UNIVERSITY OF THE WITWATERSRAND FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING

OPTIMAL YIELD AND CUT DENSITY

PREDICTION OF SEMI SOFT COKING COAL AND POWERSTATION COAL IN THE WATERBERG COALFIELD, LIMPOPO PROVINCE.

A dissertation submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science in Engineering.

By Leon Roux

Johannesburg 2011

DECLARATION

I declare that this dissertation is my own unaided work. It is being submitted to the degree of Master of Science to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

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(Signature of candidate)

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ABSTRACT

In a coal mining environment it is often difficult to relate the coal wash table data and analysis obtained from exploration drill core with the run of mine material being processed in beneficiation plants. This also affects the predicted yields, budgets and the resource and reserve determinations. The aim of this study is to determine whether a technique can be developed whereby a more accurate relationship between the exploration results used for the modelling, resource and reserve calculations and budgeting can be reconciled with the beneficiation results of products extracted from the resource. In a multi-seam and multi-product environment the problem of obtaining products at various different specifications for differing markets is exacerbated. Most product specifications are linked to the beneficiation environment, thus the need to determine relationships between these properties and the final products is tantamount to success.

Fortunately one of the less obscure properties is the ash content of the coal. To this a host of other specifications with regard to other impurities, such as sulphur or phosphorous content, may be added, depending on the application of the end product.

The *physical and mechanical properties* of coal however are the most important in the initial stages of the beneficiation process. Here *density and particle size* distribution play a major role, since, no matter which process is used in recovering various products, *density separation* is the underlying mechanism utilized whether it is by jig, drum, cyclones or flotation.

Coal plies and particles have different *relative densities*, determined by maceral composition, rank, mineral content and porosity. The *physical parameters* of coal are mostly controlled by moisture, volatile content (in terms of aliphatic or aromatic hydrocarbons), ash and carbon content which inadvertently have an effect on the *overall density of the raw coal*. Since the majority of products required are initially specified at specific ash content, the *probable relationship of ash to density* would be critical in solving the greater majority of associated problems.

The sedimentary depositional environment of the coal deposit would have contributed to the distribution of finely dispersed mineral matter within the coal plies. Changes within the environment, largely due to climatic events and differing flow regimes, could influence the amount of associated mineral material in these plies resulting in closely associated but differing densities within the raw material.

At Grootegeluk mine two major stratigraphical units, representative of two distinctly different sedimentary environments are being exploited. The first unit is the Volksrust Formation which consists mainly of intercalated bright coal (vitrinite rich) and shale in a deltaic environment, where the coal formation is considered to be autochthonous. The second unit, the Vryheid Formation, consists of relatively well defined dull coal seams inter-bedded with siltstone and sandstone beds in a fluvial environment considered to be allochthonous.

Based upon extensive studies of borehole analyses and sink and float tests, the derivation of a technique applied to the relationship of coals' physical properties has been developed which will enhance the understanding of its behaviour in the beneficiation environment. This has provided significantly better correlation between coal washing characteristics determined at fixed densities within the analytical realm and actual beneficiation results. If adopted, this technique would enhance the credibility of resource and reserve estimations, product yield predictions and actual reconciliation of product to source, post mortem. In so doing, the results would have considerable impact on marketing, economics and life-of-mine expectancy. Already the AAD methodology applied to the grade control function in a beta-testing phase has resulted in the closest monetary value to actual production income versus the predictions provided by the geological model and the mine planning budgetary values.

ACKNOWLEGEMENTS

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NOMENCLATURE

AAD	Ash adjusted density- density value derived from the application of the AAD algorithm to give the true density at that particular ash value.
allochthonous	Refers to the transportation of sedimentary material from an external source
AME	As mined elevation, pertaining to the practical floor elevation of the mining bench as measured by survey after a block has been loaded out.
Ash	Ash is the non combustible inorganic residue that remains when coal is burned comprised of sediment and minerals
AMF PP Yield	Refers to a recalculated yield based on the determination of the actual sequential package mined after survey have determined the new floor elevations, product extraction is then done using the same control parameters as the beneficiation plant at the time that this material was beneficiated.(Hence the PP Yield notation)
Autochthonous	Refers to the in-situ formation of the coal material
Coal wash table	Representation of yields at specific float densities
clarain	term used for the visual description of coals which are vitrinite/liptinite rich
composite wash curve	Plot of yields at specific fixed density fractions
cumulative wash curve	Plot of cumulative yields at the increasing density fractions
Density	Density is the concentration of matter in a body measured by the mass per unit volume of a substance
durain	Term used for the visual description of coal bands that are rich in inertinite
Fixed Carbon	The fixed carbon content of coal refers to the amount of carbon remaining after volatile matter has been expelled.
Float Sink analysis	Float sink testing in a laboratory determines the density distribution of particles of the broken coal by immersion of the broken coal in liquids of known relative density.
inertinite	The inertinite group of macerals has higher carbon and lower volatile content derived from the same basic types of organic matter as vitrinite but owe their properties to the oxidation of those materials early in the formative stages. The inertinite group essentially includes sub classifications such as semi-fusinite and fusinite.
Macerals	Microscopic viewing of coal shows particles and bands of different carbonaceous material representing coalified remains of various plant tissues and plant derived substances that existed at the time of deposition. These are collectively referred to as macerals.
Moisture	The water that forms part of the crystal structure of clays and other minerals present in coal.
Near density material	Near density material by definition relates to the material within ±0.1 g/cc of the cut point relative density at which the coal is being washed.
PME	Prescribed mining elevation, floor elevation of the prescribed bench, this elevation

	is used for the predicted yields.
Proximate analysis	Proximate analysis gives a measure of the relative amount of volatile, non-volatile organic compounds in the coal as well as the percentage of water and non combustible inorganic compounds.
PS	Power station coal also referred to as a middling product in a double stage beneficiation plant.
Relative Density	The relative density of a coal depends on the maceral composition, the rank of the material and the degree of mineral impurity. Relative density refers to the number of times that a volume of a specific substance is heavier than the same volume of water.
SSCC	Semi soft coking coal
vitrain	Term used for the visual description of coal bands that are rich in vitrinite
Vitrinite	Vitrinite is the preponderant maceral in bright bands of coal and it originates from the preservation of stems, roots and leaves of plants. Relatively high in volatile matter when compared to inertinite.
Volatiles	The material with the exception of moisture in coal that is liberated at high temperature in the absence of air.

1 INTRODUCTION AND MOTIVATION

The prediction of yields of coal during beneficiation based upon borehole data has long been a problem in the coal mining industry due to a multitude of variables such as loss of sample and different sized particles arising from the drill core to the plant.

These uncertainties affect budgetary and forecasting purposes and the definition and quantification of saleable reserves. This is especially problematic in the Waterberg Coalfield, Grootegeluk Coal Mine, as the coal qualities in this newly developing coalfield are far more variable and difficult to predict than is the case in the conventionally mined areas in Mpumalanga.

A major factor needing consideration is the very low yields of semi soft coking (on average approx 10%) and a total coal yield of only 48% on the run of mine material. Therefore it is of prime importance that yields of various products are properly predicted since a deviation of 0.5% in the predicted yield of SSCC reflects a 5% deviation in the predicted yield of this product.

The necessity of an in depth evaluation of washability and proximate analytical data pertinent to beneficiation methods for the derivation of various products with differing specifications was thus identified. This would aid in the optimal prediction and recovery from coal seams at Grootegeluk which will affect the mine’s continued competitiveness in the global arena.

For these reasons an attempt is hereby made to formulate a methodology to provide a credible association between (i) *exploration-derived* empirical analysis undertaken on the coal resource and (ii) the *final products* produced in the beneficiation plants. The process would attempt to eliminate correlation factors which cover a multitude of inaccurate and variable issues and replace them with a scientifically tested and proven methodology.

1.1 PROBLEM STATEMENT

Problems encountered in the past with regard to near density material and its representation of supposed yields at certain control specifications led to the introduction of correlation factors for the representative mining benches. These correlation factors were largely derived from actual beneficiation plant data and the behaviour of the raw material from these benches within the beneficiation environment.

The application of correlation factors to the products derived from wash tables based on empirical analysis of coal from this deposit is only relevant when material from the same defined source is compared. This implies that a particular bench such as Bench 2 or any of the other benches, mined continuously, as a single entity, for a reasonable period of time, would be used to assess the nature of the raw material laterally within the pit and between specified boundaries. This data would then be used to derive correlation factors for that specific bench.

Due to the changing mining scenario, increased volumes of throughput, admixtures of different benches and blocks within these benches with different properties, a more accurate method for yield prediction and post mortem reconciliation is required.

Assessing the fractional wash tables, the distribution and amplitude range of ash values around each fixed specific float density invokes doubt as to the credibility of those tables especially as the data population increases.

1.2 RESEARCH QUESTIONS AND HYPOTHESES

The method or technique investigated should result in a common correlation factor applicable to all material, irrespective of its source, vertically or laterally, throughout the deposit and should be based upon / or account for only one parameter. In this case the factor would relate to the liberation at a specific size fraction of the beneficiated product in association with the initial empirical wash table fractions and analysis. The current research seeks to prove that this method will enhance the accuracy of predicted yields for budgetary and forecasting purposes, allow a more credible definition and quantification of saleable reserves and reconcile beneficiation results with geologically modelled predictions.

1.2.1 RESEARCH QUESTIONS

The questions to be addressed in this research are the following:

- What is the constitution of coal and can a better understanding be achieved of the heterogeneity of the coal, its matrix composition and structure as well as its associated physical properties within the depositional environment?
- Will the above factors allow the use of physical properties to determine the relationships between them, especially the relationship between density and ash, and what effect will this have on the cumulative wash curve from which products at various specified controls, such as densities, ash content , volatiles or fixed carbon content, are derived?
- Will it be possible to determine the correct primary cutting density and secondary cut density in order to extract the specified products in a multi product environment and to do so with optimal recovery?

- Will it be possible to exclude correlation factors entirely, or derive a beneficiation plant specific correlation factor, based on material type and size fractions rather than a series of raw material origin dependant correlation factors?
- Finally, will it be possible to derive an improved, definitive wash table of the raw feedstock from the empirical analyses of exploration borehole composites, representative of the mining benches?

1.2.2 HYPOTHESES

It is hypothesized that

The density of the raw coal is directly related to the maceral composition, matrix structure and the distribution of indestructible mineral matter represented by the ash associated with the coal.

The distribution of indestructible mineral matter was influenced by the depositional environment of the coal, such that, changes in depositional environment and transportation of sedimentary detritus of different particulate sizes would influence the distribution and concentration of mineral matter leading to higher or lower densities as a result the environmental influence.

The application of derived algorithms relevant to the ash density relationship to correct wash data to true density of the raw material can be ascertained, and will result in improved predictions of qualities, and a more credible definition of resource and reserve saleable products.

If all raw feed-stock compared, from either empirical analysis or beneficiated products' was broken to the same size, in order to allow maximum liberation of the component density fractions, no correlation factor would be necessary.

2 LITERATURE REVIEW

2.1 HISTORICAL REVIEW OF BENEFICIATION AT GROOTEGELUK MINE

In order to address the foregoing, an extensive search for published literature with regard to the problem experienced at Grootegeluk Mine and specifically in the Waterberg Coalfield has yielded nothing of relevance. Some information with regard to near density material and its associated problems in the Mpumalanga area, specifically Leeuwpan Coal Mine however was found. These references refer to two aspects of the near density material problems, the first being a beneficiation plant solution dealt with and reported in a paper published by Magwai and Claassen (2007) and the second, a risk analysis approach to the management of the mineral resource by Botha (2008).

The intrinsic problem of near density material has been recognized by Botha as being related to the ash distribution at various densities and that any external factors affecting this distribution will impact on the coals washability. Botha (2008) further hypothesizes that the amount of near density material is a function of the ash distribution within the coal and that the amount of near density material is dependent on two factors, namely: (i) The unique and characteristic distribution of mineral matter within the coal and (ii) the density cut point applied in the beneficiation plant determined by the wash product requirements. No attempt at the quantification of mineral matter (indestructible) associated with the various density fractions to validate this hypothesis was made.

Although mineral matter and the subsequent ash content are important parts of the overall matrix, very little cognizance has been taken of organic matter comprising coal and its role in beneficiation and utilization. In their publication on the characteristics of Southern African coals, Falcon and Ham (1988) include a summary of the petrographic constituents of coal, highlighting the differences between the Palaeozoic coals of the northern and southern hemispheres (Laurasia and Gondwanaland respectively) and the effects of these properties on the combustion performance of coal. South African coals are rich in minerals, difficult to beneficiate and highly variable in organic composition and maturity. These coals were formed in Permian swamps under cold temperate conditions associated with the waning of a massive ice age. The Carboniferous coals of the northern hemisphere, by way of contrast, were formed in hot humid conditions in coastal coal forming swamps. Major organic differences were noted, namely, the southern hemisphere coals were said to be rich in the maceral inertinite and less reactive, while the northern hemisphere coals tend to be vitrinite rich and highly reactive.

Coal can be classified into four main levels of ranks: lignite or brown coal, bituminous coal, anthracite and graphite. Each type of coal has a certain set of physical parameters which are mostly controlled by moisture, volatile content, ash and fixed carbon content as well as different swelling characteristics (Falcon and Ham. 1988; England et al. 2002.). The coals being mined in the Waterberg are bituminous coals. Moisture in coal can originate as extraneous moisture associated with the physical mining environment, such as groundwater or capillary moisture within microstructures in the coals or, as inherent moisture structurally contained within the coal. Inherent moisture may be as a result of moisture trapped within the decomposed organic compounds or mineral moisture comprising part of the crystal structure of hydrous silicates (clays) associated with the coal. Volatile content in coal refers to the components of coal which are liberated at high temperature in the absence of air. This is usually a mixture of short and long chain hydrocarbons, aromatic hydrocarbons and some sulphur.

Ash content is the non-combustible residue left after coal is burnt. It represents the bulk mineral matter after carbon, oxygen, sulphur and moisture (including from clays) has been driven off during combustion. The fixed carbon content of the coal is the carbon found in the material which is left after volatile materials are driven off but is not representative of the ultimate carbon content since some carbon is lost in the hydrocarbons associated with the volatiles (England et al. 2002).

When assessing the proximate analysis data as reported in a wash table, ash and density are the only parameters that appear to have a consistent relationship. The proximate analysis provides, values for moisture, ash and volatile matter contents and fixed carbon content by difference at specified float densities which can then be related to the yield of material in each density fraction. Volatiles, moisture and fixed carbon are eliminated upon ignition leaving only ash, thus the most logical relationship to investigate would be that between density and ash.

The probability of an ash density relationship requires more specific detail with regard to the composition of the coal matrix, its inorganic and organic constituents and some physical data pertinent to the densities of some of these inorganic compounds. In order to understand the behaviour of raw material in a beneficiation plant the composition of the raw material should be taken into account and, in the current case, this means the maceral and mineral composition of the coal under investigation, namely, the multi-variable coal qualities and their multiple end products being mined at Grootegeluk Mine.

2.2 ORGANIC COMPONENTS IN COAL

In terms of the organic components (macerals) in coal, investigative work done by the chemistry division at the Argonne National Laboratory in Illinois with regard to the separation of coal macerals has shown that the density gradient centrifugation technique offers significant advantages over previous methods of maceral separation (Dyrkacz et al, 1992). The density gradient technique applied by these authors provided a rapid method of measuring the overall density ranges of the various macerals. Vitrinite was found to have a relatively narrow density range, suggesting that its properties should be less erratic and thus more predictable. Furthermore it was proved that liptinite macerals characteristically possess densities of 1,1g/cc, whereas vitrinite macerals have densities of 1,25g/cc to 1,35g/cc and inertinite maceral densities range from 1,4g/cc to 1,7g/cc. These results are compatible with those reported by Falcon and Snyman (1986) and Crelling (1992). Since density gradient centrifugation techniques were introduced, continuous work has been done to separate and characterize coal macerals. Good separations of liptinite, vitrinite and inertinite maceral groups have been reported as have separations of several other individual maceral types. The separations have been verified through petrography (Falcon and Falcon, 1987).

The specific density ranges for the different macerals are therefore most relevant in the gravity separation processes used in coal beneficiation as different macerals report to different densities. These facts have also been utilized to predict approximate yields and qualities of types of coal products at different densities by using petrographic analyses on raw coals (Falcon and Falcon, 1987). Further information in this regard is presented in Chapter 4

2.3 INORGANIC COMPONENTS IN COAL

In terms of inorganic (minerals) in coal, it is well known that the most abundant minerals in coal are clays, quartz, carbonates and pyrite (Stach et al, 1982, Falcon and Snyman, 1986). The densities of each mineral group are also variable, ranging from 2,5g/cc (clays and quartz) to 5g/cc (pyrite), i.e. these density values are considerably higher than the organic macerals. If macerals and minerals were liberated from one another, separation based upon density would be easy to achieve. However, when macerals and minerals are integrated and intimately mixed together in coal bands and in coaly particles, the density of that band or particle is dependent on the proportion of minerals and macerals present, and which maceral is present. The band or particle therefore has what is known as a “relative density”, meaning the density of a mixed or complex material rather than a pure material (i.e. pure mineral or maceral). This can vary widely and is the cause of difficult and often inefficient beneficiation processes as some of the mixed materials can possess relative densities between or borderline to the normal density levels used for separation. Such material is termed “near-density” material (Falcon and Falcon, 1987). Further information in this regard is presented in Chapter 4.

2.4 CORRELATION FACTORS BETWEEN FLOAT SINK TESTS AND FULL SCALE BENEFICIATION PLANT PERFORMANCE

The number of variables with regard to the physical and compositional properties of raw coal can be exacerbated further by crushing coal to different size fractions which in turn affects the degree of liberation between desirable organic materials and undesirable mineral matter. Based on the above, it is more than understandable that the prediction of product yield and quality derived from float sink tests using fine coal will differ significantly from those results finally obtained from full scale beneficiation plant where sized coal is washed. This phenomenon has invariably resulted in the introduction of correlation factors by those working in preparation plant on the mine. Such correlation factors are generally coal seam, location and product size specific.

The correlation factors used historically at Grootegeluk Mine for the estimates of products from the coal resource were comparable to those practices used globally in the coal mining industry. It is just such systems which have lead to significant discrepancies in predictions which have lead, in turn, to the need for a more realistic system with which to evaluate the process from resource to saleable products.

This process invariably involves an exercise assessing the reconciliation of final products through the process chain starting from their origin. In the mining industry context this equates to the comparison of an estimate of source (a mineral resource model, a mineral reserve model or grade control information) with a measurement from either survey or the official production from the processing plant (Glacken and Morley, 2003; Schofield, 2001). Reconciliation is essentially the process of identifying, analysing and managing variance between planned and actual results in such a way that opportunities are highlighted (Riske et al, 2007). Measuring and analysing data from the resource through the entire process chain allows the recognition of areas of possible improvement throughout the process. Riske et al (2007) recognised three main types of reconciliation and applied this to an inverted pyramid structure where information grows as you progress up the pyramid. Each layer progressing upwards, in the pyramid relies on the information obtained from the layer below and uses reconciliation as a reality check between these layers. The three main types of reconciliation are spatial, temporal and physical.

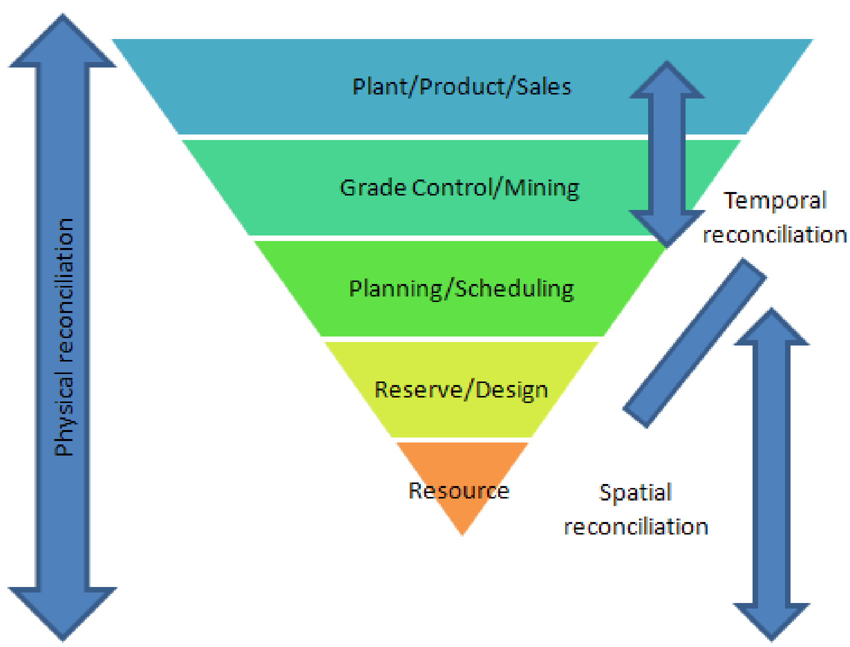


Figure 1 The reconciliation inverted pyramid.

The outcomes of these comparisons within the reconciliation cycle are invariably factors which give an indication of the accuracy of the estimate.

Although a much improved reconciliation process is currently in use at Grootegeluk Mine, the historical values were obtained mainly from the "Temporal reconciliation" region combined with some elements of the "Physical reconciliation", especially from the planning and scheduling region depicted in the inverted pyramid structure shown above. The most common form of reconciliation was a time- and physical-based reconciliation. This compared performance across the mining sequence on time based ranges and the physical quantities of materials produced at certain quality specifications from specific locations within the deposit. The usefulness of the reconciliation data remains dependant on the quality and reliability of the source data, namely *estimates* and *measurements* (Mark Noppe, 2004). The resource and reserve *estimates* are dependent upon exploration sampling data and the processes and models used to generate resource and reserve estimates from that data. Mining and beneficiation process *measurements* affecting reconciliation include survey data, despatch data (mining tonnages from the resource), belt samples, flow meter readings and weight metering. All these measurements have some degree of associated error or confidence level.

3 GROOTEGELUK COAL MINE: BACKGROUND INFORMATION

3.1 LOCALITY

Grootegeluk Mine is part of the Waterberg Area in the south-western part of the Limpopo Province of the Republic of South Africa. It is located within the boundaries of the Lephalale Magisterial District, in close proximity to the mining suburb of Onverwacht.

In general the Mine is accessed from the west via a sealed (tarmac) road, linking it with the residential suburb of Onverwacht (16km towards the east), which in turn is connected with the rest of the Bushveld towns i.e. Thabazimbi (130km to the south), Nylstroom (150km to the south-east), and Potgietersrus (160km east-southeast) via tar roads.

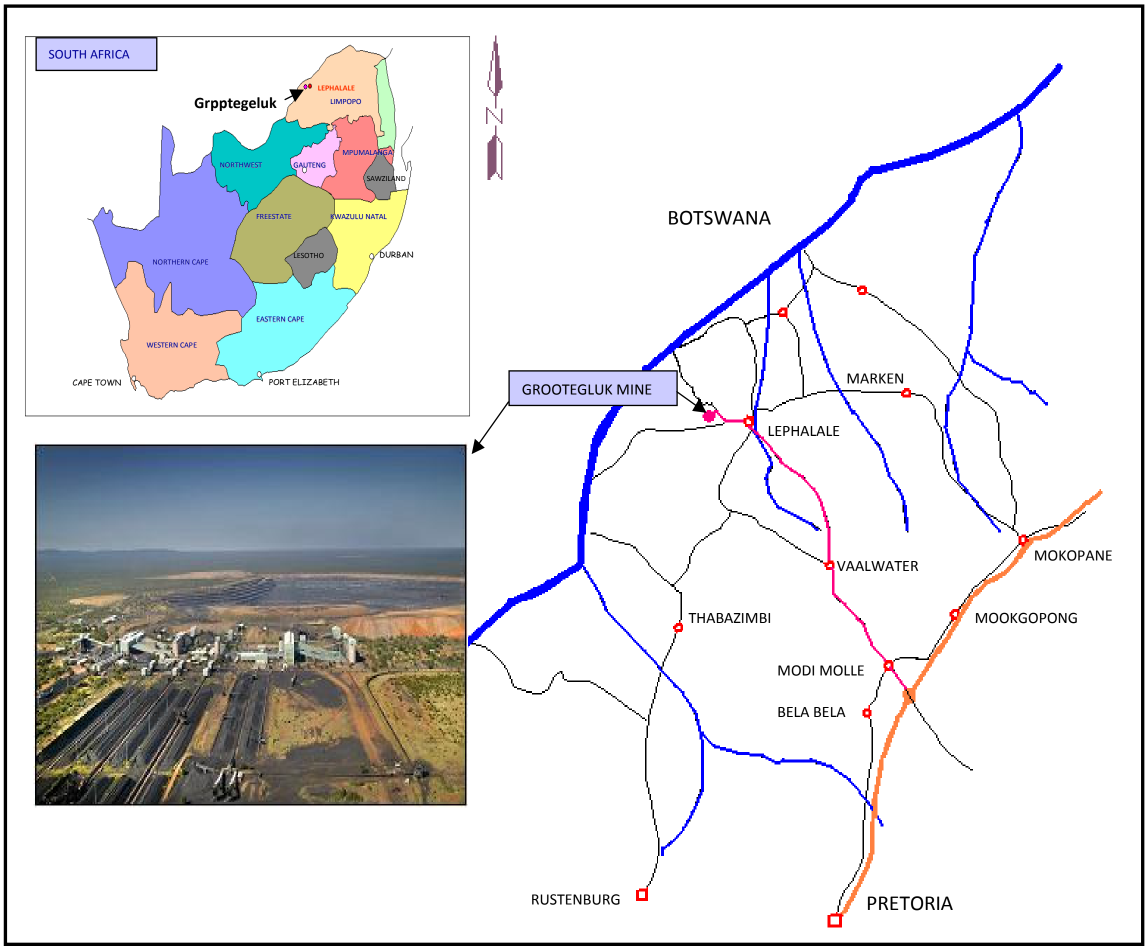


Figure 2 Locality Map of Grootegeluk Coal Mine

The Mine has a multi-product output consisting of, Thermal Coal , Semi-Soft Coking Coal and Metallurgical Coal, all sold to a fairly wide spectrum of domestic and international clients.

