, sought to head off tighter legislation by combining their efforts into an industry initiative known as the Chamber of Mines Vegetation Unit. Well resourced, the Unit conducted large-scale experiments to develop a seemingly successful methodology. By 1964/5, this methodology was prematurely deemed mature due to the industry's need to be seen as active in this field. Thus the focus of the Vegetation Unit shifted to its application across all South African mine wastes. After that, the Unit's ability to advance the methodology scientifically collapsed as the focus shifted to

demonstrating large-scale in-field application. Structurally divorced from academic research, the retirement of the Unit's dynamic manager left it on 'auto-pilot', unable to challenge alternative rehabilitation approaches'' proposed by outsiders who subsequently seduced the industry with the promise of cheaper, un-scientific methods. Critical to this process was the composition of the Committee that oversaw the operations of the Vegetation Unit which was comprised exclusively of engineers and administrators. Obsessed with the price-taking nature of their sector until the end of the gold standard in 1969, the members of this Committee failed to engage actively with the Manager of the Unit in a way that would have resourced him sufficiently to continue grassing for immediate dust suppression while at the same time refining the methodology through fundamental research. By the mid-1970s the rising gold price not only allowed the Chamber members to feel sufficiently confident in the industry's fortunes to fund large-scale strategic research, but at the same time curtailed the value of such research by making tailings dump retreatment profitable. For the next 20 years this threat of retreatment would suppress the tailings grassing market.

That the industry still needed to do something about dust and water pollution was accepted. However in the context of the potentially open-ended costs associated with grassing, it was perhaps inevitable that the industry would fall prey to the promises - however un-proven – of a new and cheaper alternative. This alternative – promoted by Fred Cartwright as the COMET concept – was pursued to the detriment of in-house grassing expertise and capacity. Thus when the COMET concept was exposed as a chimera due to the principled opposition of the Governmnet Mining Engineer, the Chamber was left without grassing skills at a time (early 1980s) when nascent environmental concerns were gaining importance in social and political spheres. This opened the previously monopolistic mine waste rehabilitation field up to commercial competitors. The industry's failing ultimately lay in its unwillingness to broaden its scientific capacity and sustain it. Instead its over-reliance on key individuals made its work disproportionately vulnerable. It would never again gain pre-eminence scientifically and commercially and the Unit was privatised in the early 1990s. As this privatisation coincided with the broader opening up of South Africa's society and economy after the unbanning of the ANC, there would never again be an entity (commercial or otherwise) that would dominate the rehabilitation sector as the Chamber's Vegetation Unit had done in the South African industry.

Note on Sources: As this research was based to a large degree upon Chamber of Mines of South Africa Archival material, references to particular file series, such as VUAF, are made. These relate to the location and theme of the files series. The archival material relating to the Vegetation Unit was partially retained by the Chamber of Mines and partially sent off with the other assets of the privatised Unit, where for commercial reasons it was not properly archived.

[1] The research for this paper was done as part of the research for a PhD at the Department of Botany at the University of the Witwatersrand which is due to be completed in 2012.

[2] For more details on the early gold rushes see A.P. Cartwright Valley of Gold Howard Timmins Cape Town 1980. / A. P. Cartwright The Gold Miners Purnell & Sons (SA) Pty Ltd ; Cape Town & Johannesburg 1962, pp. 4-24. / Owen Letcher The Gold Mines of Southern Africa ; Waterloo & Sons ; 1936, pp.27-53. / Union of