3.2 PHYSIOGRAPHY

Grootegeluk Mine is situated approximately 15 km north of the gentle elevated foothill mountain landscape of the Waterberg Mountains, in the so-called Limpopo-River Valley. A softly undulating relief dominates the area. Differential weathering of basalt, which occurs northeast of the Mine, manifest itself in the form of low-lying ridges. This gives rise to a localized, slightly more rugged terrain. Height above sea level varies between 850m and 950m.The climate is sub-tropical, with average day temperatures ranging between 30ºC and 40ºC in the summer and between 15ºC and 25ºC in the winter. The average annual rainfall is 450mm which mostly occurs as isolated tropical thunderstorms during the summer months of December, January and February. Although no natural drainage networks can be observed in the area, the gentle natural slope of the flat laying landscape is eastwards towards the Mokolo River, which meanders through the region, channelling northward where it flows into the Limpopo River. The vegetation consists of indigenous Bushveld trees and shrubs as well as a variety of grasses, which are adapted to the relatively low rainfall of the region (Bredenkamp et al, 1996)

3.3 REGIONAL GEOLOGY

The Zoetfontein Fault in the north and the Eenzaamheid in the south, underlain by the Waterberg Group stratigraphy north of the Eenzaamheid Fault, mark the boundaries of the Waterberg coalfield. The Waterberg Group stretches some 90 km southward culminating in the Waterberg and Sandrivier mountain ranges. North of the Zoetfontein fault a portion of the Group extends westwards into Botswana with the Archaean Granites representing the paleofloor, and another portion extends north-easterly.(Brandl, 1996)

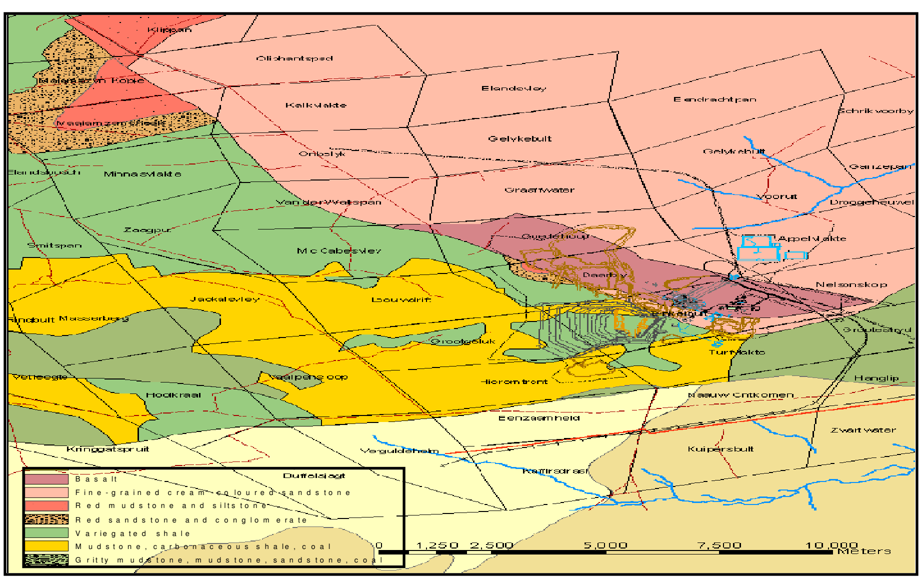


Figure 3 Part of the Regional Geological Map with Grootegeluk locale overlain.

Rocks predominantly of the Kransberg Subgroup and the Sandriviersberg formation are present in the mining area. These are comprised of coarse, yellowish, gravely, cross bedded sandstones with ferruginous laminae along the bedding planes. All the classical units of the Karoo Sequence are present in this coalfield and the subdivision of the Karoo Sequence is based mainly on lithological boundaries consisting, in descending order, of the Stormsberg Group, followed by the Beaufort Group, the Ecca Group and the Dwyka Group. The Waterberg Group (Siepker, 1986) represents the basin floor; this only pertains to certain areas. North of the Zoetfontein fault Archaean Granites formed the paleofloor (Dreyer, 1991). The Karoo groups are further subdivided into lithological units (formations) that have acquired several names over the years. Figure 1 is a 1:250 000 scale map of the regional geology (Brandl, 1996).

Starting at the basement the Dwyka Group is mostly encountered as filled depressions in the floor and consists primarily of greyish diamictite and in places rounded pebble conglomerate as well as fluvio-glacial gravels that are products of glacial weathering. The Dwyka Group is only approximately 3m thick in this region.

The Ecca Group overlays the Dwyka Group and can be subdivided into three distinct lithological units, namely the Lower Ecca (Pietermaritzburg Shale), the Middle Ecca (Vryheid Formation) and the Upper Ecca (Volksrust Formation).

The Lower Ecca is comprised of shale, siltstone, sandstones and gravels in the lower portions and is approximately 150m thick in the mining area.

The Middle Ecca in the Waterberg coalfield comprises thick yellowish to white, cross-bedded sandstones and siltstones with intercalated dark gray carbonaceous sandy shale's and inter-bedded, dull coal seams varying in thickness between 1.5m to 9m. The Middle Ecca is approximately 55m thick in the Waterberg coalfield.

The Upper Ecca, normally characterized by shale's of various hues of bluish gray to darker carbonaceous grey, in this area are uniquely interspersed with intercalated and interlaminated bright coal seams. This zone exhibits distinct cyclic sedimentation, notably upward coarsening cycles, starting with a bright coal at the base with the coal to shale ratio and gradually decreasing upwards and finally grading into relatively pure shale on top. The Volksrust shale's show an increase in carbon content with depth, starting with a light bluish grey mudstone on top, graduating to very dark grey, carbonaceous shale at its base. The Volksrust Formation in this area is approximately 60m thick.

The Beaufort Group in this area comprises of shale's of various hues of purple alternating with greenish grey in the upper portion, while light grey mudstones predominate at the base, the unit is approximately 90m thick in the mining area north of the Daarby fault. The full 90m thickness only occurs north of the Daarby fault in a small rectangular faulted block where the entire sequence has been preserved.

The Stormsberg Group overlaying the Beaufort group is subdivided into four distinct lithological units. The Molteno formation comprises white, medium to coarse-grained sandstones and is approximately

15m thick in this region. This is succeeded by the Red Beds or Elliott formation, consisting primarily of reddish brown to chocolate brown clayey mudstones, marls with interspersed calcareous nodules. Thin white sandstone lenses are also encountered in the upper portions. The Elliott formation is approximately 90m thick. The Cave Sandstone or Clarens Formation overlies the Elliott formation comprised of creamy white to yellowish to reddish brown, fine grained, well sorted Aeolian sandstone, relatively calcareous with interspersed calcareous nodules. The average thickness is of the order of approximately 80m. The Drakensberg Basalt or Letaba formation caps the Clarens Formation. In this area a small lenticular wedge north of the Daarby fault has been preserved.

The Letaba formation is comprised of successive lava flows, appearing almost as distinct beds. The lava is dark gray to black but weathers chocolate brown to purple. It has extremely fine crystalline to coarse amygdaloidal tendencies in parts, with amygdales present towards the bases of successive flows.

The basalts are fractured and weathering is found between successive lava flows. Thin lenses of sandstone similar to the Clarens also occur between lava flows especially near the base. The Letaba formation varies from a maximum of 120m to 90m thickness in this region.

3.4 EXPLORATION AND MINING HISTORY

Coals of the Waterberg Coal Field were discovered in the north-western Transvaal (now known as the Limpopo Province) in March 1920 during water drilling operations on the farm Grootegeluk 459LQ, 22km west of the present town of Lephalale (previously known as Ellisras) Trevor & Du Toit (1922).

The discovery was followed by a reconnaissance study of the area by two geologists, Dr. A.L. Du Toit and H.F. Frommurze. A few short boreholes were drilled and Trevor & Du Toit (1922) summarized the results, which at the time, amounted to a discovery of scientific interest.

Coal of coking quality was of no significance for the then foreseeable future, as the Union of South Africa still lacked its own steel industry. For power generation, more than ample coal was available from the Witbank and Natal Coal Fields. During the period 1941 to 1952 the Geological Survey, in collaboration with the Fuel Research Institute, probed the extent and potential of the Waterberg Coal Field by means of geological mapping, 143 diamond boreholes and 2 prospecting shafts.

The results of this work indicated vast resources of metallurgical and non-metallurgical coal. In 1955 the Minister of Mines reserved coal on 29 farms in the Waterberg Coal Field for ISCOR (now known as EXXARO Resources) and SASOL. Two more farms were added in 1961, 5 in 1964, and a further 89 in 1965. As a result of this reservation, ISCOR and SASOL were the only two parties qualifying to apply for prospecting or mining leases in respect of coal over a total of 125 farms in the Waterberg Coal Field.

In 1957 ISCOR acquired the property rights over six farms in the area that formed part of the 125 farms on which coal was reserved for ISCOR and SASOL. The first extensive drilling subsequent to the original 143 holes drilled by the Geological Survey comprised a series of 120 boreholes that were drilled in the shallow coal area by SASOL during 1965/1966. No mining lease was applied for and SASOL acquired only the property rights over the farm Jackalsvley 309LQ. Over a number of years ISCOR obtained bulk samples of coal for coking tests from a prospecting shaft on the farm Grootegeluk 459LQ. Additional samples of coal for coking tests were obtained from 22 large diameter boreholes (254mm core), drilled along a line between the prospecting shafts on Grootegeluk 459LQ and Hieromtrent 460LQ during 1959/1960. In May 1973 ISCOR started an intensive exploration program on the six farms originally purchased in 1957 for a final assessment of the resource and quality of metallurgical coal on these properties. In 1975 a trial box-cut was established on Enkelbult 462LQ to obtain a bulk sample for beneficiation tests. The outcome of resultant feasibility studies led to Grootegeluk Mine being commissioned in 1980 (originally designed to supply coking coal to be used as a reductant in Iscor's steel production process).

In 1979 an agreement was reached with ESKOM to provide coal to a Power Station still to be erected at the time. Although the initial tender was for a 2400MW power station, it was later increased to 3600MW. The projected life of this power station (Matimba) was 40 years and therefore a pit layout containing 40 years of saleable thermal coal was designed.

The semi-soft coking coal was and still is the product of the GG1 beneficiation plant (GG1 being the first beneficiation plant erected and commissioned at Grootegeluk Coal mine). The middlings product produced from this double stage coal beneficiation plant was stockpiled as stock feed for the Matimba power station. The run-of-mine was and currently still is extracted from what is locally referred to as the Volksrust Formation (intercalated coal-carbonaceous shale deposit) of the Karoo Sequence. As the ramp-up of the Power Station progressed, another beneficiation plant, namely GG2, was commissioned to augment thermal coal supply to the power station. Again, the run-of mine came from the Volksrust Formation, as is currently still the case.

In order to cope with the full demand of the power station after it started to generate electricity at its designed capacity (3600MW), a further beneficiation plant, GG3 (crushing and screening only), was brought on-line. This received its run-of-mine from what is locally referred to as the Vryheid Formation of the Karoo Sequence (well defined coal seams and inter-burden similar to what is encountered in the Witbank Coal Field). As the market for medium to low phosphorous coal evolved, yet more beneficiation plants, GG4/5, were commissioned to produce metallurgical coal for direct reduction and other various smaller market applications such as the cement industry, tobacco industry. The GG4/5 run-of-mine is extracted from some of the bottom coal seams of the Vryheid Formation. The GG6 beneficiation plant (phase 1) was completed and brought into production during August 2006 to produce 550ktpa of additional coking coal for Mittal Steel. The plant is an add-on to the GG2 beneficiation plant, receiving its run-of-mine also from the Volksrust Formation (intercalated coal-carbonaceous shale deposit) of the Karoo Sequence.

3.5 LOCAL GEOLOGY

This section describes the nature and distribution of the coal seams and their associated sediments. This is important background information pertinent to the locale of the mine and the material from this deposit being beneficiated.

3.5.1 VOLKSRUST FORMATION

The upper part of the coal deposit, the Volksrust Formation, comprises intercalated shale and bright coal layers with an average thickness of ± 60m. It displays such a well-developed repetition of coal-shale assemblages that it can be divided into seven major sedimentary cycles or zones (Table 1). Smaller sub-cycles ("samples") are contained within these zones; these were sampled individually during exploration of the deposit. The terms *"zone*" and "*sample*" are used at Grootegeluk instead of "*seam"* and "*ply"* due to the site-specific intercalated nature of the coal and shale.

The Volksrust Formation is classified as a '*Thick Inter-bedded Seam Deposit Type'* characterized by a succession of multiple, thinly interbedded coal and non-coal layers with a total thickness of typically between 40m and 70m as defined in the SAMREC Code. Although the thickness and coal quality of the Volksrust Formation are reasonably constant across the coal field, a large variation in the yield of semi-soft coking coal occurs vertically in the coal succession. The ash content of the coals in this formation are also relatively high, >50%.

The Volksrust Formation Zones typically start with bright coal at the base, with the ratio of coal to shale decreasing from the base of each zone upwards. The Basal Zone is the exception because the coal is more evenly distributed throughout this zone.

The Volksrust Formation shale's show an increase in carbon content with depth and they range from a massive bluish-grey mudstone at the top to carbonaceous shale's towards the Basal Zone.

3.5.2 VRYHEID FORMATION

The Vryheid Formation (± 55m thick) forms the lower part of the coal deposit and comprises carbonaceous shale and sandstone with inter-bedded dull coal seams varying in thickness from 1.5m to 9m.

The Vryheid Formation is classed as a '*Multiple Seam Deposit Type'* according to the SAMREC Code.

There are five coal seams or zones in the Vryheid Formation, all of which are comprised predominantly of dull coal with some bright coal developed at the base of Zones 2, 3 and 4. Due to lateral facies changes and changes in the depositional environment, these zones are characterized by a large variation in thickness and quality. It is inferred that these zones deteriorate in a westward direction on the Mining Rights Area and Prospecting Rights Area.

Zone 3 is the best-developed dull coal zone within the Mine Lease Area, reaching a maximum thickness of 8.9m. The basal portion of this zone yields a small fraction that has semi-soft coking coal properties.

Zone 2 is, on average, 4m thick and reaches a maximum thickness of 6m in the Mine Lease Area. The basal portion of this zone also yields a fraction that has semi-soft coking coal properties. This zone is the most constant of all the Vryheid coal zones across the entire Waterberg Coal Field regarding thickness.

Zone 1, the basal Vryheid coal zone, has an average thickness of 1.5m, but varies quite rapidly being the lower-most coal layer in the sequence. Both the Volksrust and Vryheid Formation Zones are subdivided into sampling units which are analyzed in detail (Table 1).

Table 1 Cyclic Sedimentary Subdivision of Coal sequence and Sampling Limits for Drilled Core

Formation	Formation	Group	ZONE AND SAMPLE Nos	1:500	AV. THICK-NESS (m)	% COAL (mass)	LITHOLOGY
Grootegeluk Formation	VOLKSRUST FORMATION	UPPER ECCA	ZONE 11 Samples Nos. 1A-1D		7,56	38,33	Bright coal (without siderite) intercalated with grey mudstone, carbonate lenses ± 50 cm × 3 m.
			ZONE 10 Sample Nos.2-6		9,37	53,86	Bright coal with little siderite intercalated with carbonaceous shale; carbonate lenses ± 50 cm x 3 m; thick coal bands in lower half.
			ZONE 9 Samples Nos.7-9		6,53	48,34	Bright coal with prominent siderite at base intercalated with carbonaceous shale; thick coal band in lower half.
			ZONE 8 Samples Nos.10-14		9,04	42,82	Bright coal; prominent siderite at base; intercalated with carbonaceous shale; thick coal bands in lower half.
			ZONE 7 Samples Nos.15-18		10,15	39,94	Bright coal sideritic throughout, intercalated as numerous thin bands with carbonaceous shale; prominent sideritic band at base.
			ZONE 6 Samples Nos.19-21		6,54	32,17	Bright coal, very sideritic in lower half, intercalated as numerous thin bands with cabonaceous shale.
			ZONE 5 Samples Nos. 22A-22E		13,54	21,97	Cabonaceous shale with coal bands in lower two thirds; siderite less prominent.
			Interbeds		2,60	–	Carbonaceous shale to coaly shale.
Goedgedacht Formation	VRYHEID FORMATION	MIDDLE ECCA	ZONE 4 Sample No.23		4,02	99,13	Coal, dull, heavy, some bright coal in lower half and at top, few thin shale bands; yields coking fraction.
			Interbeds		4,28		Shale, black to dark grey, carbonaceous, 1 m fossiliferous siltstone at base
			ZONE 4A Sample No 24		1,52	96,37	Coal, dull, few bright stringers, thin shale bands
			Interbeds		4,28		Shale, dark grey
			ZONE 3 Samples Nos. 25-29		7,82	96,41	Coal, dull bright laminae in lower 1,8 m which yields low ash slightly coking coal, few thin shale bands
			Interbeds		4,54		Sandstone with shale bands
			ZONE 2 Samples Nos. 30-31		3,73	98,22	Coal, dull, bright laminae in lower 2 m which yields lower ash slightly coking coal; thin shale bands
			Interbeds		13,85	–	Sandstone, medium to coarse grained, few thin shale bands, thin coal band near top
			ZONE 1 Sample No 32		1,55	98,54	Coal, dull, very few bright laminae, thin shale bands

3.5.3 FACTORS CONTROLLING GEOLOGICAL CONTINUITY

As the Waterberg Coal Field is fault bounded along its southern and northern margins it can be referred to as a graben deposit, with the Eenzaamheid Fault forming its southern limit and the Zoetfontein Fault forming its northern boundary. The Daarby Fault, with a down-throw of approximately 350m towards the north-east, divides the Coal Field into a deep north-eastern portion and a shallow south-western portion. Sedimentological facies changes also influence the continuity of the sediments and their qualities. This is especially prevalent in the Vryheid Formation Coal Zones with deterioration in coal development towards the west of the Mining Rights Area and the Prospecting Rights Area.

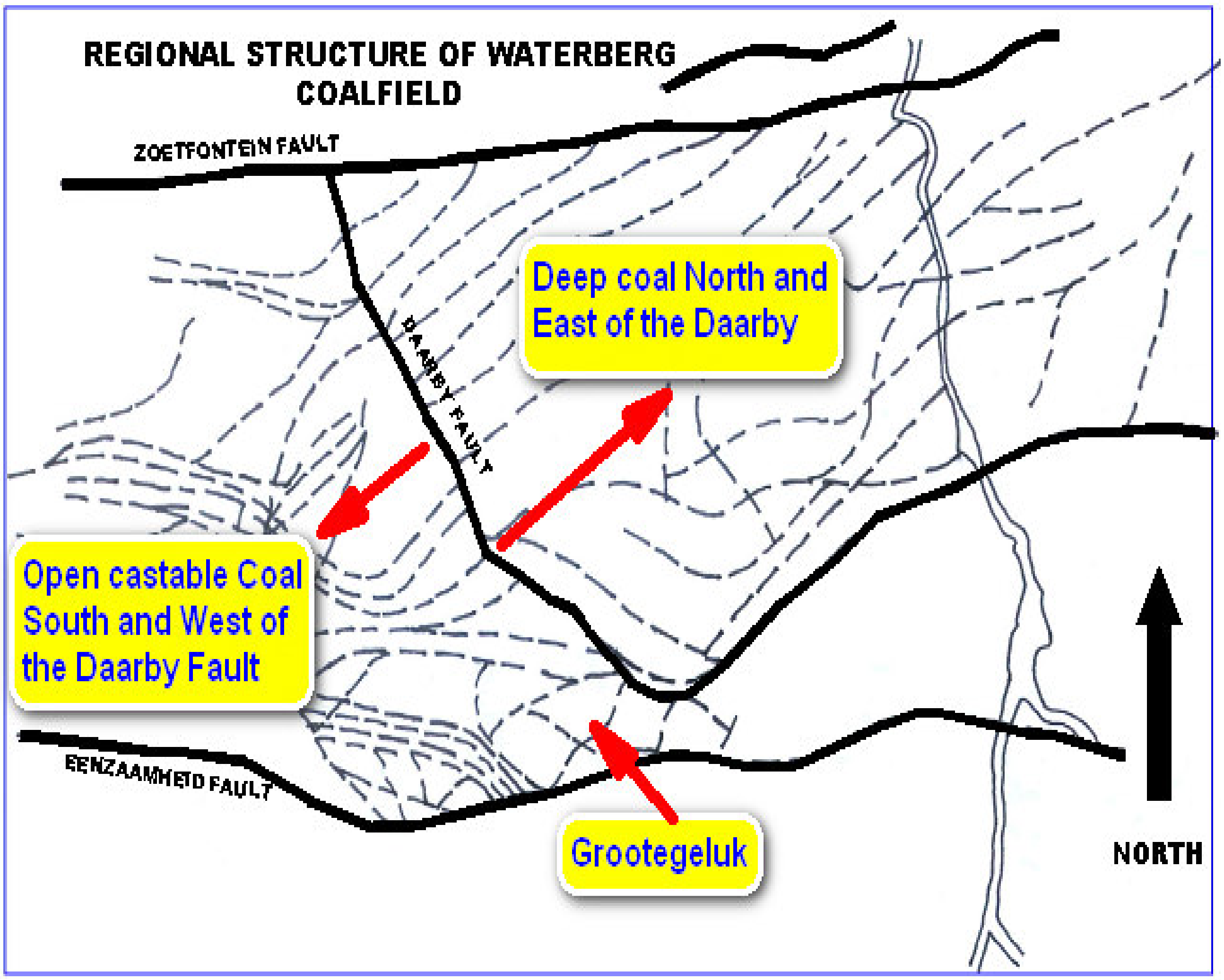


Figure 4 Regional Structure of the Waterberg Coalfield

3.6 MINING

3.6.1 MINING METHODS AND PARAMETERS.

Grootegeluk Mine is a surface mining operation where a series of parallel benches are advanced progressively across the deposit via a process of drilling, blasting, loading and hauling with truck and shovel fleets. Pre-stripping of the soft, mainly clayey overburden is done with hydraulic shovels (back-actors). The pit was established on the open cast able portion of the Waterberg Coal Field, immediately west of the Daarby Fault. This was originally brought into production to deliver a blend coking coal product to the ISCOR Steel Works. The erection of Eskom's Matimba Power Station and Iscor's Saldanha Steel Manufacturing Plant has turned the Mine into a multi-product operation that produces Thermal and Metallurgical Coal in addition to the Semi-Soft Coking Coal. The area west of the Daarby Fault was selected for mining because of low overburden thicknesses that vary between 12m to 20m giving an acceptable stripping ratio. There are relatively few structural complications and fairly constant quality parameters in the area. At present, mining activities extend down to Zone 2 of the Vryheid Formation.

3.6.2 MINING FACTORS AND ASSUMPTIONS

From the geological profile of the Volksrust Formation it is clear that due to the intercalated nature of the coal and shale, selective mining could not be considered as an option. Bulk opencast mining of the Volksrust Formation was the only feasible mining method. In 1987 Grootegeluk Mine changed from mining benches with fixed elevations to mining benches that coincide with geological contacts for the roof and floor of each mining bench in order to provide the beneficiation plants with a run-of-mine feed of less variable quality.

These geological contacts coincide with zone boundaries and simultaneously provide mine benches in the Volksrust Formation with an average height varying from 14m to 17m as shown in Figure 5. The change facilitated selective mining of Zone 5, which is characterized by a high phosphorous content and simultaneously also ensured that the floor of each mine bench coincides with a prominent shale layer, providing a smooth surface for equipment movement, while protecting the underlying coal from surface oxidation.

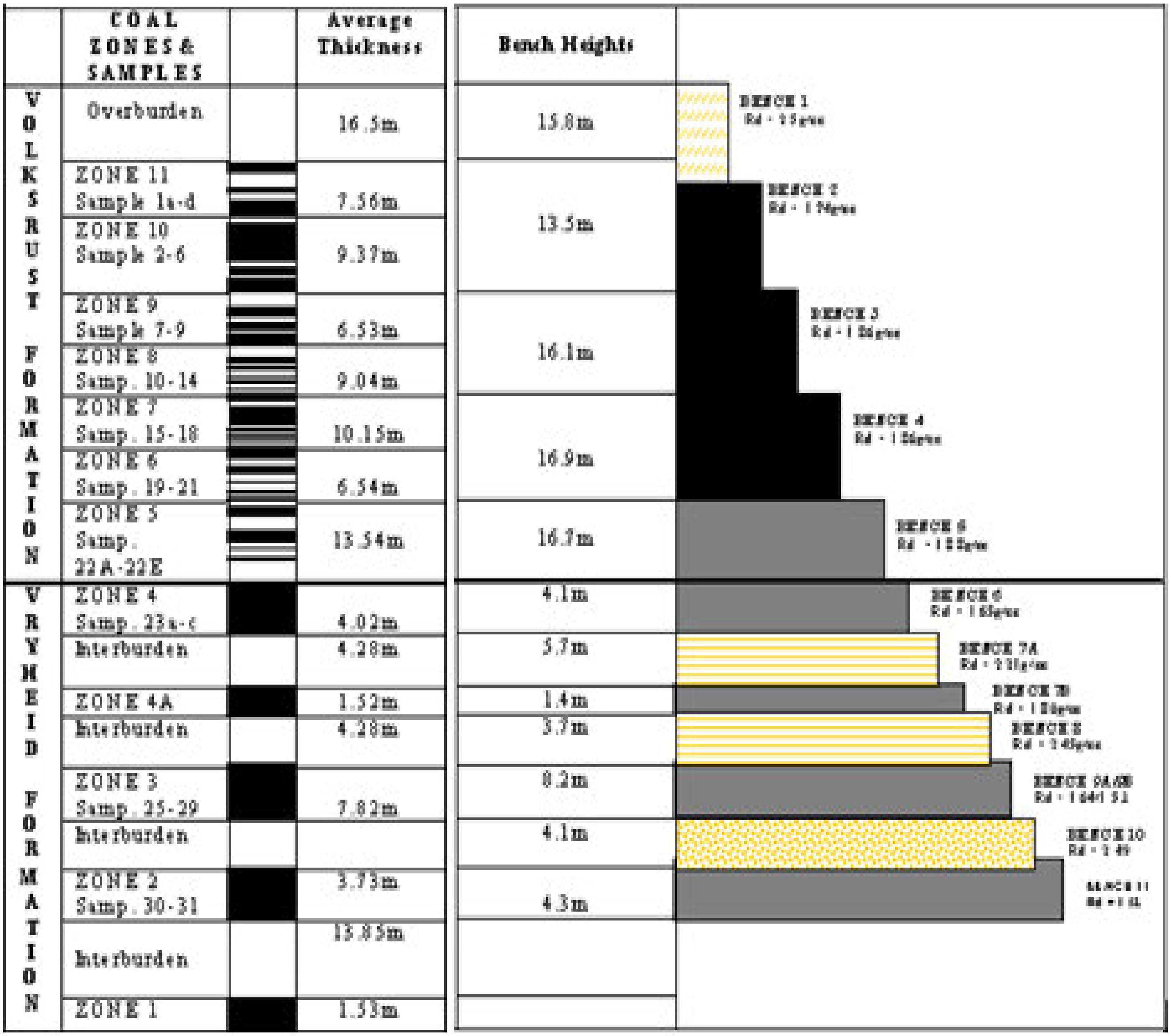


Figure 5 The mining bench delineation at Grootegeluk Coal Mine

Due to the low regional dip of the strata in a south easterly direction, following these geological contacts while developing the pit westwards also assists the drainage of storm water to the sump at the pit bottom. Although faulting in the Volksrust Formation does not seriously affect mining operations in an open pit operation at this stage, the increase in depth of weathering associated with such faulting does produce problems because of the clay (weathered shale and decomposed coal) remnants in such areas.

3.7 BENEFICIATION

3.7.1 BACKGROUND

At present Grootegeluk utilizes six processing plants to treat run-of-mine material from the various mining benches. The flow of material from the mining benches to the various plants is illustrated in Figure 5.

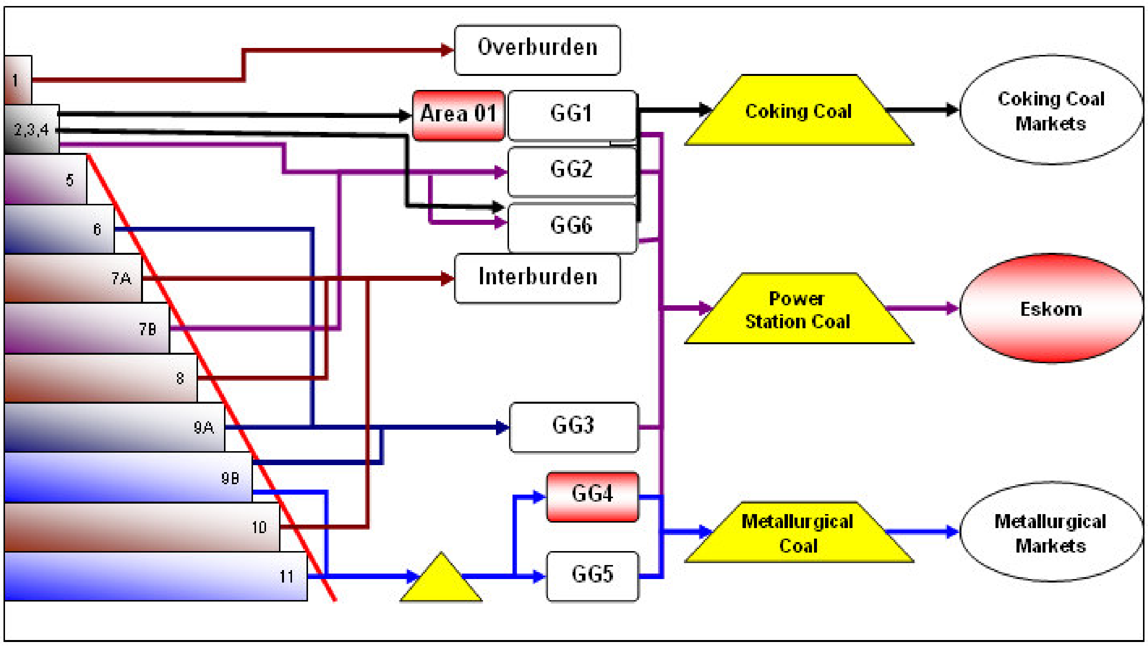


Figure 6 simplified material flow diagram.

3.7.2 VOLKSRUST FORMATION (Benches 2 – 5)

The run-of-mine material from benches 2 – 5 has high ash content (55% - 65%) due to the large amount of intercalated shale’s, thus large beneficiation facilities are required to produce the required qualities and quantities of specified products. The Grootegeluk 1 plant (GG1) produces both, semi soft blend coking coal as well as a power station middling product from mining benches 2 – 4. This is a double stage beneficiation plant producing in the order of 1.5 Mt of blend coking coal and 3.5 Mt power station coal from a 15 Mt run of mine feedstock per annum. During the primary stage an intermediary coal product and discard is produced at a separation density of 1.80g/cc. In the secondary stage the intermediary coal product is further beneficiated to produce a semi soft blend coking coal at a 10.3% ash value and a middling power station steam coal product. The characteristics of these products are summarized in Table 2 below.

Table 2 Summarized product characteristics for GG1 plant.

Blend Coking Coal (air dry basis)		
Ash %	10.3	
Roga Index	60 min	
Swelling Index	4 min	
Volatile %	38.0 max	10 - 12% yield on ROM
Moisture %	10 max	
Sulphur %	1.1	
% - 850 micron	30 max	
Power Station Coal (Middlings) (air dry basis)		
Ash %	35.0 max	
Volatile %	22.0 max	
Calorific Value (Mj/kg)	20 min	32 - 34% yield on ROM
Moisture %	11 max	
Ash initial def temp	1250° C	(reducing atmosphere)
Sulphur %	1.4 max	

Grootegeluk 2 is a single stage beneficiation plant designed to operate at a cut density of 2.0g/cc, producing approximately 4.9 Mt of power station coal from an 11.5 Mt run of mine feedstock originating primarily from mining benches 5 and 7b. Grootegeluk 6 commissioned in August 2006, a secondary beneficiation plant receives feed from GG2 plant. GG6 produces both semi soft coking coal and power station coal. Semi soft is sold to the metals or export markets, 700 000 tons per year. GG6 contributes 2.0Mt to the power station.

3.7.3 VRYHEID FORMATION (Benches 6 – 11)

The run of mine from the Vryheid Formation coal seams are processed in the following plants: Grootegeluk 3, a crushing and screening plant processing approximately 2.16 Mt of steam coal a year for the Matimba power station. This coal originates from mining benches 6 and 9a as a raw coal feedstock. Grootegeluk 4 commissioned during April 1997 supplying approximately 1.10 Mt of metallurgical coal (10 and 15% ash content, in different sizes) from mining benches 9b and 11. Grootegeluk 5 commissioned in March 1998, beneficiating to a 10% ash product for pulverized coal injection (PCI) at Vanderbijl Park Works and approximately 500, 000 tons of Corex coal for Saldanha.

4 RESEARCH METHODOLOGY – ESTABLISHING FACTORS AFFECTING THE WASHABILITY CHARACTERISTICS OF COAL IN THE WATERBERG SUCCESSION

This chapter presents the factors which affect the washabilities of the Waterberg coals and upon which the future proposed mechanism for enhanced washability predictions will be based. The factors outlined in this chapter include the composition of the Waterberg coals, their washability characteristics, the historical data previously collated at the mine and the ash-density evaluation of the data.

4.1 COMPOSITION OF WATERBERG COAL

In order to understand the distribution of varying densities within the overall coal composition, a breakdown of the coal's constituents needs to be understood.

- The natural constituents can be divided into two main groups:
- (i) the organic fraction, which can be further subdivided into microscopically identifiable macerals; The Liptinite, Vitrinite and Inertinite; and
- (ii) The inorganic fraction, which is comprised of sediment and minerals, is commonly identified as ash subsequent to combustion,

Figure 7 Schematic of the composition of coal.

In terms of the organic fraction, these macerals can be broadly broken down into three main groups, the liptinite (exinite) group, vitrinite and inertinite.

Liptinite (Exinite): The liptinite macerals are derived from the waxy and resinous parts of plants such as spores, cuticles, and resins, which are resistant to weathering and diagenesis. This group of macerals is very sensitive to advanced coalification and the liptinite macerals begin to disappear in coals of medium volatile rank and are absent in coals of low-volatile rank. When the liptinite macerals are present in a coal, they tend to retain their original plant form and thus they are usually "plant fossils" or phyterals. The phyteral nature of the liptinite macerals is the main basis on which they are classified into “Sporinite”, “Cutinite”, “Resinite”, and “Alginite”.

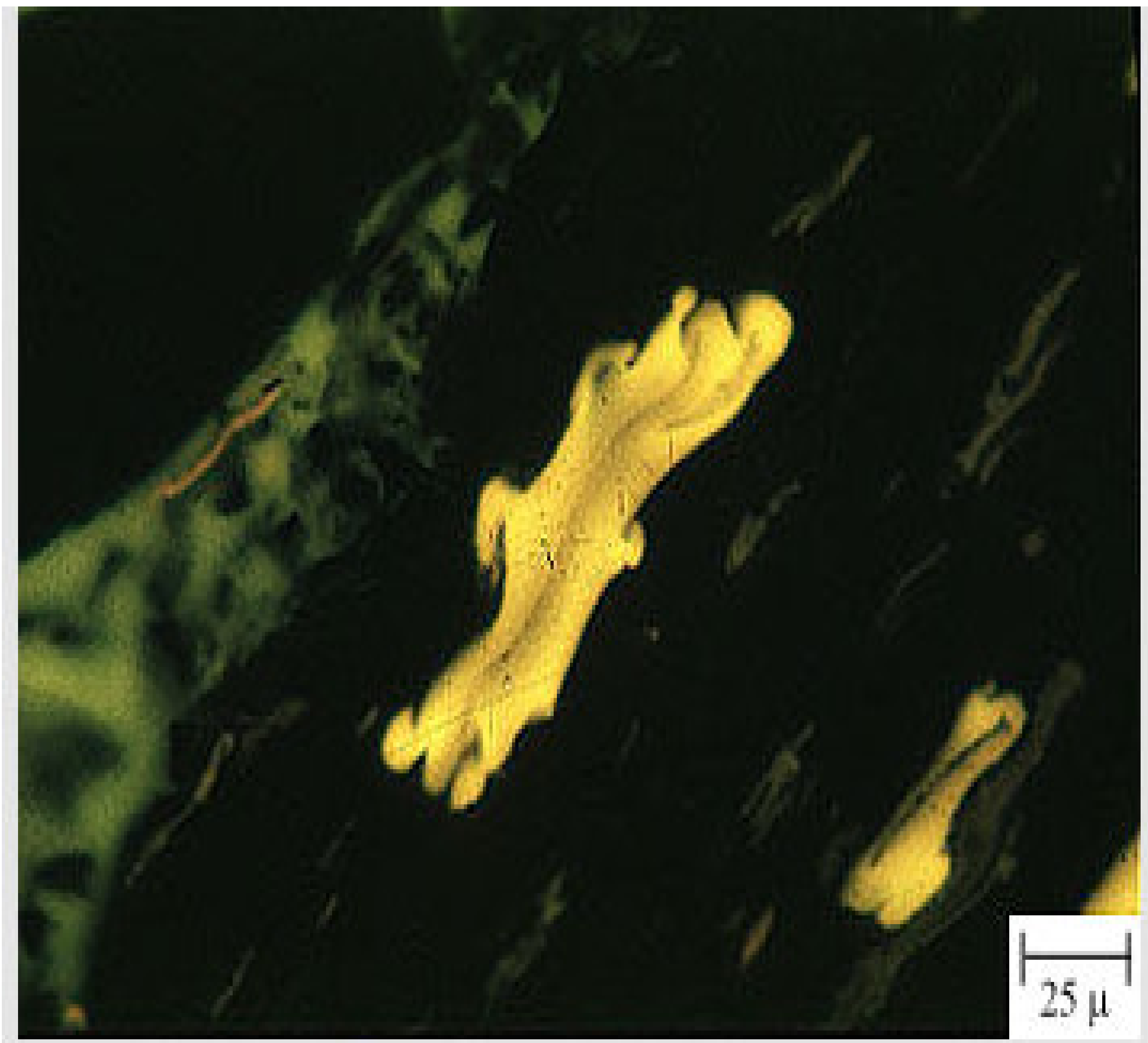


Figure 8 Sporinite fluorescing under ultra violet light. Maceral Group Liptinite. (Photomicrograph Atlas, ASTM, 2008)

Vitrinite: Vitrinite macerals are derived from the cell wall material (woody tissue) of plants, which are chemically composed of the polymers, cellulose and lignin. The vitrinite group is the most abundant group and commonly make up 50 to 90% of most North American coals. However, most Gondwanaland coals and some western Canadian coals are vitrinite poor. Vitrinite rich bands of coal are termed vitrain and vitrinite- and exinite-rich coals are termed clarain.

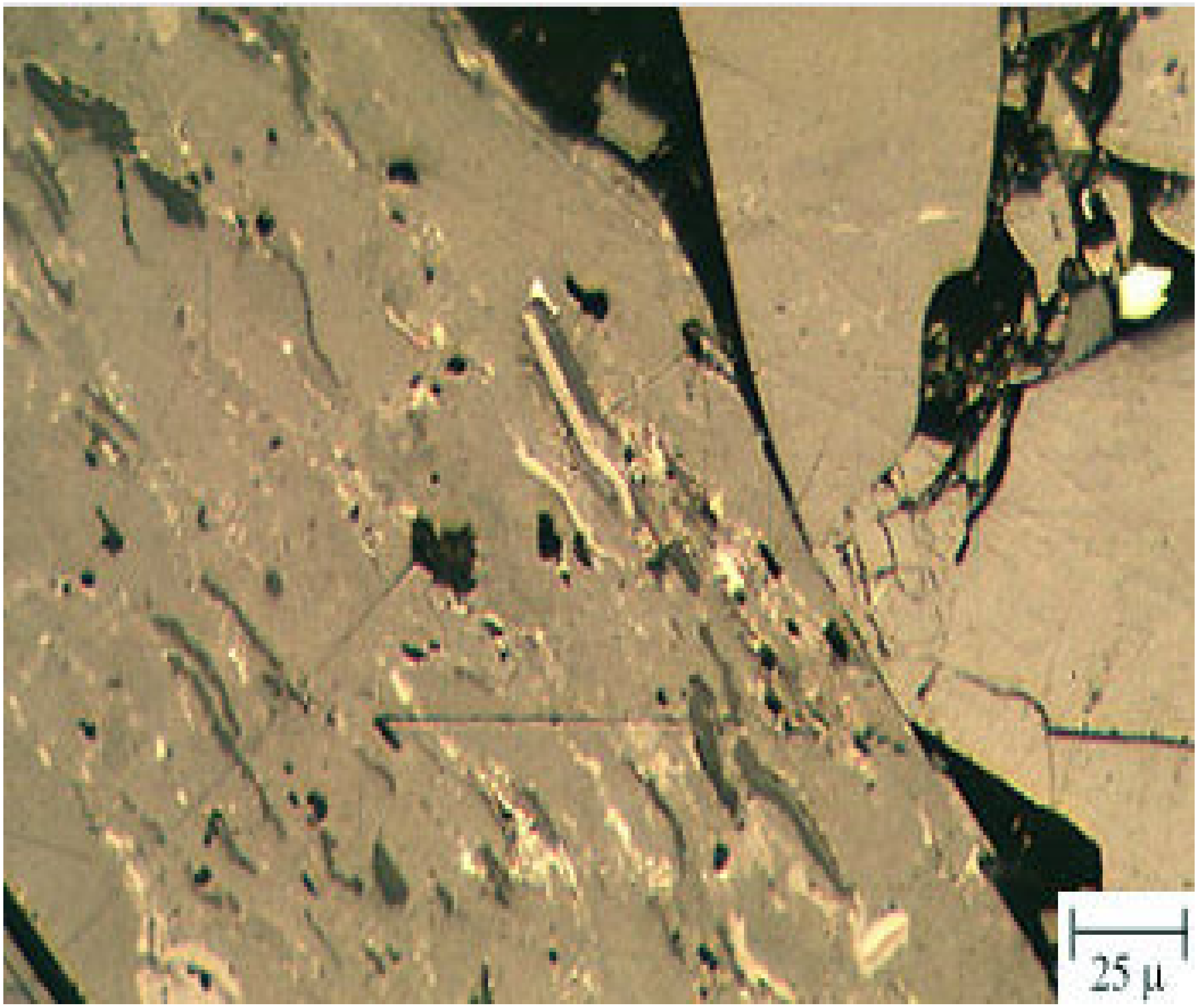


Figure 9 Telovitrinite showing no cell structure. The detrovitrinite acts as a matrix holding dark particles of liptinite macerals and bright particles of inertinite. (Photomicrograph Atlas, ASTM, 2008)

Inertinite: The inertinite macerals are derived from plant material that has been strongly altered and degraded in the peat stage of coal formation. For example, fossil charcoal is the inertinite maceral, fusinite. The inertinite macerals have the highest reflectance of all the macerals and are distinguished by their relative reflectance's and structures. They include such types as "fusinite", "semifusinite", "macrinite", "micrinite", and "sclerotinite". Inertinite-rich bands of coal are termed durain.

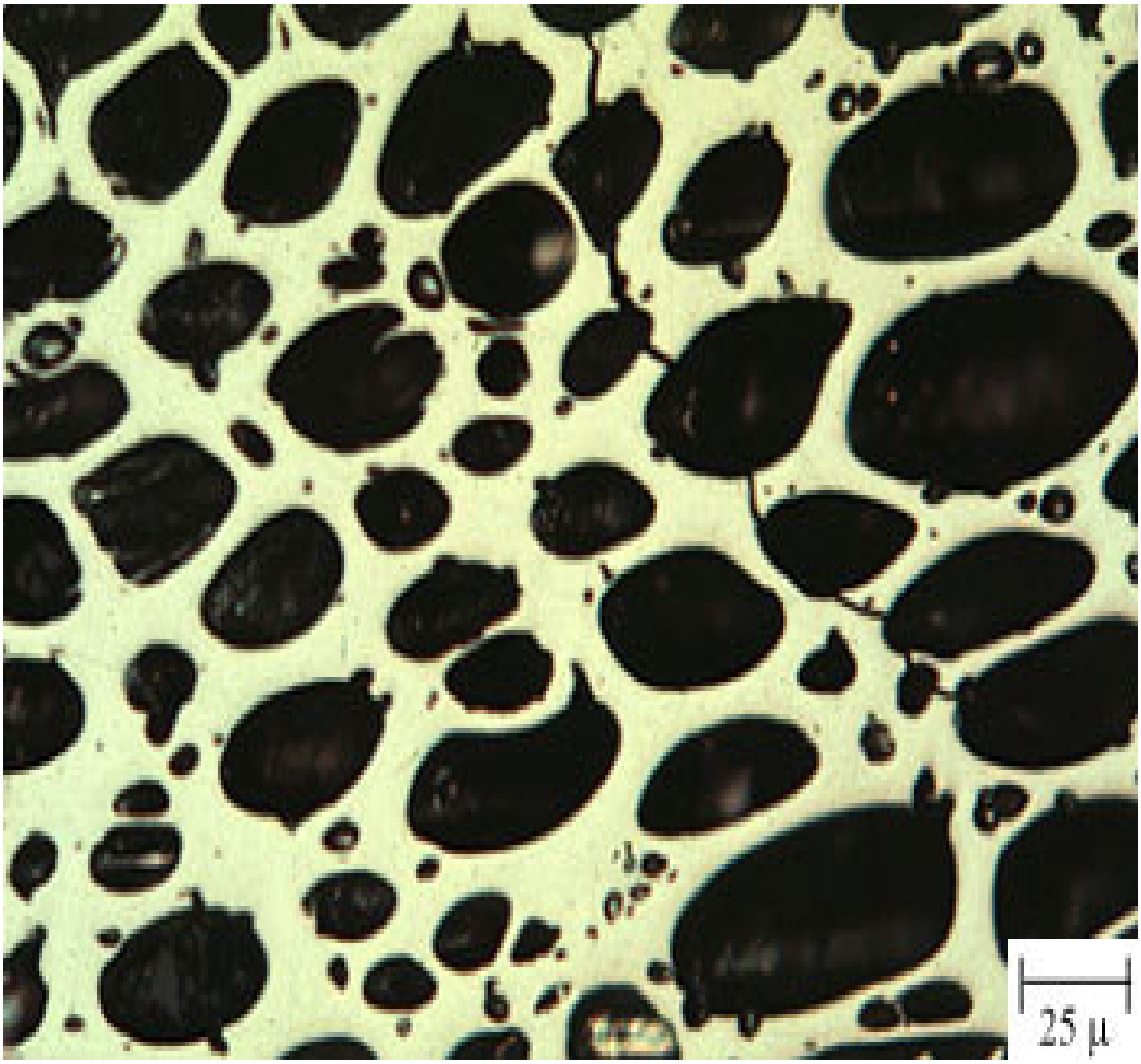


Figure 10 Fusinite with a characteristic open cell structure. It is the structure of pyrolyzed woody tissue, appearing similar to charcoal. Maceral Group Inertinite (Photomicrograph Atlas, ASTM, 2008).