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[3] J R F Handley Historic Overview of the Witwatersrand Goldfields Handley ; Howick (RSA); 2004, p.126-139.
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[5] For fuller details of the metallurgical process see for example R J Adamson Gold Metallurgy in South Africa printed by Cape and Transvaal Printers for Chamber of Mines of South Africa ; Cape Town ; 1972
[6] Handley Historic Overview of the Witwatersrand Goldfields 2004 pp.139-143. / see also Adamson, Gold Metallurgy in South Africa
[7] John J Stephens Fuelling the Empire: South Africa's Gold and the Road to War J Wiley ; London ; 2003 ; p.94, p.148.
[8] R J Adamson Gold Metallurgy in South Africa printed by Cape and Transvaal Printers for Chamber of Mines of South Africa ; Cape Town ; 1972 p152.
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[12] R J Adamson Gold Metallurgy in South Africa printed by Cape and Transvaal Printers for Chamber of Mines of South Africa ; Cape Town ; 1972 p.159.
[13] R J Adamson Gold Metallurgy in South Africa printed by Cape and Transvaal Printers for Chamber of Mines of South Africa ; Cape Town ; 1972 pp.159-172. / Chamber of Mines of South Africa Code of Practice for the construction of slimes dams and the condition in which they should be left at the time of closure Chamber of Mines of South Africa ; Johannesburg ; 1968.
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[15] R J Adamson Gold Metallurgy in South Africa printed by Cape and Transvaal Printers for Chamber of Mines of South Africa ; Cape Town ; 1972 p.154/5.
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[35] During 2008 an Honours student at the Department of Botany, Joseph Chauke was commissioned to survey the following newspapers for references. The research contract was structured in a way to incentivise the identification of such references – i.e. each identified reference would attract a finders fee. The Star and the Rand Daily Mail as well as the Magazine Dum were surveyed without success.Equally the public correspondence file of the Chamber of Mines, which contains newspaper clippings and letters from the public is devoid of this issue.
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[44] Mrost (1973) p.3-4 / D.D Marsden 'An Outline of the History of the Chamber of Mines Vegetation Unit and its Current Techniques' unpublished memorandum ; Chamber of Mines ; 21 January 1986 p.2../ Thatcher p.23.
[45] The oxidization of the pyrites gives rise to the presence of sulphuric acid and high dissolved solid content in both mine drainage and in seepage occurring in residue disposal areas and structures. In the gold ores of the Witwatersrand formation it constitutes up to 3% of the mined product. The oxidization of pyrite occurs in three principal stages, the first two involving oxidization and the third hydrolysis.

$2FeS_2 + 7O_2 + 2H_2O = 2FeSO4 + 2H_2SO4$

$4FeSO4 + 2H_2SO4 + O_2 = 2Fe2(SO4)3 + 2H_2O$

These two processes are chemical reactions that can take place in the absence of bacteria although their presence probably accelerates the rate of reaction. Oxidizing bacteria are however necessary to promote an appreciable rate for the second reaction. Both processes are oxidation reactions requiring aerobic conditions but the final reaction;

3. $3Fe_2(SO4)3 + 12H_2O = 2HFe3(SO4)2(OH)6 + 5\ H_2SO4$

which is the most acid forming, is a hydolysis reaction that can take place anaerobically, usually over a considerable period of time. / V P Evangelou 'Pyrite Chemistry: The Key for Abatement of Acid Mine Drainage' in Walter Geller, Helmut klapper & Wim Salomons (editors) Acidic Mining Lakes: Acid Mine Drainage, Limnology and Reclamation Springer ; Berlin ; 1998 ; pp.197-206.. / J O Kempe 'Review of Water Pollution problems and control Strategies in the South African Mining Industry' paper presented at the 11th International IAWPR Conference and Symposium held in Cape Town and Pretoria during 1982., p.10. / / J G Thompson 'Acid Mine Waters in South Africa and their amelioration' Water SA Vol 6, No.3 , July 1980.

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[51] Chamber of Mines Steering Committee on Investigations into Mine Effluents 'Minutes of Meeting of the Steering Committee on Investigations into Mine Effluents held in the Chamber of Mines Building on Friday, 18th November, 1955 at 9:30am' pp.5- 7. / D.D Marsden 'An Outline of the History of the Chamber of Mines Vegetation Unit and its Current Techniques' unpublished memorandum ; Chamber of Mines ; 21 January 1986. pp.4-5. / Chamber of Mines Steering Committee on Investigations into Mine Effluents 'Minutes of Meeting of the Steering Committee on Investigations into Mine Effluents held in the Chamber of Mines Building on Tuesday, 12th April, 1955 at 2:30pm' p. 3.