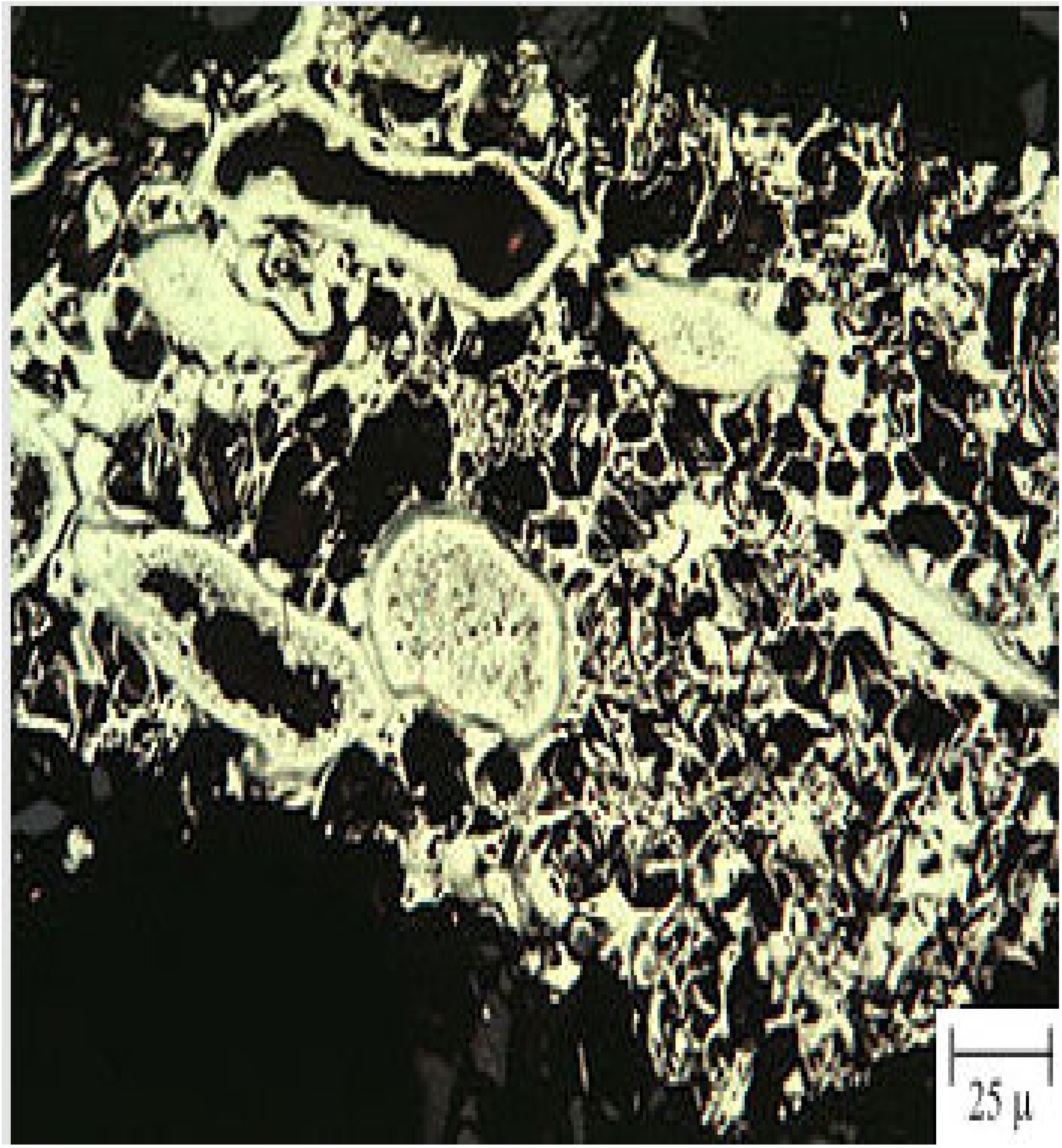


Figure 11 Fusinite showing a delicately preserved plant structure. (Photomicrograph Atlas, ASTM, 2008).

South African coals contain only small amounts of spore coats, leaf cuticles and other remains of leaves and seeds, which form parts of black durain and clarain, which are rarely found. South African coals are mixtures of vitrain and grey durain and vary from coals with a preponderance of vitrain (bright coal) through various banded mixtures with grey durain to pure durain (dull coal). (England et al, 2002)

In the Waterberg however, specifically in the Volksrust Formation, an abundance of vitrain occurs. Maceral analyses of the coal seams and the inter-bedded carbonaceous mudstones show that vitrinite is the dominant maceral (up to 90 %), whereas inertinite, liptinite and reactive semi-fusinite generally occur in minor or trace proportions. The vitrinite content increases upward in the formation, with a concomitant decrease in inertinite (including reactive semi-fusinite) from around 60% inertinite at the base of the formation. The upward increase in the vitrinite concentration is associated with a decrease in the energy of the depositional environment, which would have been instrumental in the preservation of the vitrinite. (Faure et al.1996).

4.2 WASHABILITY CHARACTERISTICS

Examples of the ranges of densities exhibited by organic macerals are illustrated below.

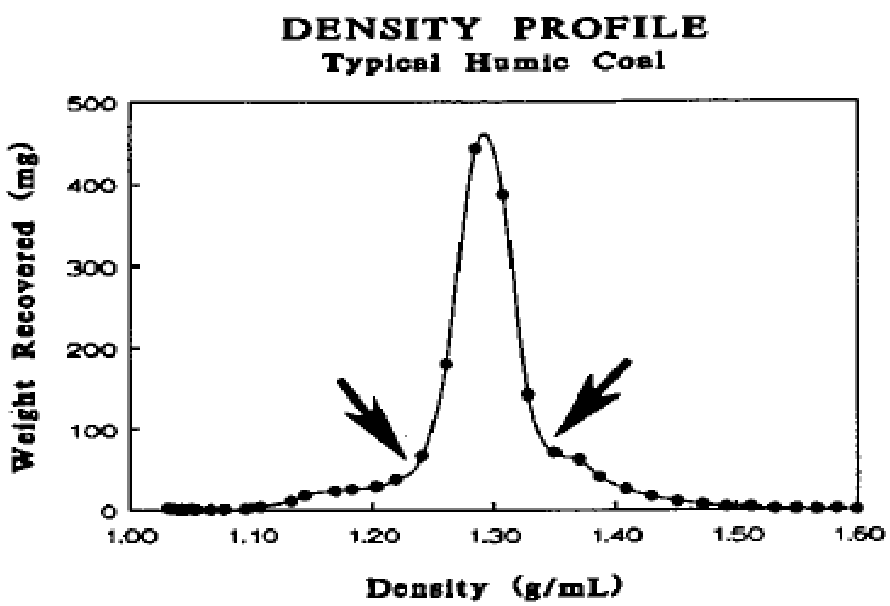


Figure 12 Typical Humic/Vitrinite peak. (Crelling, 1992)

A typical density profile of a humic coal is illustrated in Figure 10. The main peak represents the vitrinite group macerals, the low density shoulder representing the liptinite group and the high density shoulder representing the inertinite group. The arrows indicate typical cut points between the macerals.

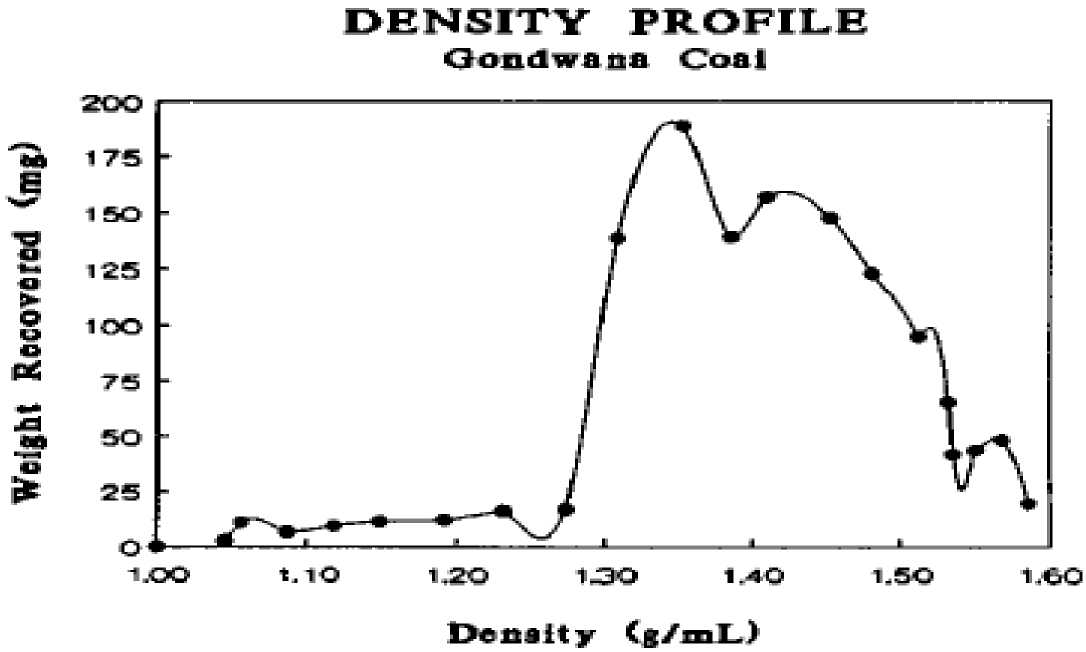


Figure 13 Typical Vitrinite / Inertinite Gondwana Coal. (Crelling, 1992)

The second selected density profile is that of an inertinite rich coal, the original sample obtained from South Africa representative of a typical Gondwana coal (Crelling, 1992). The highest peak represents vitrinite (1.30 to 1.35 g/cc) while the bulk of the sample is representative of the inertinite group macerals on the high density side of the vitrinite, i.e. 1.40g/cc to 1.50 g/cc.

These two figures above illustrate clear density peaks and ranges for the macerals in coal. In terms of washabilities, such macerals could be separated cleanly and easily through the use of well defined density cuts. Similarly, minerals with densities greater than 2.5 g/cc, if liberated and existing independently from the macerals, would also be separated easily in a beneficiation process on the basis of their high density values. However, if mineral matter was to be included in a particle of vitrinite, for example, the combined density or “relative density” of that particle would be higher than that for vitrinite. Similarly, if both vitrinite and inertinite were to be associated together in a particle, the combined or relative density of that particle would lie somewhere between the vitrinite and inertinite values. In both cases, the complex particles would possess densities out of their normal component ranges and therefore separation into specific quality fractions would not be clear, clean or easy. It is particles such as these that give rise to near-density materials in the washing process.

The vitrinite in the Volksrust Formation is intimately associated with minute layers of clay, some in discreet bands and some as tiny particles embedded within the vitrinite band itself. The latter clay-rich coaly bands give rise to a variable range of relative densities which, in turn, are difficult to separate at fixed density cuts in sink and float washability tests as they tend to hover at the density boundaries. By way of example, most of the problems with regard to the Semi Soft Coking Coal product exist as a result of the distribution and quantity of near density material in the lower density regions of the bright coals.

In terms of formal beneficiation parlance, '*near density*' material is defined as the material within ±0.1 g/cc of the cut point relative density at which the coal is being washed as defined in "Coal preparation in South Africa 2002"(England et al, 2002).

The following photographs are of hand samples of coal taken from the Volksrust Formation at Grootegeluk Mine. These illustrate the complex banding in coal (i.e. the matrix) with bright bands of vitrinite interspersed with dull bands and mineral clasts. During mechanical breakdown the larger vitrinite bands and clasts are easily liberated while the Inertinite bands require more energy to break down. Some particles, on breaking down, are also likely to possess some vitrinite, inertinite and/or mineral matter mixed within them. It thus follows logically that the inherent matrix of a coal would, in effect, influence the liberation of the various components in that coal. This is further exacerbated by the impact of size of particle on crushing. For example, where coal is broken to -13mm top size, not all the desirable vitrinitic material would be liberated because some would remain in the matrix of the large particles. The sink float results of such material would exhibit lower yields than surmised from the proximate analysis. If the core were crushed finer, the overall yield would be higher.

The top size of broken material will therefore dictate the yields obtained, whether coal is sourced from a small borehole core or as coarse run-of-mine material supplied directly to the washing plants. The possibility of liberation of the vitrinite material within the matrices as shown in the figures below would therefore be greater when obtained from crushing to smaller sizes, as would occur when preparing a borehole core. Given that vitrinite is much sought after as a high value low ash semi soft coking coal blend product, the correct prediction of yield from the washing process is of great economic relevance.

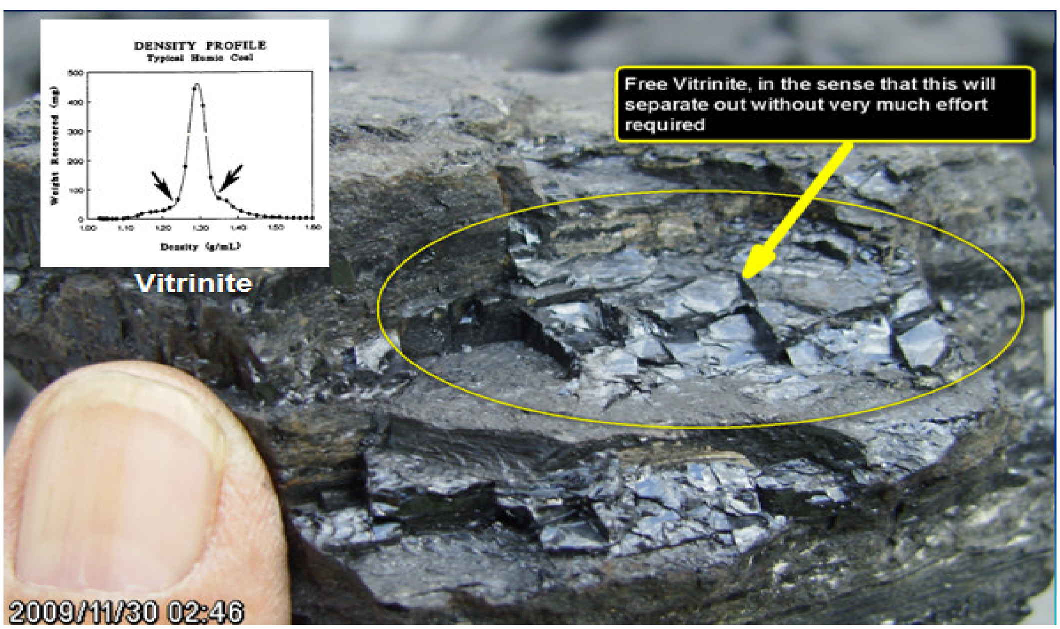


Figure 14 Typical Volksrust Formation Coal.

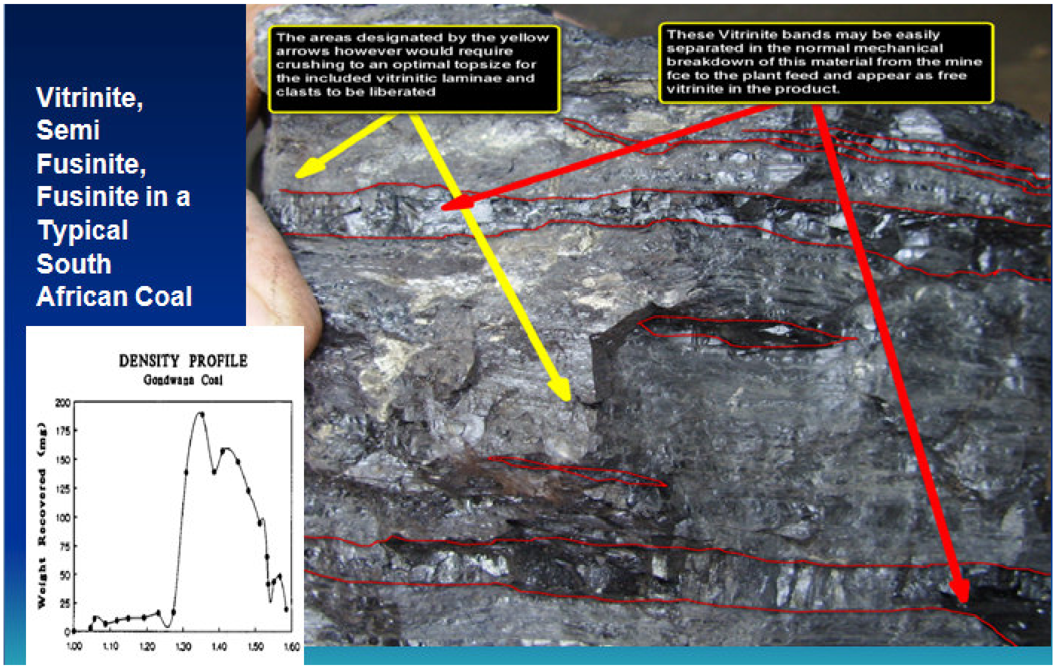


Figure 15 Typical Volksrust Formation Coal showing more inertinite with thin lenses of vitrinite.

4.3 HISTORICAL DATA FROM GROOTEGELUK MINE

Considering the foregoing information and assessment concerning the Grootegeluk mining benches in the Volksrust Formation, i.e. benches 2 through 5, the historical data obtained from Grootegeluk Mine will now be presented. Figure 14 presents the plot of averaged yields for the respective float fraction yields, for the various benches. This indicates the data spread as obtained from the Mine's empirical fractional analysis.

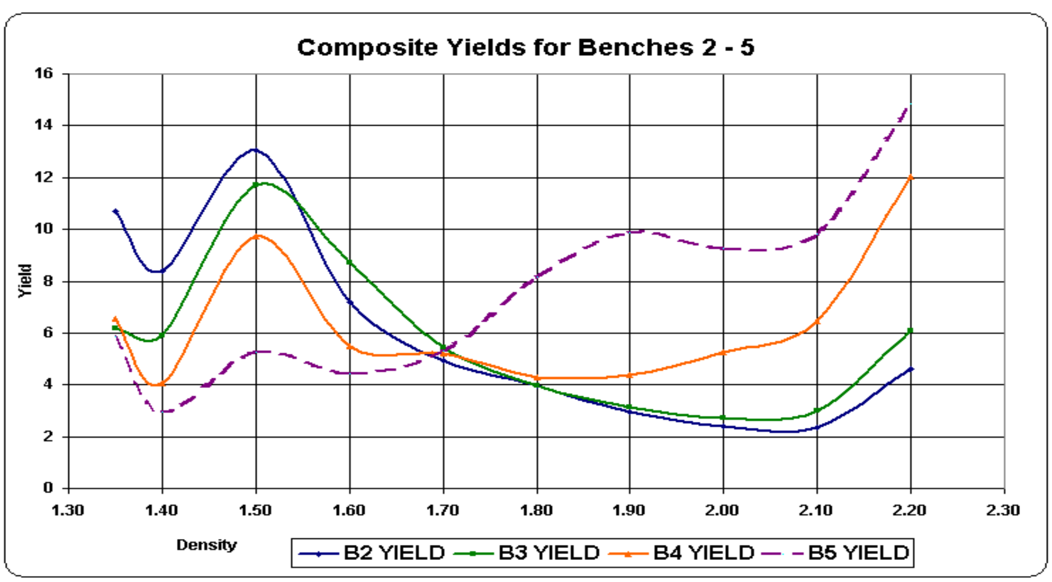


Figure 16 Composite plot of float fraction yields for Benches 2 through 5.

The washability analyses were undertaken from an initial float density of 1.35g/cc, to 1.40g/cc and then at 0.1g/cc increments to 2.2g/cc on material broken to -13mm. This does not allow any scope for determining actual yields of vitrinite material or any macerals at a lower density than vitrinite. The 1.35g/cc starting point is already slightly higher than the cut limit indicated in the plot of a typical humic coal shown in Figure 6. The range of density fractions used for float sink analysis was chosen so that sufficient material would be available for the spectrum of analysis required to be done, thus each fractional density actually represents the cumulative densities within that range, i.e. Starting at 1.35g/cc, the float product may represent material with densities as low as 1.1g/cc thru 1.35g/cc. The inadequacy of this led to the evaluation of the ash and density data to determine whether a relationship between the two parameters could be established in the hopes that this relationship could then be utilized to improve the evaluation of the proximate data.

4.4 ASH-DENSITY EVALUATION OF ANALYTICAL DATA

A total of approximately 31,000 sets of fractional float data extracted from the Grootegeluk geological database were used for the current investigation. This data was then further subdivided into three categories, namely, coal samples, shale samples and, where applicable, bench composites.

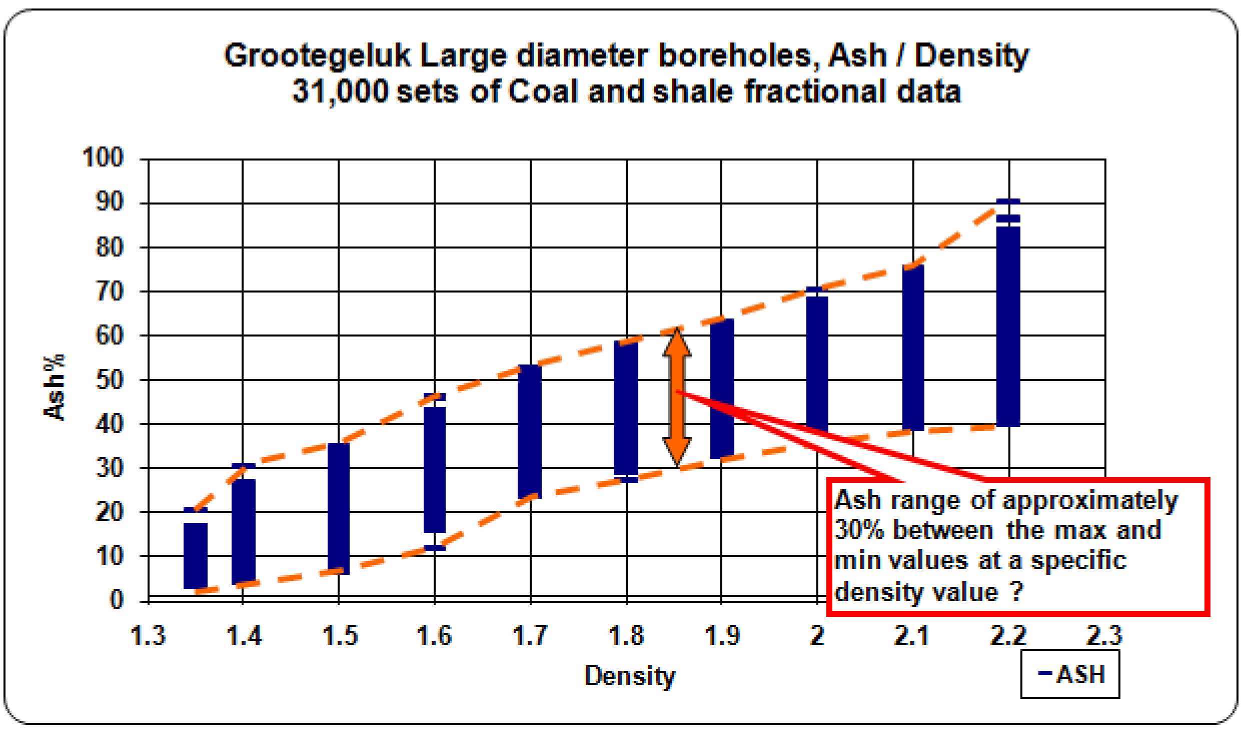


Figure 17. Illustration of the range of ash determinations around a specific density fraction

The problem related to near density material is illustrated in Figure 17 showing a range of up to approximately 30 basis points of difference between the lowest and highest ash values obtained from proximate analysis of the float fractions obtained within the specific density ranges. Normal plotting of these results dictates that the highest density value represents all the material that floated between the previous cut off and the next higher density value. The next graphic Figure 18 outlines the major objective of this investigation.

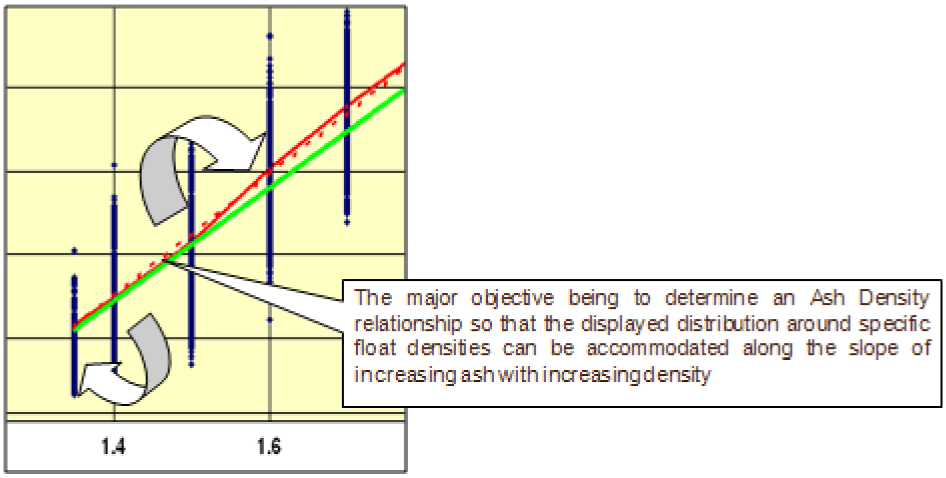


Figure 18 The above schematic attempts to illustrate the objective to be attained. That is, to present an even distribution of ash values relating to true density values along the slope of increasing density.

The most relevant outcome of the assessed data has been plotted and is shown in Figure 19.

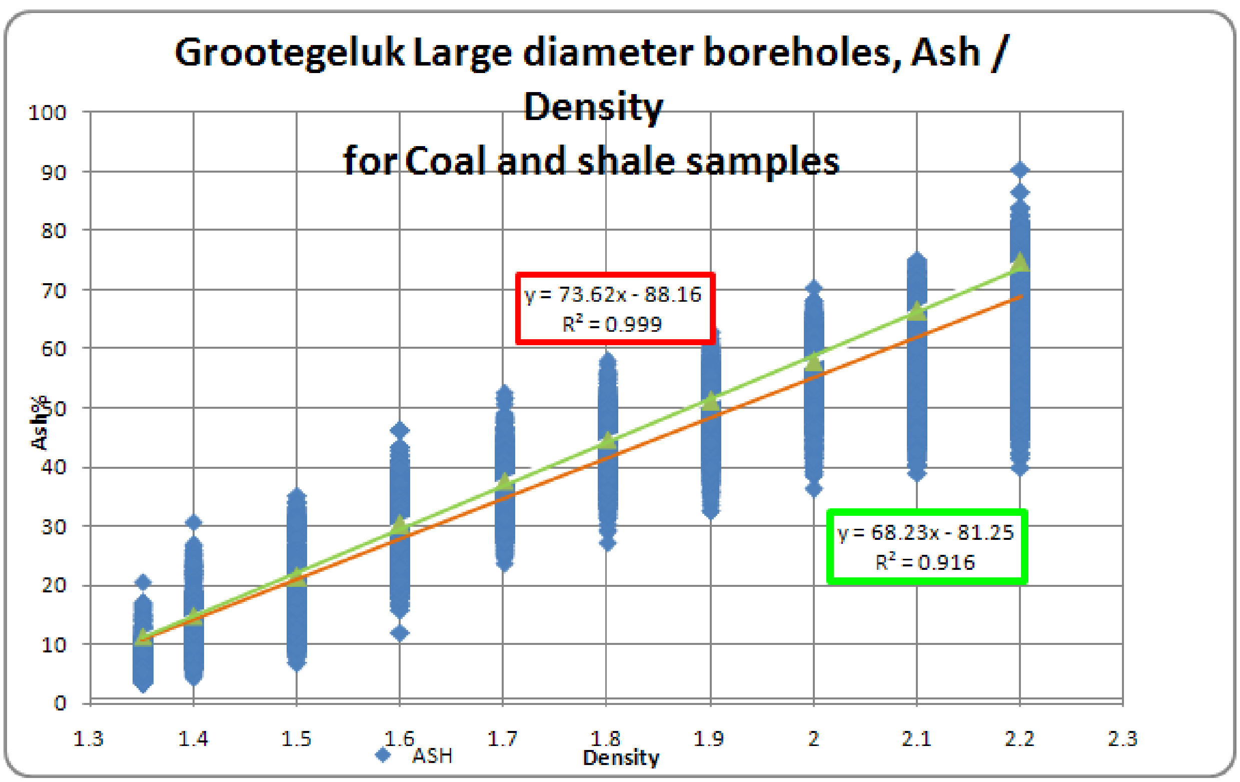


Figure 19 Grootegeluk coal Ash/Density relationship

Figure 19 portrays the distribution of fractional ash analyses at the various density fractions as well as an averaged linear trend in bright green across this distribution. This trend serves to indicate the general values applicable to wash table construction for product extraction based on coal and shale analysis data. Superimposed on this plot are the results of samples consisting of coal analysis data only, with a fitted trend in red.

4.5 WATERBERG COAL FIELD SAMPLING STRATEGY

It is necessary, at this point, to clarify the "coal only" sample statement. Due to the intercalated nature of coal and shale within the deposit, a specific correlation and sample identification methodology was introduced by Dreyer (pers. com) and this has been applied at Grootegeluk. A brief explanation of the sampling strategy applied at Grootegeluk and in the Waterberg by Exxaro is outlined below to clarify the reason for the subdivision of samples into a coal and shale component.

Core recovered from the exploration drilling is laid out in 20m lengths on corrugated iron sheets, depth corrected to correspond with drilling record and then marked out by depths with regard to changing lithologies on the core.

The samples are logged to 1cm accuracy. Once the hole is completed final depth adjustments are made so that the entire sequence and its different sedimentary cycles can be seen. The geologist then logs the core lithologically and produces a log profile of the borehole for correlation and sample delineation purposes.

On completion of correlation and sample delineation the information with regard to sample boundaries is marked out on the core and on the corrugated sheets with the relevant sample identification indicated.

The borehole is now ready to be sampled. Samples are selected, split into coal and shale portions based on the criteria that shale or coal bands smaller than 1cm be included with the respective overruling lithology, by implication then, small shale bands or laminae within coal sequences, less than 1cm in width will be included with the overriding lithology.

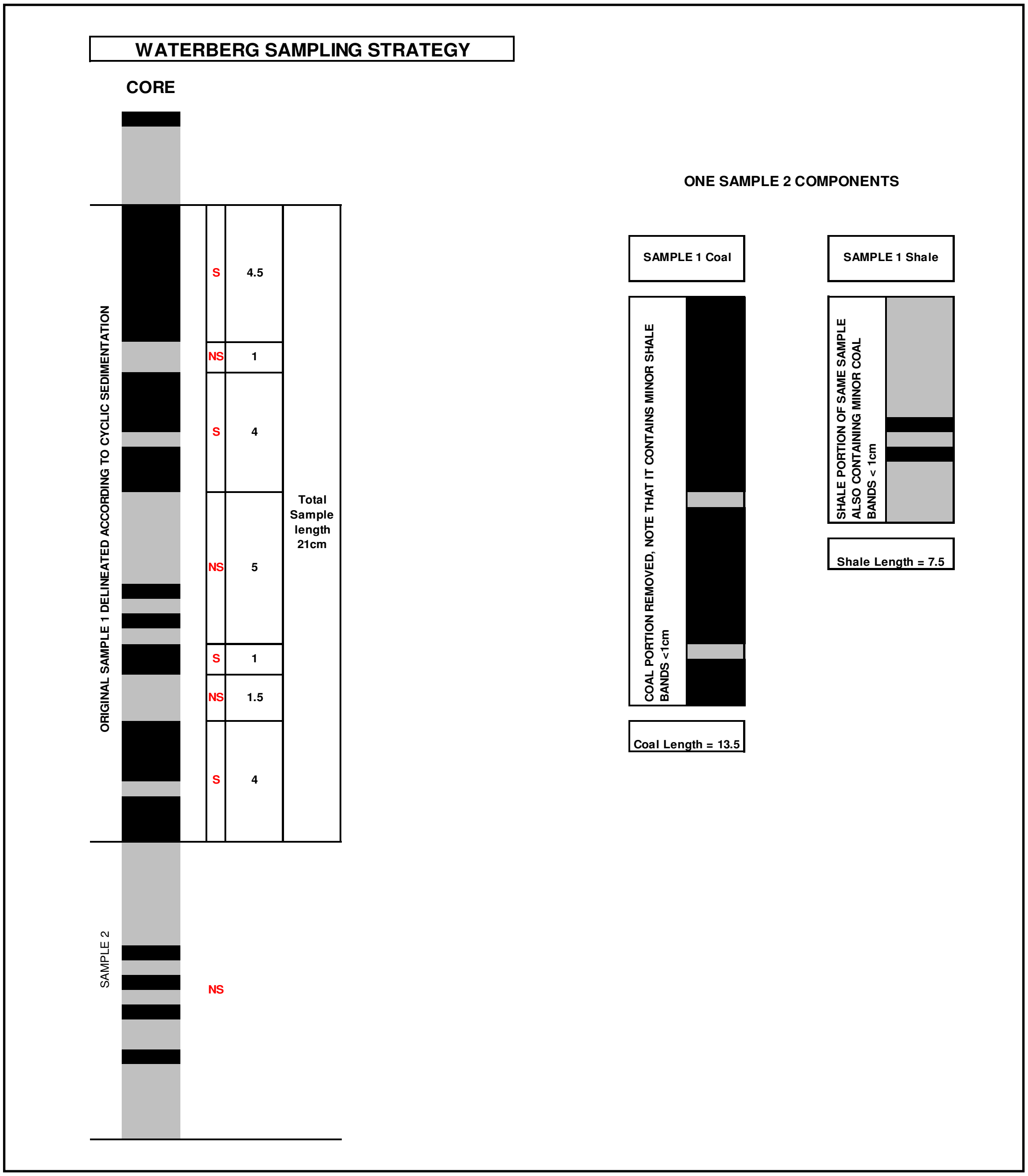
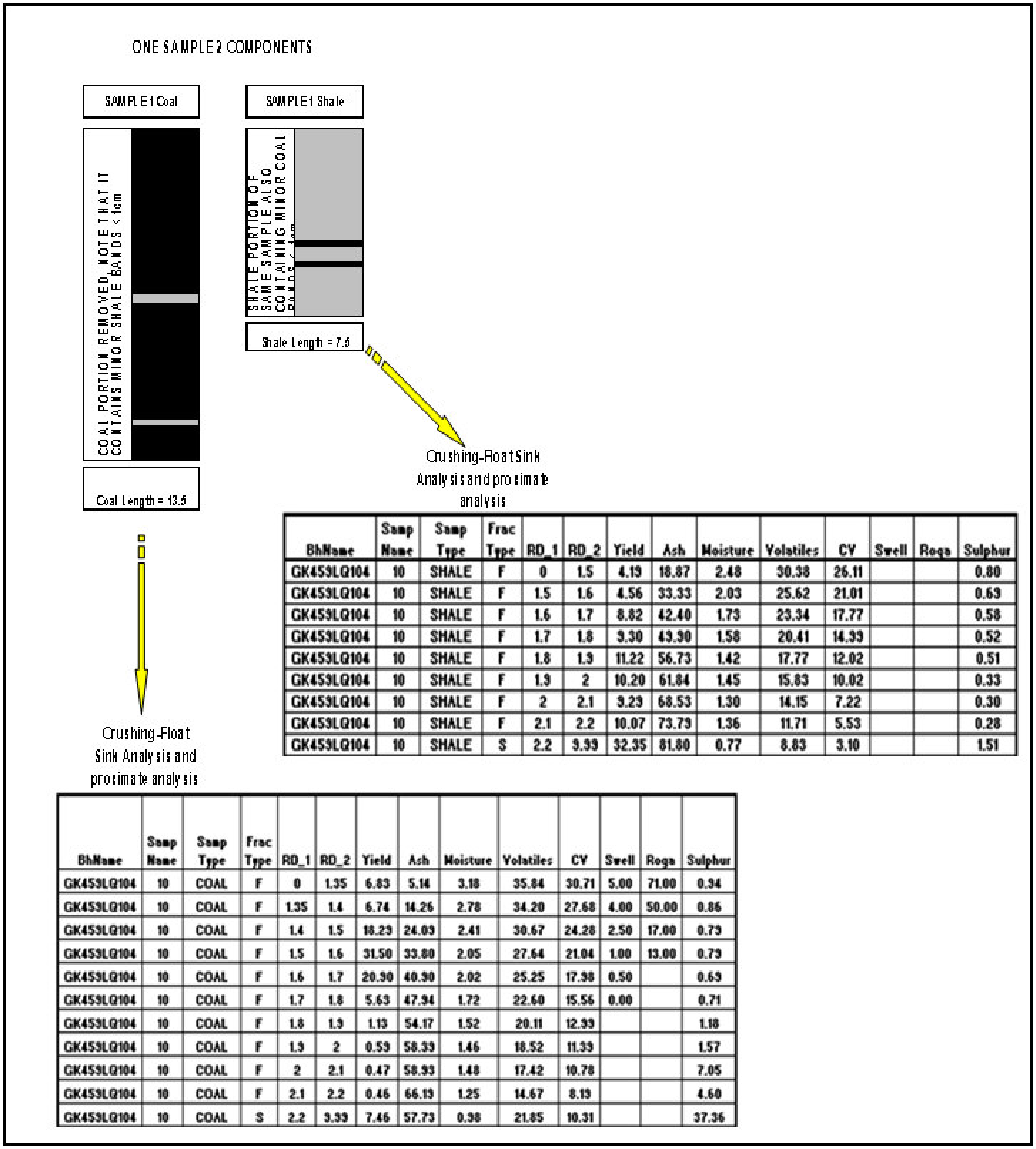


Figure 20 Grootegeluk Coal Mine, core sampling strategy.

The single correlated sample above is broken into two components, a coal portion and a shale portion, analyzed separately and then re-composited to obtain a single sample representative value from the separate wash tables. The coal samples are washed (sink floated) from Rd 1.35 – 2.20 g/cc while the shale samples are washed from Rd 1.50 – 2.20g/cc.



BhName	Samp Name	Samp Type	Frac Type	RD_1	RD_2	Yield	Ash	Moisture	Volatiles	CV	Swell	Roga	Sulphur
GK459LQ104	10	SHALE	F	0	1.5	4.19	18.87	2.48	30.38	26.11			0.80
GK459LQ104	10	SHALE	F	1.5	1.6	4.56	33.33	2.03	25.62	21.01			0.69
GK459LQ104	10	SHALE	F	1.6	1.7	8.82	42.40	1.73	23.34	17.77			0.58
GK459LQ104	10	SHALE	F	1.7	1.8	9.30	49.90	1.58	20.41	14.99			0.52
GK459LQ104	10	SHALE	F	1.8	1.9	11.22	56.73	1.42	17.77	12.02			0.51
GK459LQ104	10	SHALE	F	1.9	2	10.20	61.84	1.45	15.83	10.02			0.33
GK459LQ104	10	SHALE	F	2	2.1	9.29	68.53	1.30	14.15	7.22			0.30
GK459LQ104	10	SHALE	F	2.1	2.2	10.07	73.79	1.36	11.71	5.53			0.28
GK459LQ104	10	SHALE	S	2.2	9.99	32.35	81.80	0.77	8.83	3.10			1.51

BhName	Samp Name	Samp Type	Frac Type	RD_1	RD_2	Yield	Ash	Moisture	Volatiles	CV	Swell	Roga	Sulphur
GK459LQ104	10	COAL	F	0	1.35	6.83	5.14	3.18	35.84	30.71	5.00	71.00	0.34
GK459LQ104	10	COAL	F	1.35	1.4	6.74	14.26	2.78	34.20	27.68	4.00	50.00	0.86
GK459LQ104	10	COAL	F	1.4	1.5	18.29	24.09	2.41	30.67	24.28	2.50	17.00	0.79
GK459LQ104	10	COAL	F	1.5	1.6	31.50	33.80	2.05	27.64	21.04	1.00	13.00	0.79
GK459LQ104	10	COAL	F	1.6	1.7	20.90	40.90	2.02	25.25	17.98	0.50		0.69
GK459LQ104	10	COAL	F	1.7	1.8	5.63	47.94	1.72	22.60	15.56	0.00		0.71
GK459LQ104	10	COAL	F	1.8	1.9	1.13	54.17	1.52	20.11	12.99			1.18
GK459LQ104	10	COAL	F	1.9	2	0.59	58.39	1.46	18.52	11.39			1.57
GK459LQ104	10	COAL	F	2	2.1	0.47	58.93	1.48	17.42	10.78			7.05
GK459LQ104	10	COAL	F	2.1	2.2	0.46	66.19	1.25	14.67	8.19			4.60
GK459LQ104	10	COAL	S	2.2	9.99	7.46	57.73	0.98	21.85	10.31			37.36

Figure 21 Grootegeluk wash table configuration.

The values and concomitant trends shown in Figure 19 were established from the detailed evaluation of different compositional sets of data, such as shale values, coal values and bench compositions for individual benches, a breakdown of the Volksrust Formation (Upper Ecca) and Vryheid Formation (Middle Ecca) and a combination of the most relevant sections. The regression results indicate an improvement in the alignment of the related ash density values from R^2=0.9167 to R^2=0.999.

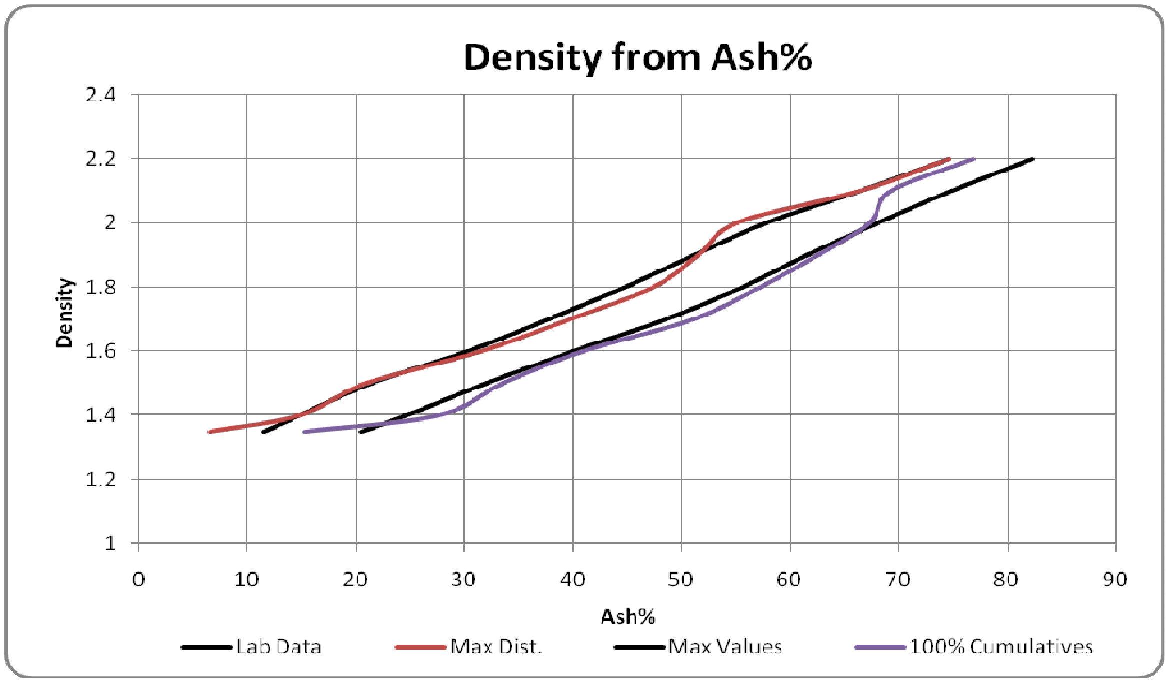


Figure 22 Density Ash plots from evaluation data.

Figure 22 is a plot of some of the evaluated data. Laboratory data in this figure are the same as the data portrayed in Figure 17. "Max Dist." refers to normal distribution plots of individual fractional values combined for the range of fractions used (an example of these distribution plots is shown in Figures 23 & 24). The "100% cumulative" is based on the maximum ash values per fraction; these are also derived from the distribution plots mentioned above. "Max values" pertain to the highest ash values per density fraction obtained from the analysis.

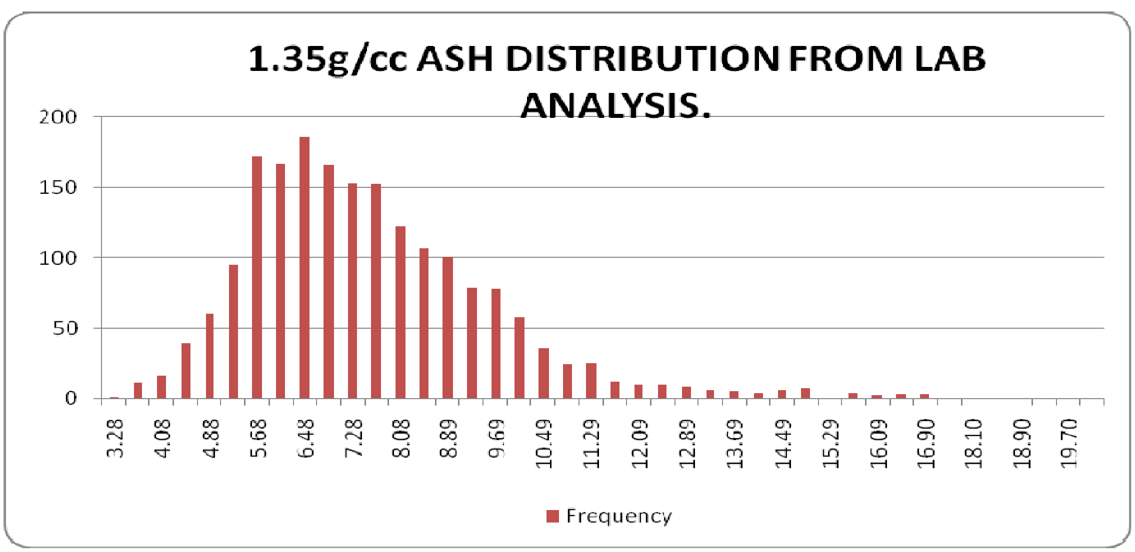


Figure 23 Normal distribution plot of 1.35g/cc range of laboratory ash analyses

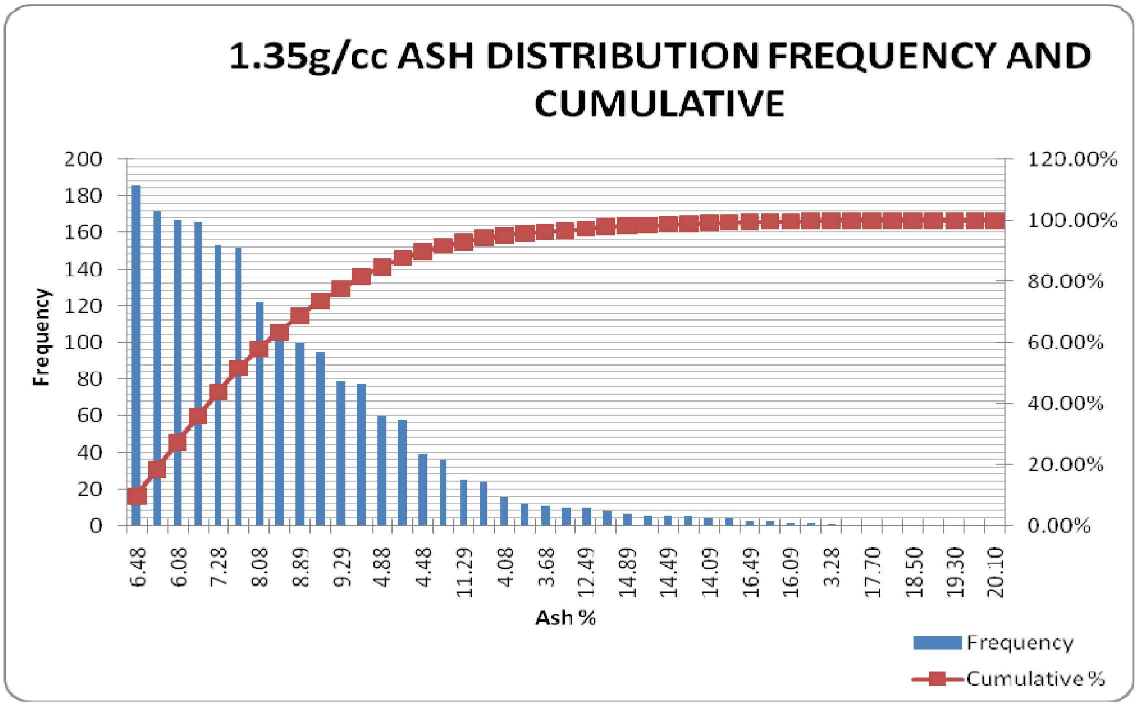


Figure 24 Sorted distribution and cumulative plot

Splitting and evaluating the data into categories, i.e. laboratory refined ash-density, maximum ash-densities and the distribution data from Figure 19, results in the following observation: Laboratory refined coal ash-density floats give a regression result of R^2 =0.999 and the maximums a regression of R^2 =0.9981, both illustrating a near linear relationship as depicted in Figure 25. The evaluation of the laboratory data was based on the most frequent occurrence of a particular ash value at the fixed density fraction.