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[57] Interview B Cook 26 January 2006/ D Chernik "The Promotion of a Vegetative Cover on Mine Slimes Dams and Sand Dumps: Contributions to discussions' W H Cook JSAIMM vol.60 July 1960 p.751
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[93] Transvaal and Orange Free State Chamber of Mines Technical Advisory Committee Minutes of the Meeting of the Technical Advisory Committee held in the Chamber of Mines Building on Tuesday, 21st January, 1964, at 9:30am extract 'Vegetation Unit' VUAF - 38

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Committee, Technical Advisory Committee T.A.C. Circular No.65/67 'Air Pollution Act: Establishment of Vegetation on Sand Dumps and Slimes Dams' dated 20th March 1967. VUAF-38b

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[100] Transvaal and Orange free State Chamber of Mines Gold Producers Committee Minutes of meeting of the Taxation Sub-Committee held on 21st February, 1964, in the Chamber of Mines Building, extract 'Atmospheric Pollution Prevention Bill' p.1. - VUAF – 38. / Transvaal and Orange Free State Chamber of Mines Memorandum from the Legal Department 'Atmospheric and water Pollution from Mine Dumps' dated 25th November, 1965 p.9. attachment to Transvaal and Orange Free State Chamber of Mines Gold Producer's Committee, Technical Advisory Committee T.A.C. Circular No.65/67 'Air Pollution Act: Establishment of Vegetation on Sand Dumps and Slimes Dams' dated 20th March 1967. VUAF-38b / Transvaal and Orange Free State Chamber of Mines Memorandum from the Manager to the Gold Producers Committee 'Atmospheric Pollution Prevention Act: Dust Nuisance from Sand dumps and Slimes Dams dated 11th March 1966 p.7. attachment to Transvaal and Orange Free State Chamber of Mines Gold Producer's Committee, Technical Advisory Committee T.A.C. Circular No.65/67 'Air Pollution Act: Establishment of Vegetation on Sand Dumps and Slimes Dams' dated 20th March 1967. VUAF-38b / Transvaal and Orange Free State Chamber of Mines Gold Producer's Committee, Technical Advisory Committee T.A.C. Circular No.65/67 'Air Pollution Act: Establishment of Vegetation on Sand Dumps and Slimes Dams' dated 20th March 1967. p.1. VUAF-38b. / Transvaal and orange Free State Chamber of Mines Seventy-Sixth Annual report for the year 1965 Chamber of Mines ; Johannesburg ; 1966, p. 41.

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[102] Chamber of Mines Services (Pty) Ltd Memorandum to A B Daneel Technical Advisor 'Vegetation Unit' dated 30th of May, 1967, VUAF-38b.

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[104] Chamber of Mines of South Africa, Seventy-Ninth Annual Report: 1968 Chamber of Mines ; Johannesburg ; 1969, p.34. / Chamber of Mines Services (Pty) Ltd Vegetation Unit Monthly Report December 1967, p.4-5, VUAF-38b.

[105] Chamber of Mines of South Africa Vegetation Unit Committee of Management Minutes of the Meeting of the Committee of Management of the Vegetation Unit held in Room 601, Chamber of mines Building, on Friday, 23rd May, 1969, at 2;30pm, p.3. VUAF-13e

[106] Interview with former Vegetation Unit foreman Robbie Smith, January 5th, 2010.

[107] Chamber of Mines Services (Pty) Ltd Vegetation Unit: Report on Condition of Vegetation on Completed Projects at September 16th , 1968 attachment to Chamber of Mines of South Africa Committee of Management Vegetation Unit Circular No.28/68 'Manager's Monthly Report August, 1968' dated 23rd September, 1968.

[108] Chamber of Mines of South Africa Vegetation Unit Committee of Management Minutes of the Meeting of the Committee of Management of the Vegetation Unit held in Room 601, Chamber of Mines Building, on Thursday, 28th May, 1970, at 2;30pm, p.2. VUAF-13e

[109] Chamber of Mines of South Africa Research Organization Physical Science Laboratory S J Vorster and J D Greig 'Project No.11A/512/67 Investigation of Problems arising in the Vegetation of Slimes Dams and Dumps: Investigation into failure of Vegetation at Consolidated Main Reef Mines and estate, Ltd' Attachment to Chamber of mines of South Africa Committee of management Vegetation unit Circular No.26/69 'Research Report on Investigations into the Failure of Vegetation at C.M.R.' dated 26th August, 1969.p.2., VUAF-2c.