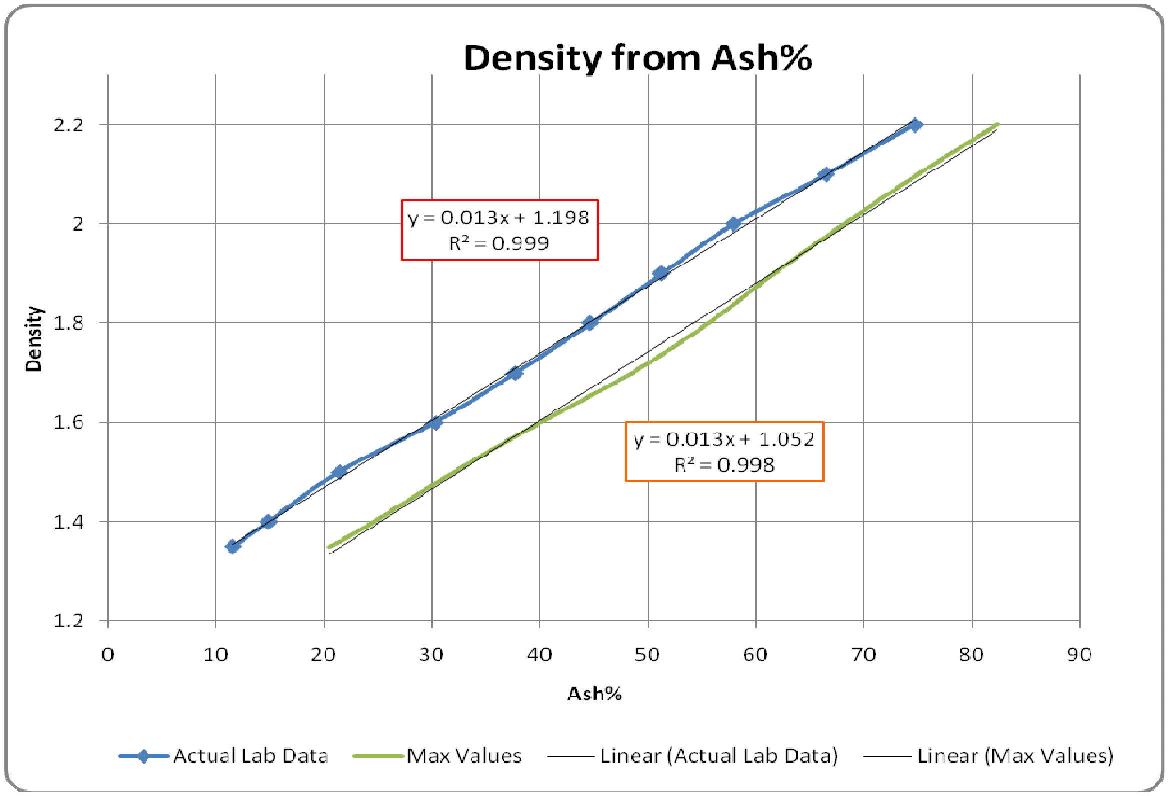


Figure 25 Laboratory-derived coal ash-density relationship.

On assessing the regressions obtained, the values derived for the refined laboratory coal ash/density values which give a near linear relationship are probably the most representative of the materials being studied. Thus it would appear to be appropriate to use this algorithm for ash density adjustments in wash tables of predicted material taken from blast blocks in the mine for beneficiation in the GG1 plant. Bench 3 samples, taken during a closed loop test from four cored boreholes within the blast block being investigated, were analyzed as a bench 3 composite and plotted on the same basis ($_4$Roux L. 2006). These also resulted in a regression compatible with the evaluation conducted. This is shown in Figure 26. Regressions obtained from the composite evaluation result in a linear fit with R^2 =0.992.

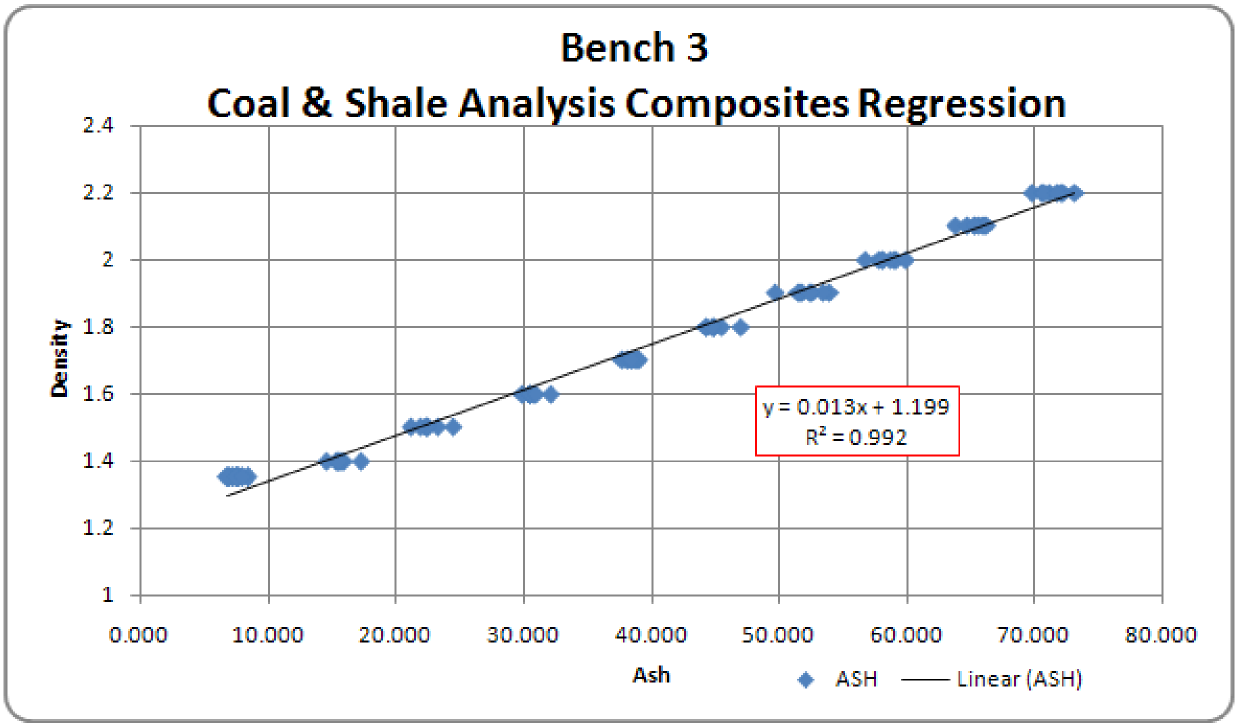


Figure 26 Linear regression of bench 3 ash/density from closed loop test data

This fact that the applied algorithm's regression with actual bench composites gives the correlation that it does, serves to justify the application of this approach to wash table information in order to align the data more closely with the relevant cut densities of the raw material. This is turn results in a less biased end result for predictive purposes.

Further proof of the hypothesis was obtained from float and sink data performed at lower densities on borehole GKSPES36, one of the special cored holes drilled during a closed loop test. This borehole was sampled to represent bench 3, initial float sink analysis was done from 1.35g/cc to 2.2g/cc, and sufficient material was still available to extend the float sink analysis into the lower density regions.

This sink float test was then repeated from 1.25g/cc. The results were used to re-construct the wash table and the relevant regressions were calculated to compare actual laboratory data with the values obtained through extrapolation by applying the ash/density adjustment algorithm. Regression results obtained from this exercise were R^2=0.9973.

Rd Float	Moist	Ash %air d	Ash %Ad	Vol %air d	Vol %Ad	CV Calc	CV	Tot %Sulphur	Pyritic Sulphur	Sulphates	Organic	Yield
1.25	2.7	2.5	2.6	36.2	37.2	32.06		0.88	0.02	0.02	0.84	0.8
1.30	2.3	5.0	3.7	36.3	37.1	32.20		0.85	0.05	0.02	0.78	3.2
1.35	2.0	10.4	10.7	36.3	37.1	29.81		0.92	0.18	0.03	0.71	3.2
1.40	1.8	15.4	15.7	35.5	36.1	28.19	27.59	0.92	0.26	0.08	0.58	4.1
1.50	1.3	22.5	22.8	33.2	33.6	25.97	25.02	0.94				11.0
1.60	1.6	30.6	31.1	29.7	30.2	22.81	21.76	0.99				8.2
1.70	1.4	38.9	39.4	26.8	27.2	20.00	18.74	1.09				5.1
1.80	1.6	45.0	45.7	24.1	24.5	17.63	16.16	1.29				3.9
1.90	1.4	52.7	53.4	21.1	21.4	15.13	13.64	1.11				3.1
2.00	1.3	59.2	60.0	18.0	18.3	12.94	10.76	1.11				2.6
2.10	1.4	66.0	66.9	15.1	15.3	10.56	8.01	0.89				2.9
2.20	1.3	71.2	72.1	13.7	13.9	8.89	6.13	0.85				3.1
2.50	1.4	79.9	81.0	10.8	10.9	5.97	2.63	0.74				48.8

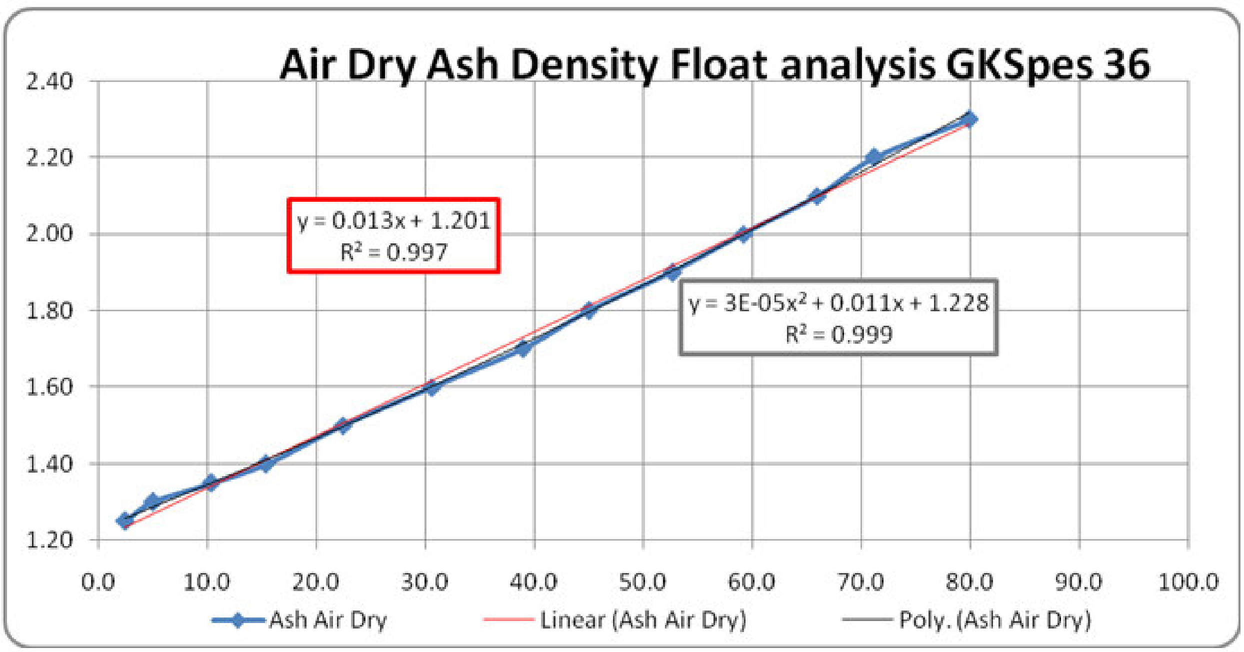


Figure 27 Washability data and plot of extended analysis on GKSPES36

Three sets of linear equations for the ash density relationship listed below were obtained during this evaluation. The first from the 31,000 datasets, the second from the bench 3 composites and the last from actual float/sink extended analysis. The R^2 correlations of these regressions are so close that any one of the equations could be applied successfully, although the best has been chosen for further evaluation.

Table 3 Summary of regressions obtained from ash/density data.

	Linear Regressions for Ash/Density			R-Fit
1)	0.0136	* Ash +	1.198	0.999
2)	0.0136	* Ash +	1.1994	0.9926
3)	0.0136	* Ash +	1.2018	0.9973

Utilizing the determined algorithm, 0.0136*Ash + 1.198g/cc to adjust the density values in the wash tables that were used to generate Figure 16, repeated below, results in a totally different plot showing the true nature of the raw material adjusted to true density of the respective float fractions shown in Figure 29.

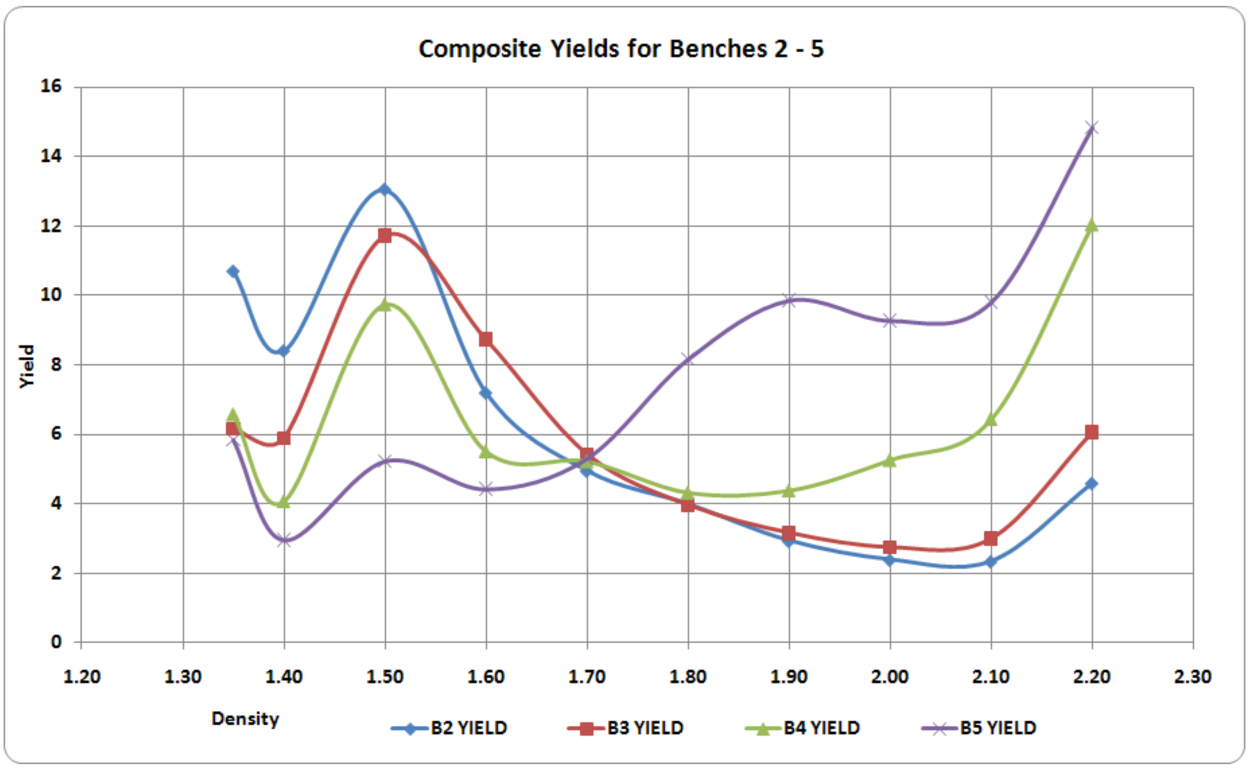


Figure 28 Composite plot of float fraction yields for Benches 2 through 5.

In Figure 16, repeated above, the float yields are plotted at the maximum float density for each fraction analysed, staring at 1.35g/cc through 2.20g/cc as per laboratory results.

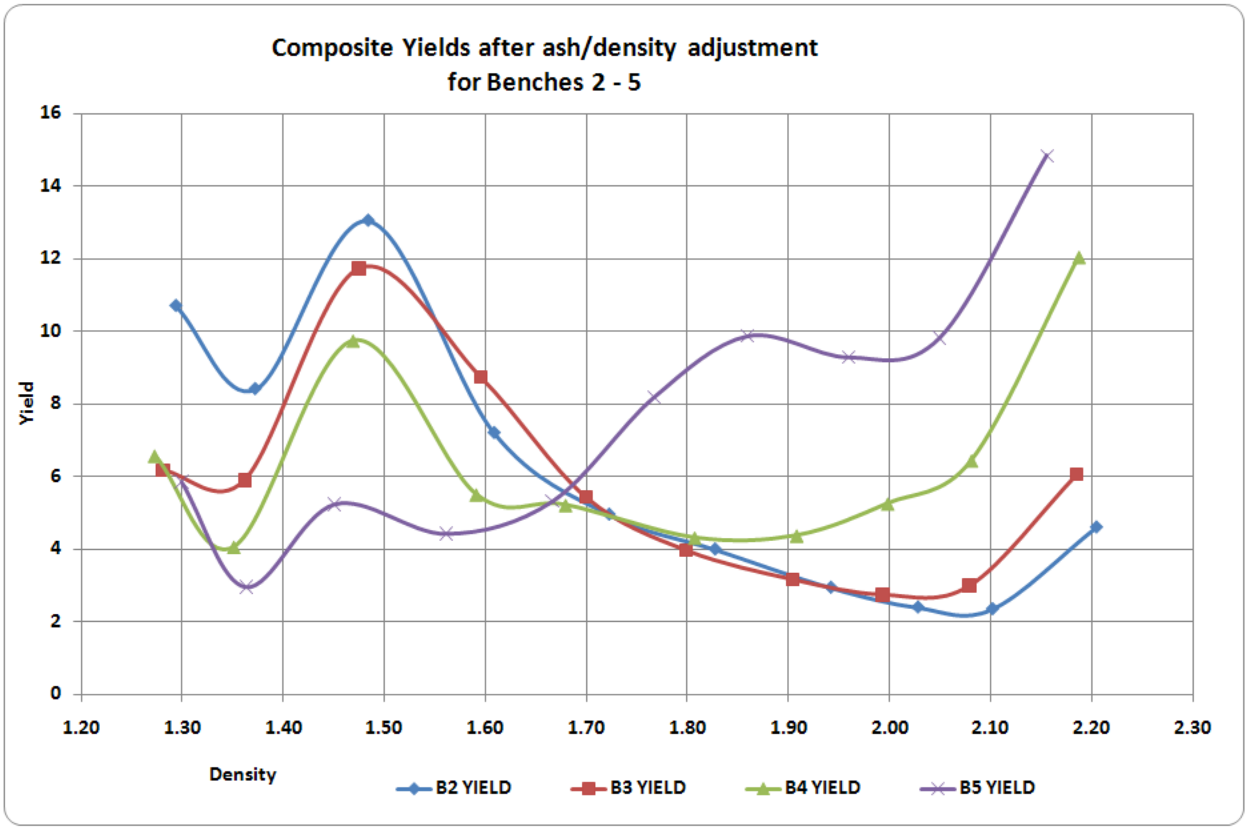


Figure 29 Ash adjusted density plots of benches 2-5 float fraction yields

In Figure 29 the true density derived from the application of the ash adjusted density algorithm of free vitrinite has been plotted, it is noteworthy that the free vitrinites are now in their representative range between 1.25g/cc and 1.35g/cc, what this implies is that the material shown in Figure 16 at a density of 1.35g/cc is in fact below 1,3g/cc. Both Figures show that bench 2 exhibits the highest vitrinite yield for semi soft coal, while benches 3 and 4 and 5, are substantially lower. Benches 3 & 4, however, appear to have more vitrinites closely associated with semi-fusinite, the vitrinites probably matrix bound and not as easily liberated.

5 RESULTS AND DISCUSSIONS

This chapter presents discussions and applications based upon the new algorithms developed above, relating ash to density and its implication to predicted yields in beneficiation. This includes the application of the ***ash adjusted density*** (AAD) concept to the environment of deposition of the Waterberg coals which relates in turn to the yields of desirable semi soft coal products. In addition AAD was applied to the liberation of low ash semi soft coking coal and high ash middlings and compared to historical yield predictions and to current actual yields in beneficiation plant.

5.1. YIELD DISTRIBUTION AND DENSITY RELATIONSHIP RELATED TO DEPOSITIONAL ENVIRONMENT

If one were to analyze each sample in the vertical succession with respect to the distribution of low density material, a reasonably good estimate as to prevailing conditions at the time of deposition would be formed as well as the probability of expected yields being attained at specified ash controls. This type of analysis would also allow the evaluation of sample composites of various combinations within the vertical succession, and their effective wash tables. A borehole GK459LQ125 was randomly selected, each sample's analysis composited to reflect a wash table taking both litho-types, the coal portion and shale portion into account, a zone differentiation made, illustrating the samples within that specific zone and finally a zone composite wash table derived. Note the changes in yields at the fractional values as a result of this, as well as, the effect of the distribution of fractional portions as a result of either fining or coarsening upward sedimentary cycles in the geophysical log portrayed in Figures 30 and 31. The complete evaluation of Borehole GK125 is portrayed graphically in Appendix E.

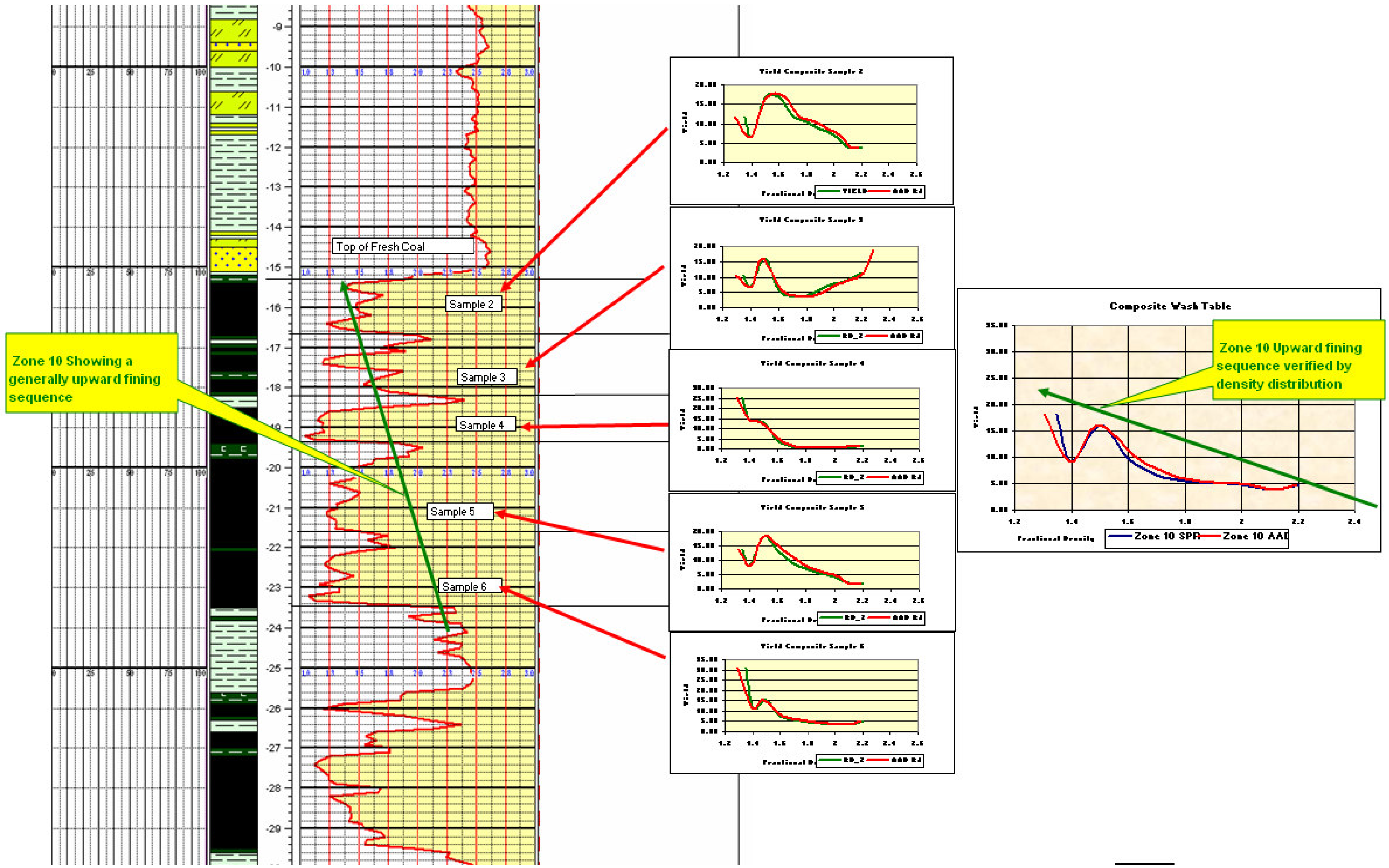


Figure 30 Geophysical log depicting sample delineation, individual sample composite wash curves, samples within a zone and the zone composite wash curve.