[110] Chamber of Mines of South Africa Vegetation Unit Committee of Management Extract from Minutes of the meeting of the Committee of Management of the Vegetation Unit held in the Chamber of Mines Building on Thursday , 28th March, 1968 at 2:30. p.3.' VUAF-13e. / Chamber of Mines of South Africa Vegetation Unit Committee of Management Minutes of the meeting of the Committee of Management of the Vegetation Unit held in the Chamber of Mines Building on Thursday , 27th June, 1968 at 2,30pm, p.2., VUAF-13e.

[111] Interview with former Vegetation Unit foreman Robbie Smith, January 5th, 2010.

[112] Interview with former Vegetation Unit foreman Robbie Smith, January 5th, 2010.

[113] The content of this section is based upon the manager's Monthly Reports contained in VUAF-2c files.

[114] Chamber of Mines Services (Pty) Ltd Vegetation Unit: Report on Condition of Vegetation on Completed Projects at September 16th , 1968 attachment to Chamber of Mines of South Africa Committee of Management Vegetation Unit Circular No.28/68 'Manager's Monthly Report August, 1968' dated 23rd September, 1968.
[115] Chamber of Mines of South Africa Vegetation Unit Committee of Management Minutes of the Meeting of the Committee of Management of the Vegetation Unit held in Room 601, Chamber of Mines Building, on Thursday, 24th July, 1969, at 2;30pm, p.2. VUAF-13e
[116] Chamber of Mines of South Africa Vegetation Unit Committee of Management Minutes of the Meeting of the Committee of Management of the Vegetation Unit held in Room 601, Chamber of Mines Building, on Thursday, 28th August, 1969, at 2;30pm, p.2. VUAF-13e.
[117] Chamber of Mines of South Africa Committee of Management Vegetation Unit Circular No.8/69 'Springs Mines Limited: Certificate of Closure Requirements of the department of Water Affairs' dated 27th February 1969, p.2.
[118] Chamber of Mines of South Africa Vegetation Unit Committee of Management Minutes of the Meeting of the Committee of Management of the Vegetation Unit held in Room 601, Chamber of mines Building, on Friday, 23rd May, 1969, at 2;30pm, p.3. VUAF-13e / see for example Chamber of Mines of South Africa Vegetation Unit Committee of Management Minutes of the Meeting of the Committee of Management of the Vegetation Unit held in Room 608, Chamber of Mines Building on Thursday , 3rd December, 1970, at 2:30, p.3., VUAF-13e. / Chamber of Mines Services (Pty) Ltd Letter to the Regional Mining Engineer, Ministry of Mines Causeway, Bulawayo 'Coverage of Mine Dumps and Slimes Dams' dated 20th January 1971, VUAF-38.
[119] Chamber of Mines Services (Pty) ltd Letter from W H Cook to Technical Advisor Chamber of Mines 'Stabilisation by Vegetation of Evaporation Dam Wall Coalbrook Colliery' dated 17th November, 1971.p.3., VUAF-38. / Chamber of Mines Services (Pty) ltd Letter from the secretaries to the Manager, Clydesdale (Tvl) Collieries Ltd, Coalbrook Colliery 'Stabilisation of Evaporation Dam Wall by Vegetation' dated 30th November, 1971, p.3, VUAF. / Interview Eric Heyman, Environmental Manager AngloPlatinum 1996-2008, 28 May, 2008 / Letter Rustenburg Platinum Mines Ltd. to the Secretaries Chamber of Mines Services (Pty) Ltd 'Grassing of Slimes Dam' dated 19th December, 1970, VUAF-38.
[120] Vaal Reefs Exploration and mining Company Ltd Letter from A H Arnold manager West to the General Manager Chamber of Mines vegetation unit 'Slimes Dam Vegetation' dated 22nd October , 1971, VUAF-38.
[121] Chamber of mines Services (Pty) Ltd Letter from the secretaries of the Chamber of Mines Services (Pty) Ltd to the Consulting Mechanical and Electrical Engineer, Gold Fields of South Africa 'Protection f Slimes Dams and Sand Dumps Elandsforntein Estate Company Ltd and G.F. Industrial Property Company Ltd' dated 15th November, 1971., attachments, VUAF-38.
[122] Chamber of Mines of South Africa Vegetation Unit Committee of Management Minutes of the Meeting of the Committee of Management of the Vegetation Unit held in Room 601, Chamber of Mines Building on Thursday , 4th February, 1971, at 2:30, p.3., VUAF-13e..
[123] Chamber of Mines of South Africa Vegetation Unit Committee of Management Minutes of the Meeting of the Committee of Management of the Vegetation Unit held in Room 601, Chamber of Mines Building on Thursday , 4th February, 1971, at 2:30, p.1-3, VUAF-13e. / Chamber of Mines of South Africa Vegetation Unit Committee of Management Minutes of the Meeting of the Committee of Management of the Vegetation Unit held in Room 601, Chamber of Mines Building on Thursday , 4th March, 1971, at 2:30, p.3., VUAF-13e.
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[129] R W Johnson How Long will South Africa Survive? p.87 / John Lang Bullion Johannesburg: Men, Mines and the Challenge of Conflict Jonathan Ball Publishers ; Johannesburg pp.429-430
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[132] Chamber of Mines Services (Pty) Ltd. Memorandum for KM Beaton from Company Secretary ' Vegetation Unit – Committee of Management air and Water Pollution Sub-Committee: Circular Recipient Lists' dated 4th March 1975. VUAF-5a / Chamber of Mines of South Africa Minutes of the Meeting of the Committee of Management of the Vegetation Unit and of the Pollution Control Sub-Committee held at 10:00 am on Wednesday 13th of August, 1975, in Room 607, of the Chamber of Mines Building' Pollution Control Sub-Committee Circular 21/75 dated 2nd October, 1975. p.2. /

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[142] Kempe (1982) p.29.

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[148] Chamber of Mines of South Africa Pollution Control Sub-Committee Circular 38/76 'Research and Laboratory Report for the Quarter ended 30 June, 1976' dated 11th August 1976 p.2. / Chamber of Mines of South Africa Minutes of the Meeting of the Committee of Management of the Vegetation Unit and of the Pollution Control Sub-Committee held at 9:30am am on Wednesday 24th of November 1976, in Room 607, of the Chamber of Mines Building' p.2.

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[153] B J Cook 'The Rehabilitation of residue Deposits as practiced by mining companies in the Rand mines Group' PU-NTC Institute for Ecological Research 'Revegetation Symposium for Mining Groups which was held on the campus of the Potchefstroom University for CHE on 29 and 30 April 1985, p.68.

[154] B J Cook 'The Rehabilitation of residue Deposits as practiced by Mining companies in the Rand mines Group' PU-NTC Institute for Ecological Research 'Revegetation Symposium for mining Groups which was held on the campus of the Potchefstroom University for CHE on 29 and 30 April 1985, p.68-9.

[155] Interview John Easton 22nd November 2006

[156] Chamber of Mines of South Africa Minutes of the Meeting of the Committee of Management of the Vegetation Unit and of the Pollution Control Sub-Committee held at 9:30 am on Wednesday 23th of February, 1977, in Room 607, of the Chamber of Mines Building' p.2.

[157] Unsigned memorandum not dated 'Pollution Control Laboratory' taken from Manager Files Box probably written by or for FD Cartwright, 1978/9, p.1.

[158] Handwritten notes of the discussion dated 13 September 1977 unsigned from Manager's Files box.

[159] Pollution Control Sub-Committee Circular 1/77 dated 18th February 1977 Research and Laboratory report for the period ended 31st December 1976. / Pollution Control Sub-Committee Circular 8/78 'Pollution Control Section: Research and Laboratory report: quarter ended 31st December 1977, dated 9th February 1978. /

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[161] Pollution Control Sub-Committee Circular 34/77 'Pollution Control Section: Research and Laboratory report: quarter ended 30th September 1977, dated 10th November 1977.