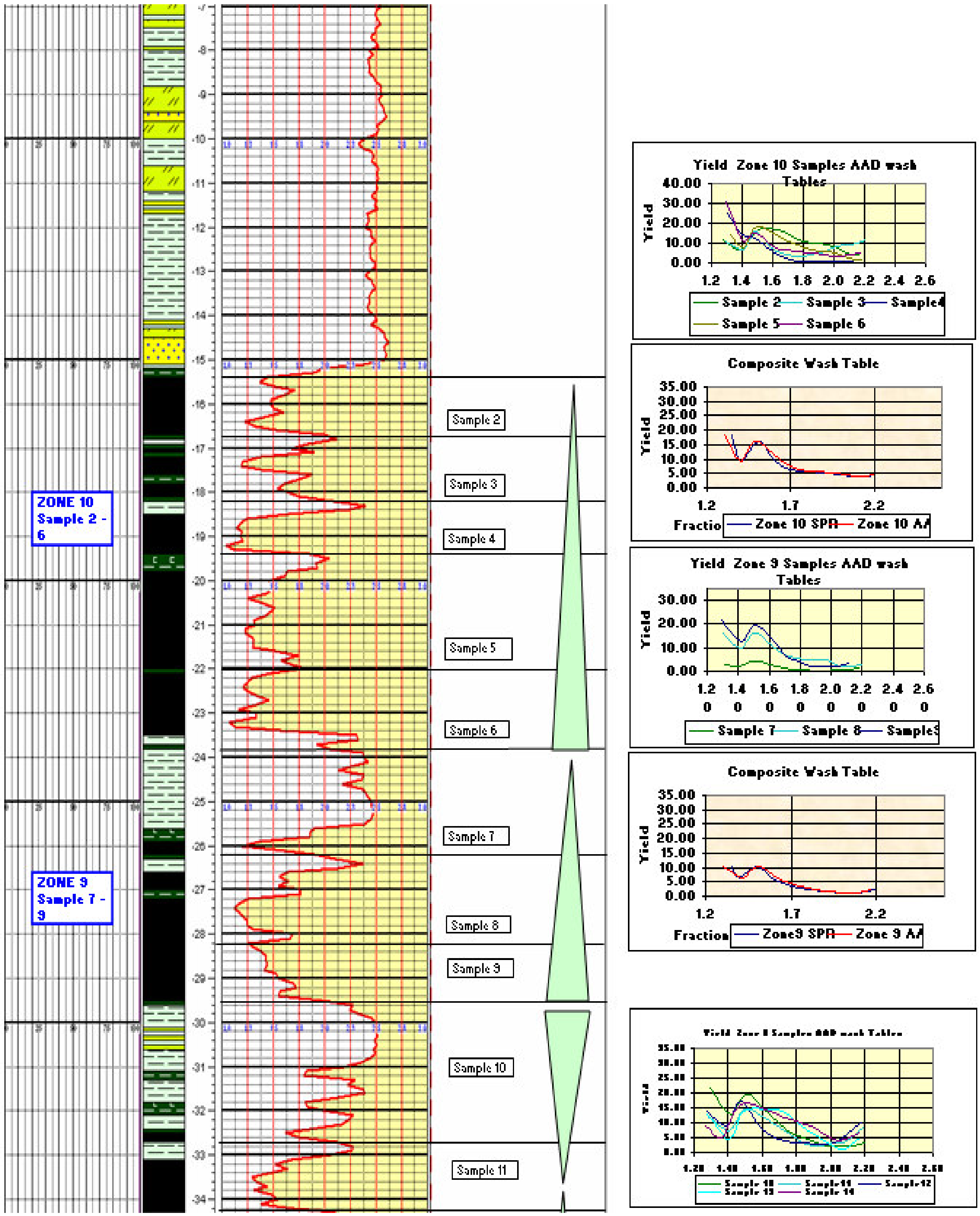


Figure 31 Section of geophysical log showing upward coarsening and fining cycles related to zones as well as analytical composites for comparative purposes.

This exercise was then expanded to include composites of the benches as per definition and comparisons made for the Volksrust Formation and the Vryheid Formation. The first set of comparisons of yields at the fixed density ranges as obtained from float sink analysis indicate a higher yield distribution at approximately 1.50g/cc in the Volksrust Formation. The plotted bench values, Figure 32 are also indicative of the increasing low density yield material from bench 5 with the lowest yields in this low density range increasing upwards to bench 2, with the highest yields.

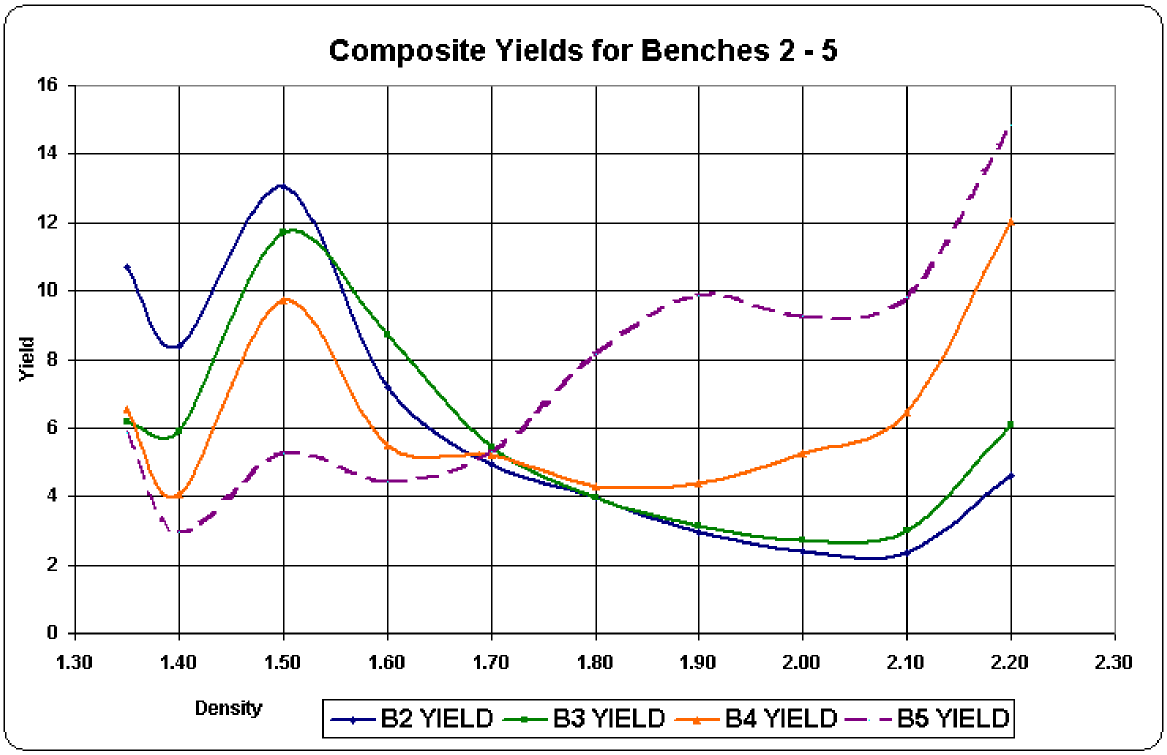


Figure 32 Density yield distribution for benches 2 thru 5 indicative of a low energy regime.

The ash adjusted (AAD) composite plot highlights the material in the lower density regime and shows a gradual transformation in depositional environment with regard to sediment transport and energy regime. Bench 2, 3 and 4 trends portray one set of conditions while bench 5 reflects a change in scenario. Benches 2, 3 & 4 appear to be associated with slightly lower energy regimes allowing settling of lower density material with some moderate reworking close to the source, while bench 5 displays settlement after transportation with a relatively even mixture of representative density materials.

The effective yield of a low ash, semi soft blend coking coal from benches 2 and 3 derived from freely disseminated vitrinite should thus be higher than those from benches 4 and 5, with 5 being the lowest. This however is not portrayed in the cumulative plot of the ash adjusted densities as shown in

Figure 34. Bench 3 & 4 exhibit relatively lower yields in the low density range and may require additional mechanical breakdown to liberate the vitrinite component.

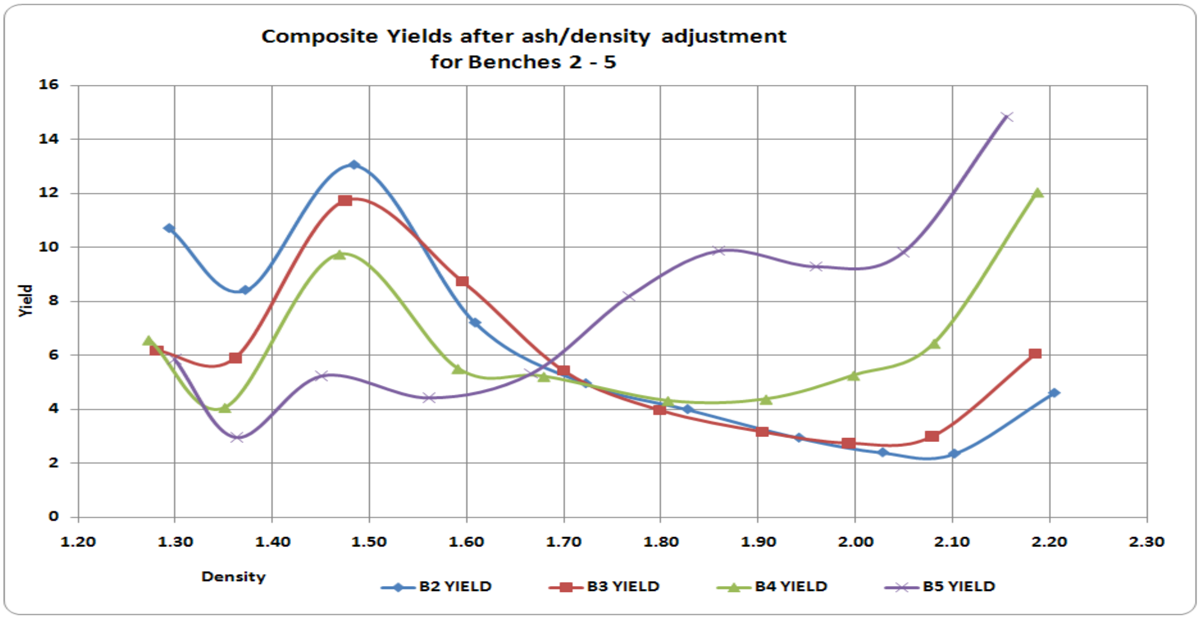


Figure 33 Ash adjusted composite plot of benches 2 thru 5

The vitrinite component may be entrapped in a semi-fusinite matrix. Unfortunately, due to increased phosphorous in bench 5, this bench is not considered suitable for a semi- soft coking coal blend product, thus only benches 2 thru 4 are beneficiated for this purpose.

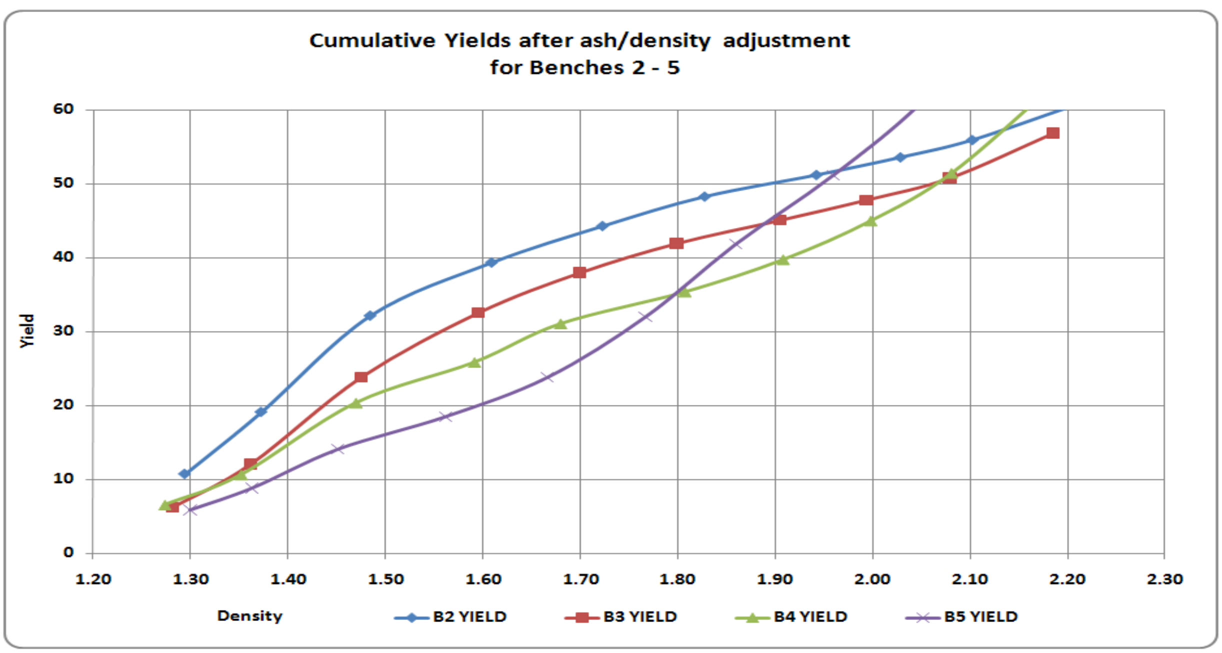


Figure 34 Cumulative yield plot of ash adjusted density for the density range between 1.25g/cc and 1.60g/cc.

The second set of comparisons of yields at the fixed density ranges as obtained from float sink analysis for the lower benches indicate a random yield distribution at varying fixed density values for the individual benches in the Vryheid Formation suggesting varying depositional properties associated with a fluvial environment.

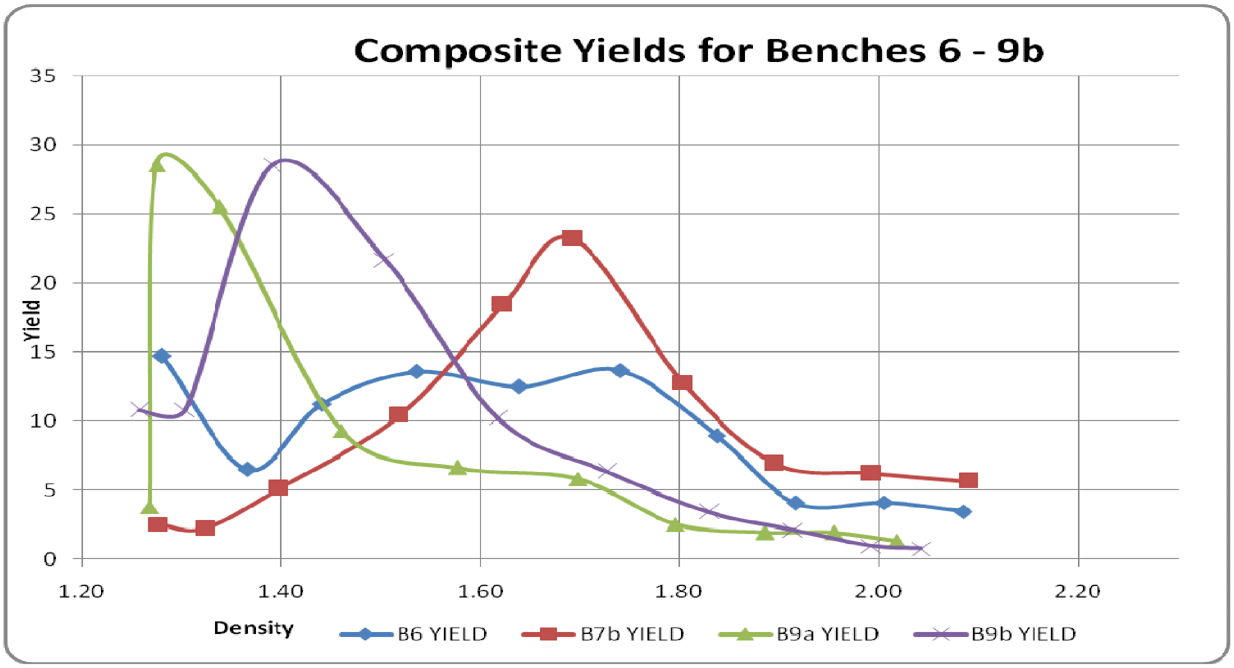


Figure 35 Composite yield density plots for benches 6 thru 9b

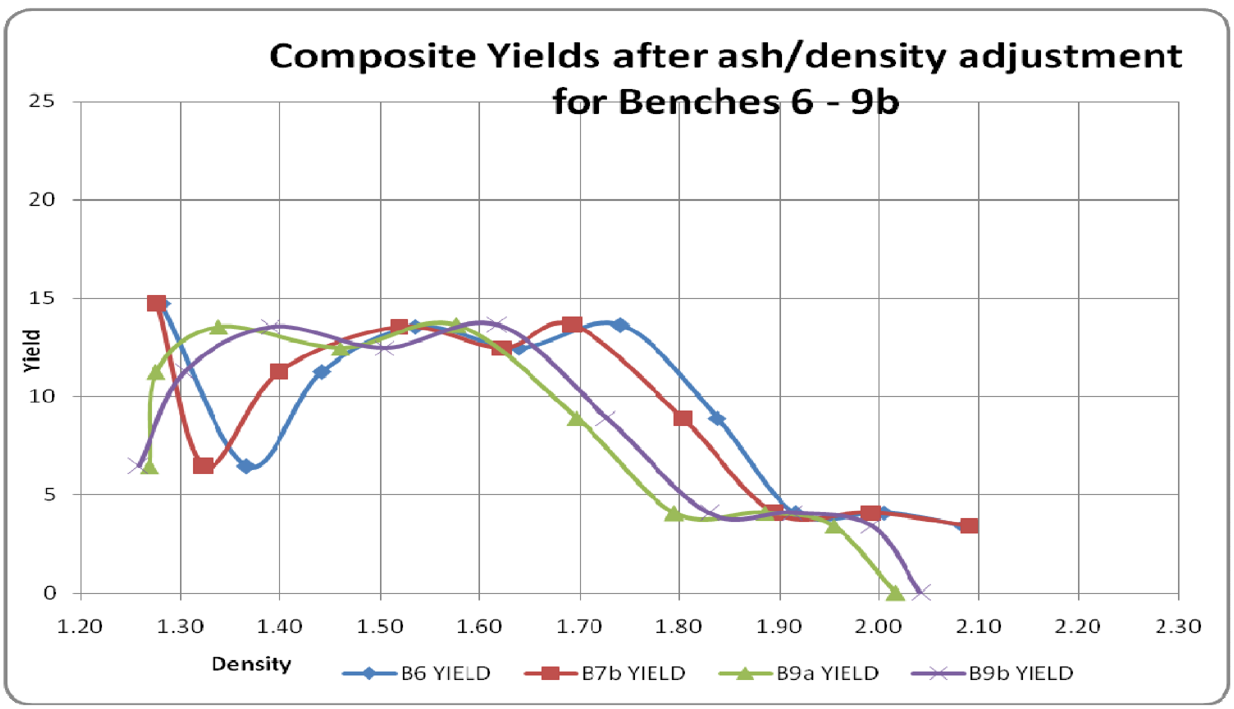


Figure 36 Composite plots of Ash adjusted density distributions for benches 6 thru 9.

The ash adjusted composite plot shows a wide range of density values at more or less the same yield, with some probable, bright (vitrinite rich coals) in benches 6 and 7b, the remaining material in the range between 1,35 / 1,40 g/cc to 1.85 / 1.87g/cc suggesting a higher energy regime and reasonable transportation of sedimentary material. Benches 9a and 9b, essentially split due to higher phosphorous in bench 9a than in 9b, making 9a coal less favourable for the metallurgical market, are generally better than the previous benches due to lower densities, ranging in this case between 1.33 g/cc and approximately 1.75 g/cc. This is supported by plots of the cumulative ash values of these benches.

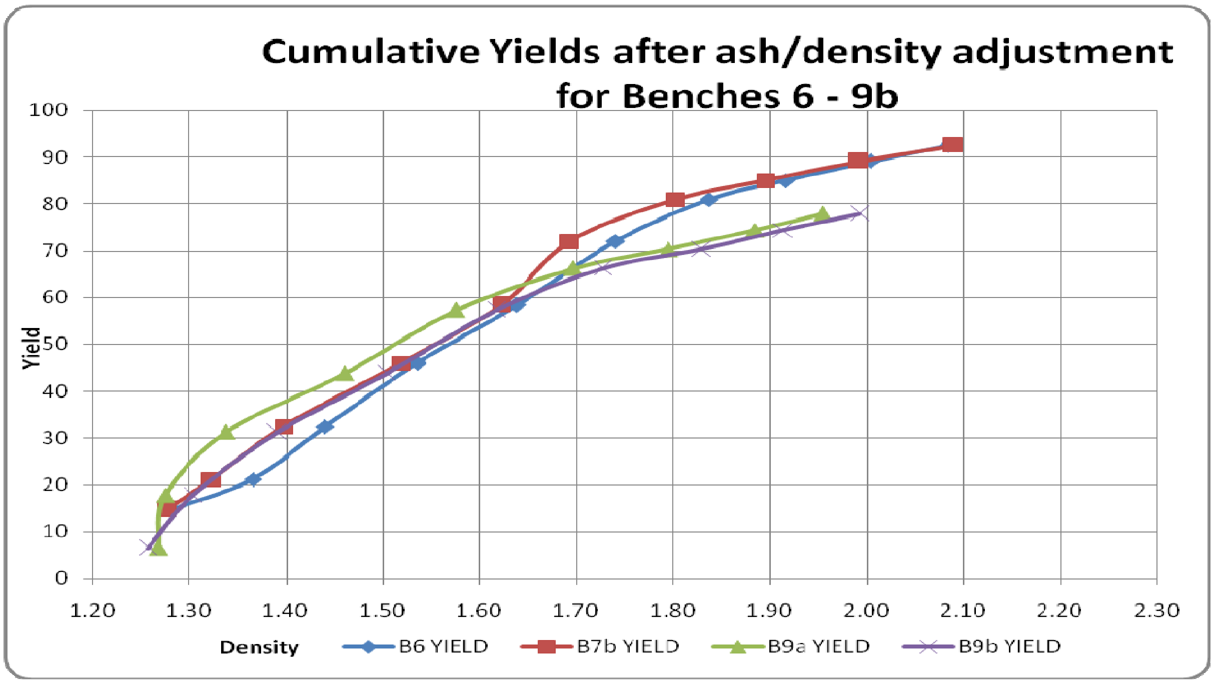


Figure 37 Plot of the cumulative yield, after ash density adjustment highlighting quality differences between benches 6 / 7b and bench 9a / 9b.

The foregoing plots have verified a relationship between density and ash distribution as a result of the depositional environment.

The application of Ash Adjusted Density (AAD) to wash table information as well as petrography highlights the vitrinite content in the majority of the samples in the Waterberg coalfield succession. Two extracts from the main stratigraphical units, the Volksrust Formation and the Vryheid Formation, illustrate the fractional proximate yields and maceral yields pertaining to the two main depositional environments. The first, sample 6 from zone 10 in the Volksrust Formation, Figure 38 displays very high vitrinite yields typical of deposition within a very low energy environment, while sample 23b, Figure 40, from zone 4 in the Volksrust Formation depicts transported and reworked material from an external source in a higher energy environment.