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[163] M van der Westhuizen & J Easton-Groves 'Binding the dust' Nuclear Archive Magazine July 1979 p.23.

[164] Chamber of Mines of South Africa Minutes of the Meeting of the Committee of Management of the Vegetation unit and of the Pollution Control Sub-Committee held at 9:30am on Wednesday 29th of November 1978, in Room 606 of the Chamber of Mines Building, p.9.

[165] Interview John Easton, 22 November 2006.

[166] Interview John Easton, 22 November 2006. / Interview Brian Cook 26 January 2006 / Pollution Control Sub-Committee Circular 24/77 'Pollution Control Section: Research and laboratory Report: Quarter ended 30th of June, 1977 p. 2. / F Cartwright Memorandum to Technical Advisor 'The Use of retired Residue deposits upon which to deposit other urban and trade wastes' included in Chamber of mines of South Africa Pollution Control Sub-Committee Circular No.30/79 "Research into the Prevention of Pollution from mine dumps' dated 23rd May 1979. p.2.

[167] Chamber of Mines of South Africa Memorandum to Mr G H Grange, Technical Advisor 'Vegetation Unit: Proposed Re-organisation and Expansion of Office Organisation at No 16 Shaft, Crown Mines.' From E de J van Zyl Chief Company secretary, Chamber of Mines dated 6th October 1978. included in Chamber of Mines of South Africa Pollution Control Sub-Committee Circular 60/78 'Vegetation Unit: Proposed Re-organisation and Expansion of Office Organisation at No 16 Shaft, Crown Mines' dated 6th November 1978.

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[170]. Chamber of Mines of South Africa Minutes of the Meeting of the Committee of Management of the Vegetation Unit and of the Pollution Control Sub-Committee held at 9:30 am on Wednesday 29th of November, 1978, in Room 606, of the Chamber of Mines Building' pp.5-6. /Interview John Easton, 22 November 2006

[171] Lipton Capitalism & Apartheid p. 124
[172] Lipton Capitalism & Apartheid pp. 123-124
[173] Chamber of Mines of South Africa Memorandum from F D Cartwright to the Technical Advisor 'Reorganization of the Pollution Control Section' dated 3rd April, 1979.
[174] Letter from B J Turner Adm. Secretary Vegetation Unit to Chamber Technical Advisor dated 6th November, 1978 / Letter by T I Petersen, to Chamber General Manager 'Labour Unrest: Vegetation st Balmoral Mine dated 2nd October 1978
[175] Letter from Witwatersrand Gold Mining Company Ltd to Chamber of Mines dated 18th December, 1978 in Manager's Files archive box.
[176] Chamber of Mines of South Africa Minutes of the Meetings of the Committee of management of the Vegetation Unit and of the Pollution Control Sub-Committee held at 9.30am on Wednesday, 28th of November, 1979, in Room 606 of the Chamber of Mines Building p. 4 taken from Minute book no Circular reference.
[177] Chamber of Mines of South Africa Vegetation Unit Planning Committee Record of Meeting held on Friday, 26th August, 1977 at 10;00 am at the Vegetation Unit Headquarters p21 / Chamber of Mines of South Africa Vegetation Unit Planning Committee Record of Meeting held on 6th October 1977, at 2:30 pm in Rm 604 Chamber of Mines Building, p.2 / Chamber of Mines of South Africa Vegetation Unit Planning Committee Record of Meeting held on 61st May 1978, at 2:30 pm in Rm 608 Chamber of Mines Building, p. 3.
[178] Chamber of Mines of South Africa, Committee of Management of the Vegetation Unit and Pollution Control Sub-Committee, Meeting of the Committee of Management of the Vegetation Unit and the Pollution Control Sub-Committee held at 2:15pm on Wednesday 30th May, 1979 at Impala Platinum Refinery, Springs.p.9.
[179] F.D. Cartwright 'Some Seventy years in the Shrouding of mining Residue Deposits for Environmental Protection' Water Science Technology Vol. 15 1983 pp.88-89.
[180] Cartwright (1983) p. 88.
[181] Chamber of Mines of South Africa Pollution Control Sub-Committee Circular No.36/78 'Chamber of Mines of South Africa: Handbook of Guidelines for Environmental protection – Volume 1/1978 – Protection of Tailings Deposits Against Water and Wind erosion' dated 1st August 1978 p.1
[182] Chamber of Mines of South Africa Pollution Control Committee Circular No. 4/79 'Pollution Control Section Research and Laboratory Report: Quarter ended 31st December 1978' dated 30th January 1979. p.2.
[183] Chamber of Mines of South Africa Pollution Control Circular No. 25/79 'Pollution Control Section: Research and Laboratory Report: Quarter ended 31st March 1979' dated 11th May, 1979. p.2-3.
[184] Interview John Easton, 22 November 2006. / Interview Oskar Steffen 21 November 2008./ Interview Professor Jeff Blight 1st February 2009.
[185] text from a submission made by Cartwright to the PCC for consideration with respect for inclusion and revision of the Vol1/1979 Guidelines, appended to Chamber of Mines Pollution Control Sub-Committee Circular No. 19/83 'Handbooks of guidelines for Environmental Protection' dated 3rd August 1983 p.2-3.
[186] Chamber of Mines of South Africa, Committee of Management of the Vegetation Unit and Pollution Control Sub-Committee, Meeting of the Committee of Management of the Vegetation Unit and the Pollution Control Sub-Committee held at 9:30am on Wednesday 23rd August, 1979 ain Room 606 of the Chamber of Mines Building' .p.1.
[187] Chamber of Mines of South Africa, Committee of Management of the Vegetation Unit and Pollution Control Sub-Committee, Meeting of the Committee of Management of the Vegetation Unit and the Pollution Control Sub-Committee held at 2:15pm on Wednesday 30th May, 1979 at Impala Platinum Refinery, Springs.p.2. / Chamber of Mines of South Africa Pollution Control Circular No. 25/79 'Pollution Control Section: Research and Laboratory Report: Quarter ended 31st March 1979' dated 11th May, 1979. p.1-3.
[188] Chamber of Mines of South Africa Pollution Control Circular No. 25/79 'Pollution Control Section: Research and Laboratory Report: Quarter ended 31st March 1979' dated 11th May, 1979. p.1-3.
[189] There is no reference to a vigourous debate being mounted concerning this fundamental change in approach in the minutes of the relevant Chamber Sub-Committee, other than an occasional *reference to the obvious benefits*.. Chamber of Mines of South Africa, Committee of Management of the vegetation Unit and pollution Control Sub-Committee Minutes 1978 -1982 various dates.
[190] Chamber of Mines of South Africa, Committee of Management of the Vegetation Unit and Pollution Control Sub-Committee, Meeting of the Committee of Management of the Vegetation Unit and the Pollution Control Sub-Committee held at 9:30am on Wednesday 23rd August, 1979 at in Room 606 of the Chamber of Mines Building, p.2.
[191] Internal Chamber of Mines Memorandum to Mr F.D. Cartwright Pollution Control Officer 'The Future of Reclamation: Grassing and other Methods' written and sent by J Easton-Groves Scientific Officer Pollution Control Section ; dated May 7th, 1979. p.1.
[192] Chamber of Mines of South Africa, Committee of Management of the Vegetation Unit and Pollution Control Sub-Committee, Meeting of the Committee of Management of the Vegetation Unit and the Pollution Control

Sub-Committee held at 9:30am on Wednesday 23rd August, 1979 at in Room 606 of the Chamber of Mines Building, p.5. / Interview John Easton-Groves 22nd November 2006.
[193] Interview John Easton, 22 November 2006. / Chamber of Mines of South Africa, Committee of Management of the Vegetation Unit and Pollution Control Sub-Committee, Meeting of the Committee of Management of the Vegetation Unit and the Pollution Control Sub-Committee held at 9:30am on Wednesday 23rd August, 1979 at in Room 606 of the Chamber of Mines Building, p.3.
[194] Second Submission to the Water Research Commission concerning Water Pollution Problems in the Mining Industry p.5. in Chamber of Mines of South Africa Letter to the Chairman and CEO, Water Research Commission 'Hydrological Effects of Total Extraction' dated 12th July, 1979, p.4.
[195]Second Submission to the Water Research Commission concerning Water Pollution Problems in the Mining Industry p.5. in Chamber of Mines of South Africa Letter to the Chairman and CEO, Water Research Commission 'Hydrological Effects of Total Extraction' dated 12th July, 1979, p.4.
[196] South African Turf Research Organization, 'Proceedings: South African Turf Research Symposium held at Burgerspark Hotel on Tuesday June 5', 1979 p.8.
[197] Chamber of Mines of South Africa Vegetation unit Planning Committee Record of Meeting held at 2:30pm on Monday, 1st May 1978 in Rm 608 of the Chamber of Mines Building, Johannesburg p.1.
[198] for this correspondence see addendums to Chamber of Mines Pollution Control Sub-Committee Circular No.61/79 'Atmospheric Pollution Prevention Act, 1965:Updating of Dust Fund' dated 22nd November 1979.
[199] for this correspondence see addendums to Chamber of Mines Pollution Control Sub-Committee Circular No.61/79 'Atmospheric Pollution Prevention Act, 1965:Updating of Dust Fund' dated 22nd November 1979.
[200] Chamber of Mines of South Africa Minutes of the Meetings of the Committee of Management of the Vegetation Unit and of the Pollution Control Sub-Committee held at 9.30am on Wednesday, 28th of November, 1979, in Room 606 of the Chamber of Mines Building p. 6 taken from Minute book no Circular reference., p.7.
[201] Chamber of Mines of South Africa Minutes of the Meetings of the Committee of Management of the Vegetation Unit and of the Pollution Control Sub-Committee held at 9.30am on Wednesday, 28th of November, 1979, in Room 606 of the Chamber of Mines Building p. 6 taken from Minute book no Circular reference. p.7-9
[202] Chamber of Mines of South Africa Minutes of the Meetings of the Committee of Management of the Vegetation Unit and of the Pollution Control Sub-Committee held at 9.30am on Wednesday, 28th of November, 1979, in Room 606 of the Chamber of Mines Building p. 6 taken from Minute book no Circular reference. p.7-9
[203]Chamber of Mines Letter to the Government Mining Engineer 'Atmospheric Pollution Prevention Act 1965:Updating of Dust Fund' dated 10th March 1980 appended to Pollution Control Sub-Committee Circular No.13/80 dated 15th April, 1980 p.2.
[204] Chamber of Mines Letter to the Government Mining Engineer 'Atmospheric Pollution Prevention Act 1965:Updating of Dust Fund' dated 10th March 1980 appended to Pollution Control Sub-Committee Circular No.13/80 dated 15th April, 1980 p.3
[205] Chamber of Mines Letter to the Government Mining Engineer 'Atmospheric Pollution Prevention Act 1965:Updating of Dust Fund' dated 10th March 1980 appended to Pollution Control Sub-Committee Circular No.13/80 dated 15th April, 1980 p..3
[206] Chamber of Mines Letter to the Government Mining Engineer 'Atmospheric Pollution Prevention Act 1965:Updating of Dust Fund' dated 10th March 1980 appended to Pollution Control Sub-Committee Circular No.13/80 dated 15th April, 1980 p..3 / also Pollution Control Sub-Committee Circular No.13/80 Atmospheric Pollution Prevention Act, 1965: Updating of Dust Funds' dated 15th April, 1980 p.1.
[207] Letter by Government Mining Engineer to Chamber of Mines 'Atmospheric Pollution Prevention Act, 1965: Updating of Dust Funds' dated 31 March 1980 appended to Pollution Control Sub-Committee Circular No.13/80 Atmospheric Pollution Prevention Act, 1965: Updating of Dust Funds' dated 15th April, 1980 p.1.
[208] Chamber of Mines of South Africa Minutes of the Meetings of the Committee of management of the Vegetation Unit and of the Pollution Control Sub-Committee held at 9.30am on Wednesday, 20th of August, 1980, in Room 607 of the Chamber of Mines Building taken from Minute book no Circular reference.
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[232] Chamber of Mines of South Africa Ninety-Fourth Annual Report for the year 1983 Chamber of Mines ; Johannesburg ; 1983 , p.65
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