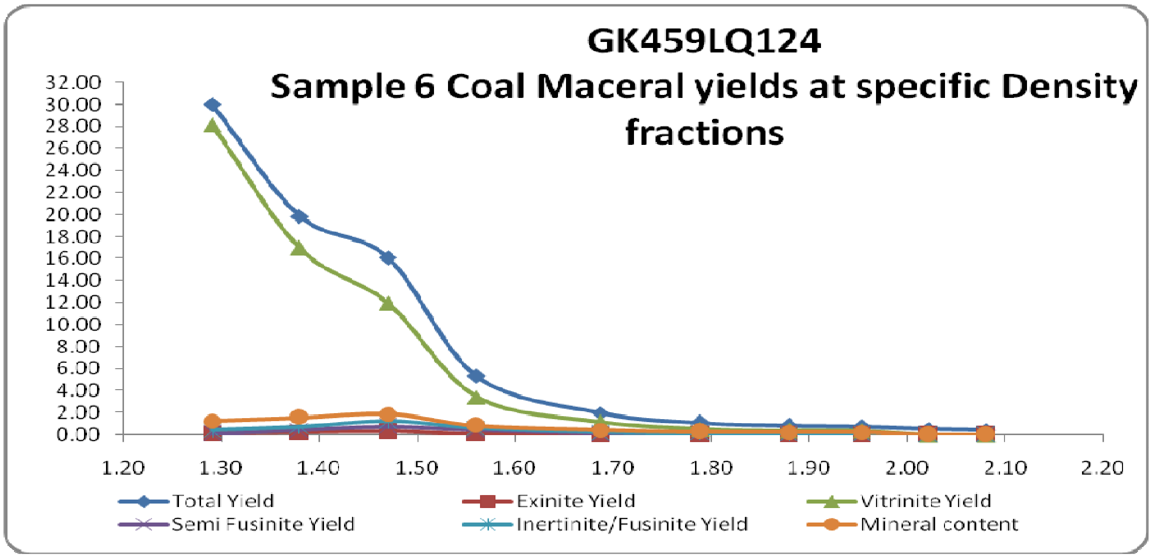


Figure 38 Example of a sample from the Volksrust Formation, low energy environment.

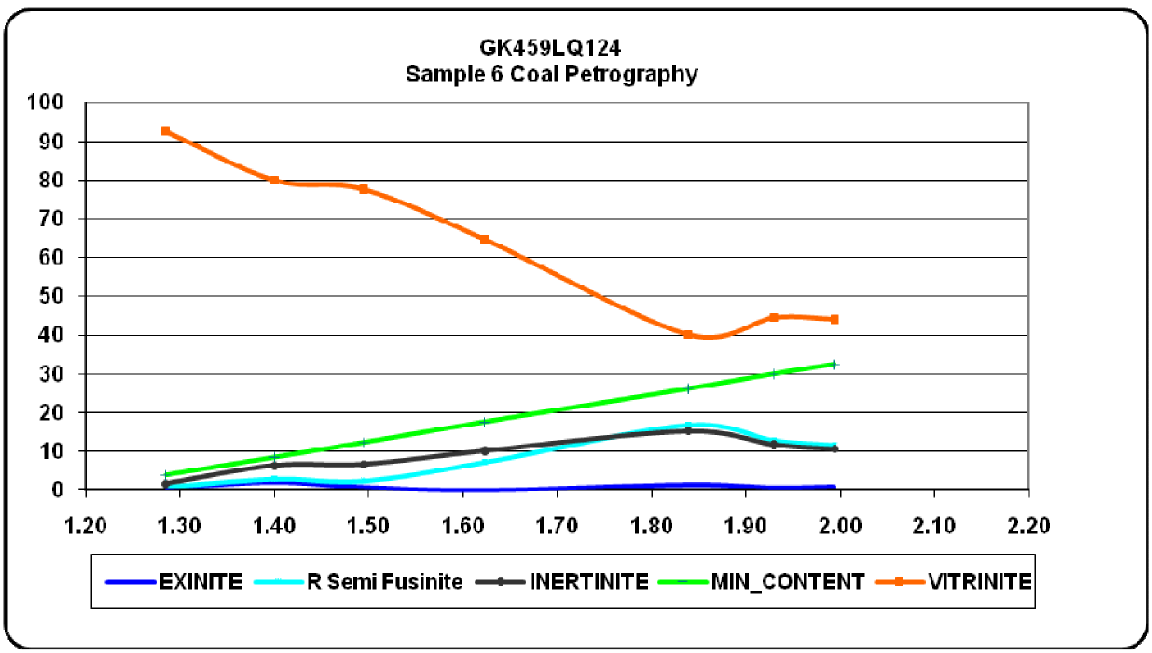


Figure 39 Volksrust Formation, low energy environment petrographic analysis.

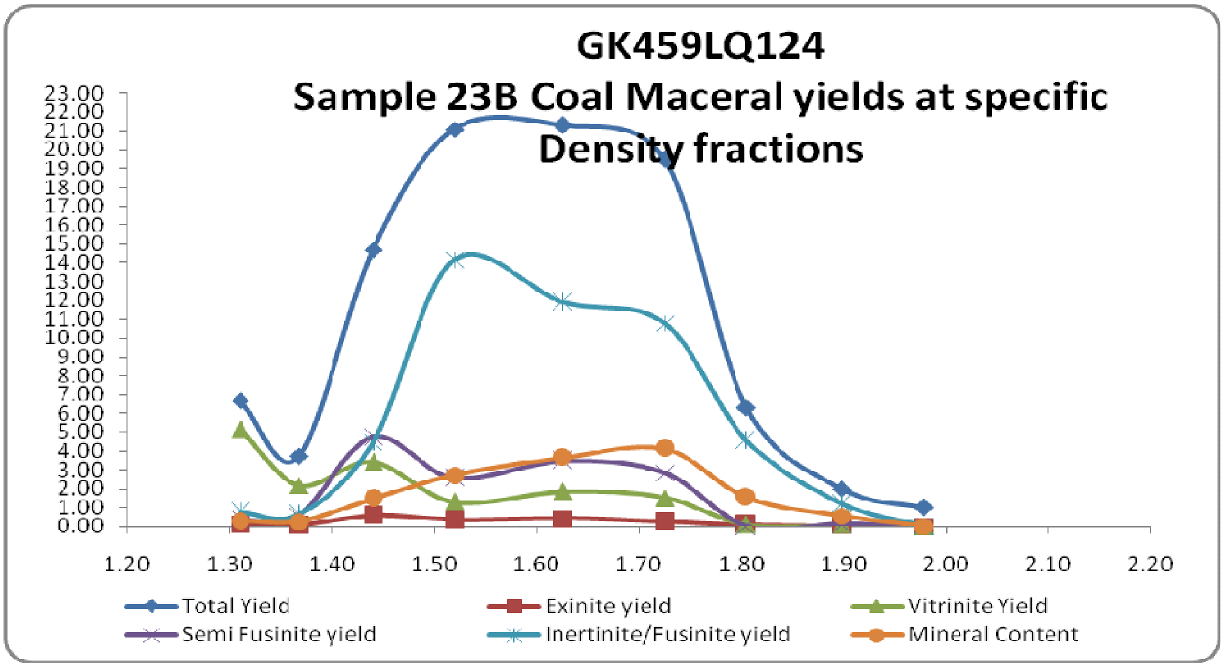


Figure 40 Sample 23B, zone 4 in the Vryheid Formation, reworked transported sediment from exterior source, higher energy environment.

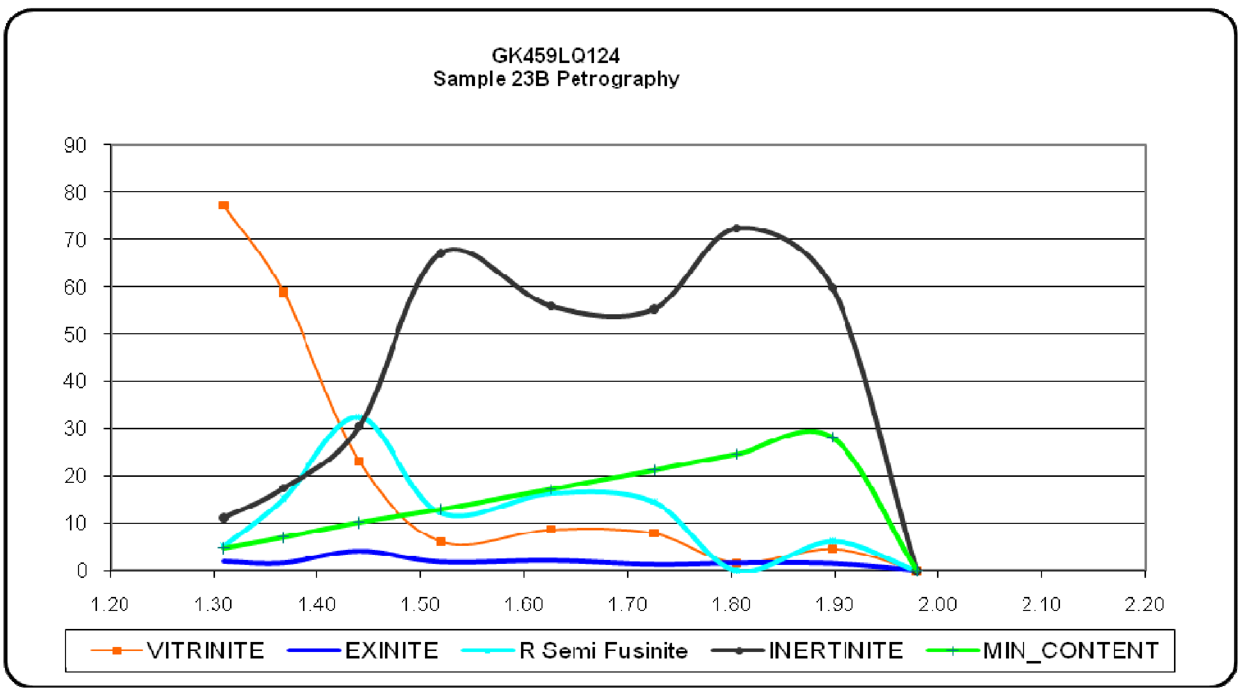
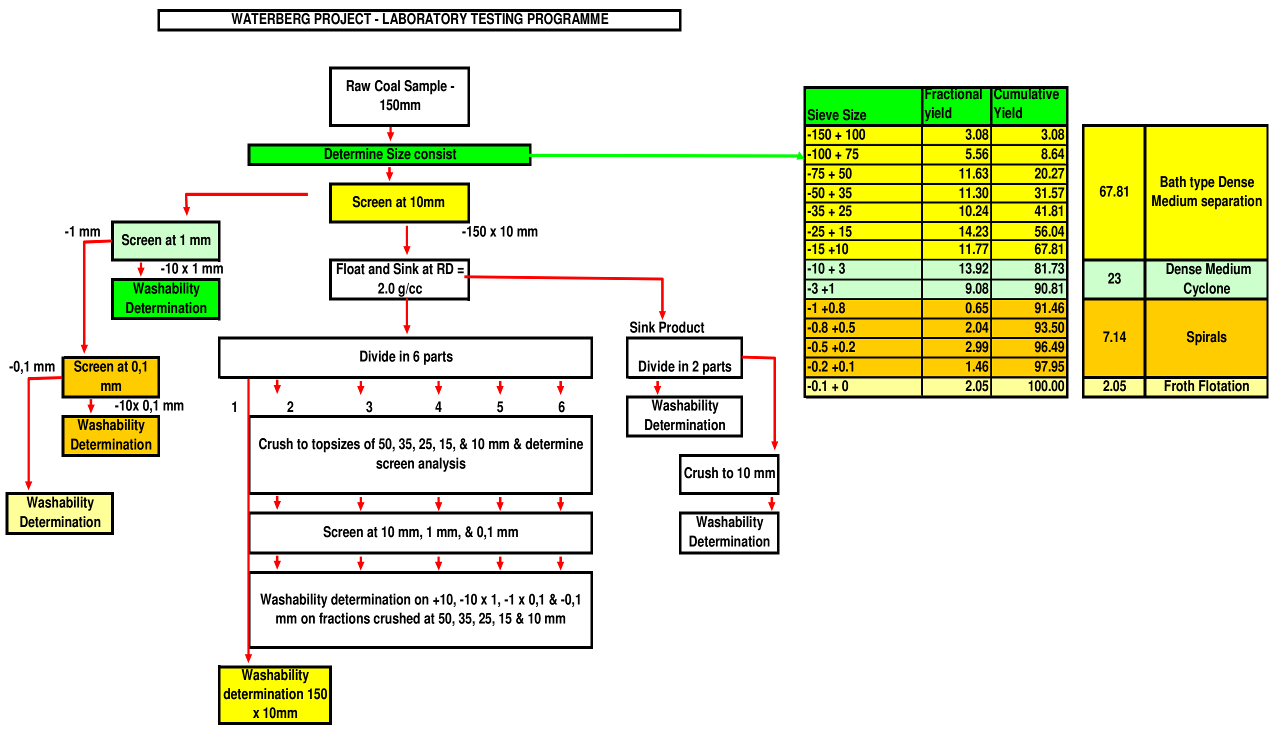


Figure 41 Sample 23B, zone 4 in the Vryheid Formation, reworked transported sediment from exterior source, higher energy environment Petrography analysis.

5.2 LIBERATION OF LOW ASH SEMI SOFT COKING COAL RESULTING FROM FEED STOCK, TOP SIZE WITHIN THE BENEFICIATION ENVIRONMENT.

During 1991 and 1992 an investigation was conducted by G J De Korte and published in a report sponsored by THE NATIONAL ENERGY COUNCIL, REF No 234/89", The utilization potential of coal from the Waterberg coalfield ". The main objective of this report was to synthesize beneficiation data on Waterberg coal in order to assist decision makers in planning and design from a sound database. The work was based on bulk samples obtained from mining benches 2, 3 and 4 at Grootegeluk coal mine. These were subjected to a carefully formulated project entailing, sampling, screening and analysis of different size fractions accordingly. The bench 2 results have been used in this evaluation. The outline sketched below illustrates the breakdown of this project.



Sieve Size	Fractional yield	Cumulative Yield		
-150 + 100	3.08	3.08	67.81	Bath type Dense Medium separation
-100 + 75	5.56	8.64		
-75 + 50	11.63	20.27		
-50 + 35	11.30	31.57		
-35 + 25	10.24	41.81		
-25 + 15	14.23	56.04		
-15 +10	11.77	67.81		
-10 + 3	13.92	81.73	23	Dense Medium Cyclone
-3 +1	9.08	90.81		
-1 +0.8	0.65	91.46	7.14	Spirals
-0.8 +0.5	2.04	93.50		
-0.5 +0.2	2.99	96.49		
-0.2 +0.1	1.46	97.95		
-0.1 + 0	2.05	100.00	2.05	Froth Flotation

Figure 42 Schematic of Laboratory testing program.

This data has been used to formulate a better understanding of the processes employed at Grootegeluk Coal Mine and more specifically problems encountered in the semi soft coking coal beneficiation plants, products, and the influence of size fractions on yields of these products in the process.

The emphasis of this evaluation is based on the work relating to the division of the bulk material in the size ranges from <150mm and > 10mm into six equal samples and their concomitant wash tables and analysis.

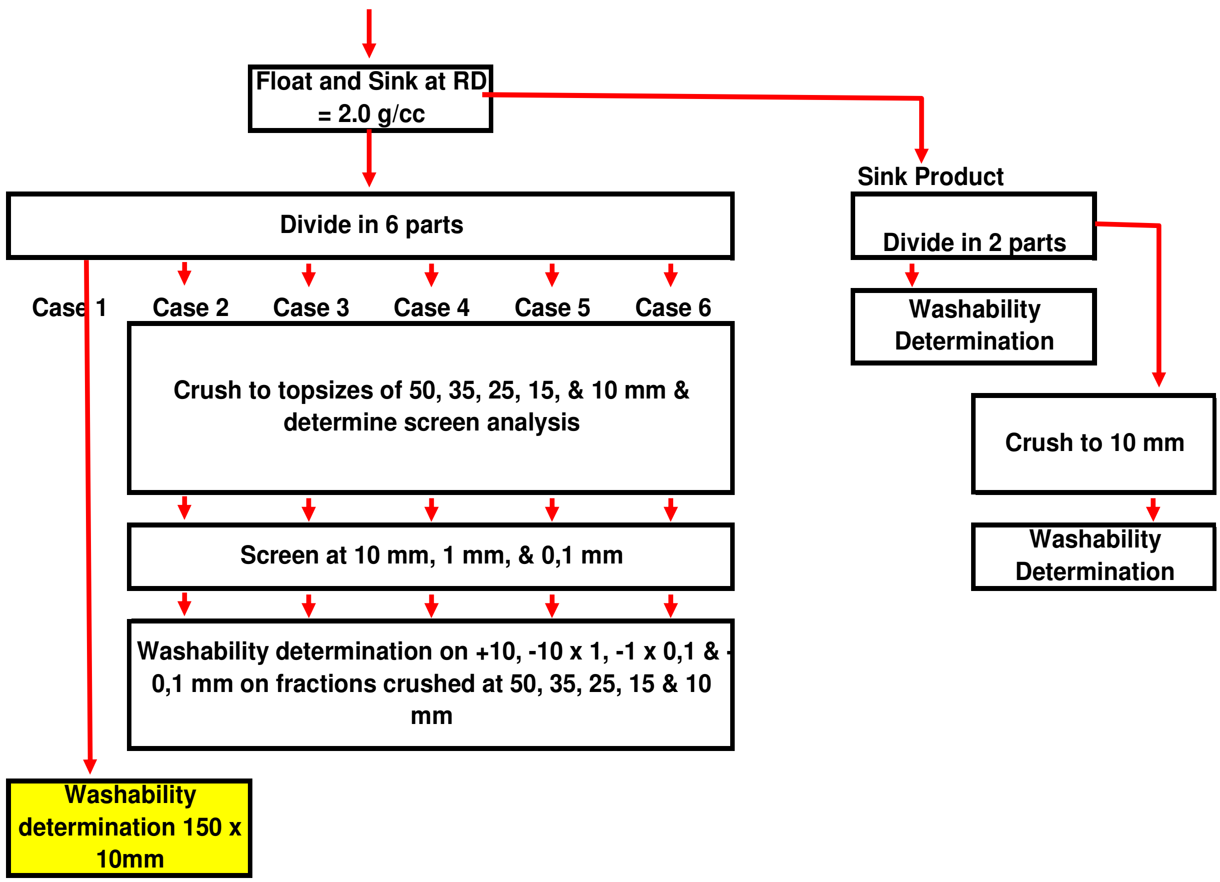


Figure 43 Schematic of sample breakdown for laboratory testing program.

A summary of the wash data from the evaluation is shown in the tables below giving an indication of the optimal size fraction for economical extraction.

The first table represents the original fractional/size breakdown, yields obtained applying the various methods of beneficiation and the actual methods utilized. The second small intermediary table cumulates the yields obtained by the individual methods and the last table shows cumulative yields for combinations of the methods. The beneficiation methods excluding froth flotation are applicable to both GG1 and GG6 beneficiation plants at Grootegeluk.

Sieve Size	Fractional yield	Cumulative Yield		
-150 + 100	3.08	3.08	67.81	Bath type Dense Medium separation
-100 + 75	5.56	8.64		
-75 + 50	11.63	20.27		
-50 + 35	11.30	31.57		
-35 + 25	10.24	41.81		
-25 + 15	14.23	56.04		
-15 +10	11.77	67.81		
-10 + 3	13.92	81.73	23	Dense Medium Cyclone
-3 +1	9.08	90.81		
-1 +0.8	0.65	91.46	7.14	Spirals
-0.8 +0.5	2.04	93.50		
-0.5 +0.2	2.99	96.49		
-0.2 +0.1	1.46	97.95		
-0.1 + 0	2.05	100.00	2.05	Froth Flotation

CUMULATIVE TABLE					
Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1.83	4.96	6.18	5.24	4.63	
8.67	2.21	4.35	3.79	7.94	12.01
3.88	0.86	1.50	1.96	3.76	5.40
0.56					

		< 150 mm	< 50 mm	< 35 mm	< 25 mm	< 15 mm	< 10 mm	Max Yields
Bath type Dense Medium	Yield=	1.83	4.96	6.18	5.24	4.63	0.00	6.18
Bath & Cyclone Dense Medium	Yield=	10.50	7.17	10.53	9.03	12.58	12.01	12.58
Above & Spirals	Yield=	14.38	8.03	12.03	10.99	16.34	17.41	17.41
& Froth Flotation	Yield=	14.93						

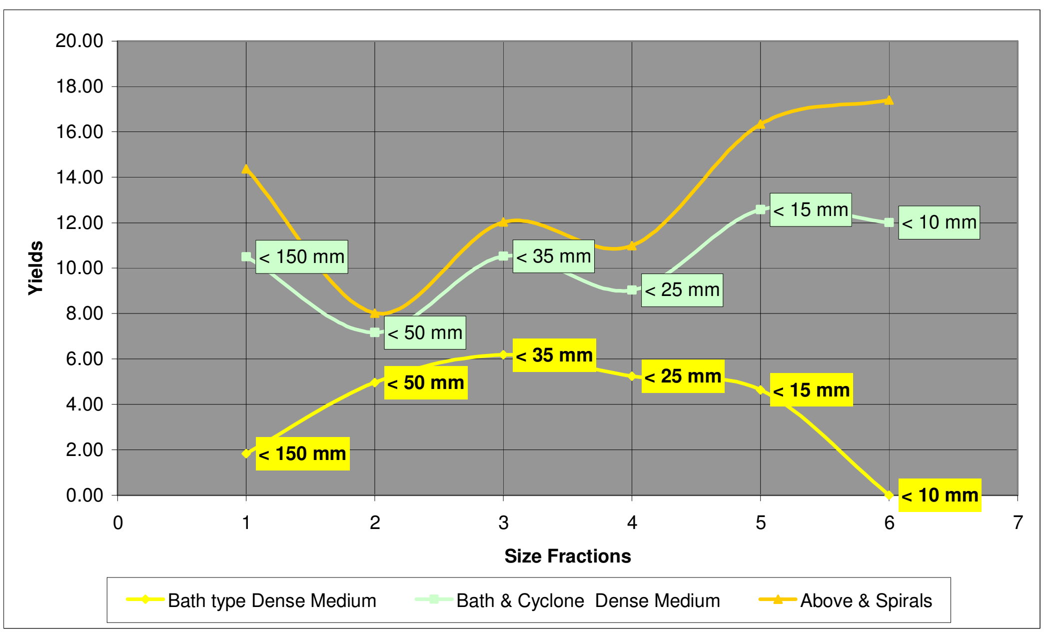


Figure 44 Schematic reflecting the results of the six subdivided samples at their various top sizes and the beneficiation mediums used for separation

The plot above reflects the results of the six subdivided samples at their various top sizes and the beneficiation mediums used for separation. The yield distributions shown reflect only the semi soft coking coal yields. These portrayed values should not be misconstrued with any trends; the erratic nature may be attributable to the initial subdivision of the bulk sample since it may have been extremely difficult to obtain a relatively homogenous representative blend given the top sizes of the raw material.

From the above however, and as stated by De Korte, the -15mm top size in this exercise appears to be optimal. The standards for laboratory analysis on exploration borehole core samples at Grootegeluk, however, require the core to be broken to -13mm. This is in accordance with the range between -10mm and -15mm.

The loss of low ash coal to fines and super fines however increases as the top size is reduced and at these low top sizes, the loss at -15mm is less than that at -10mm. The loss at -15mm loss is approximately 2% while the loss, should the size be further reduced to -10mm, increases to 5%+. Therefore the determined top size of -15mm would be more acceptable.

In order to produce a baseline for comparison, ash yield values obtained for Grootegeluk material and various ratios of admixtures from the different benches were regressed to provide a baseline for material within the >20mm - >25mm range (Roux 2010) , This was used to reflect a probable 100% theoretical yield.

Values depicting an 83% and 73% correlation were then determined and introduced in the plots following, so that a visual depiction of the distribution of size fractions could be obtained from the results of the investigation for yield comparison purposes related to the different sizes and separation media utilized (Roux, 2010).

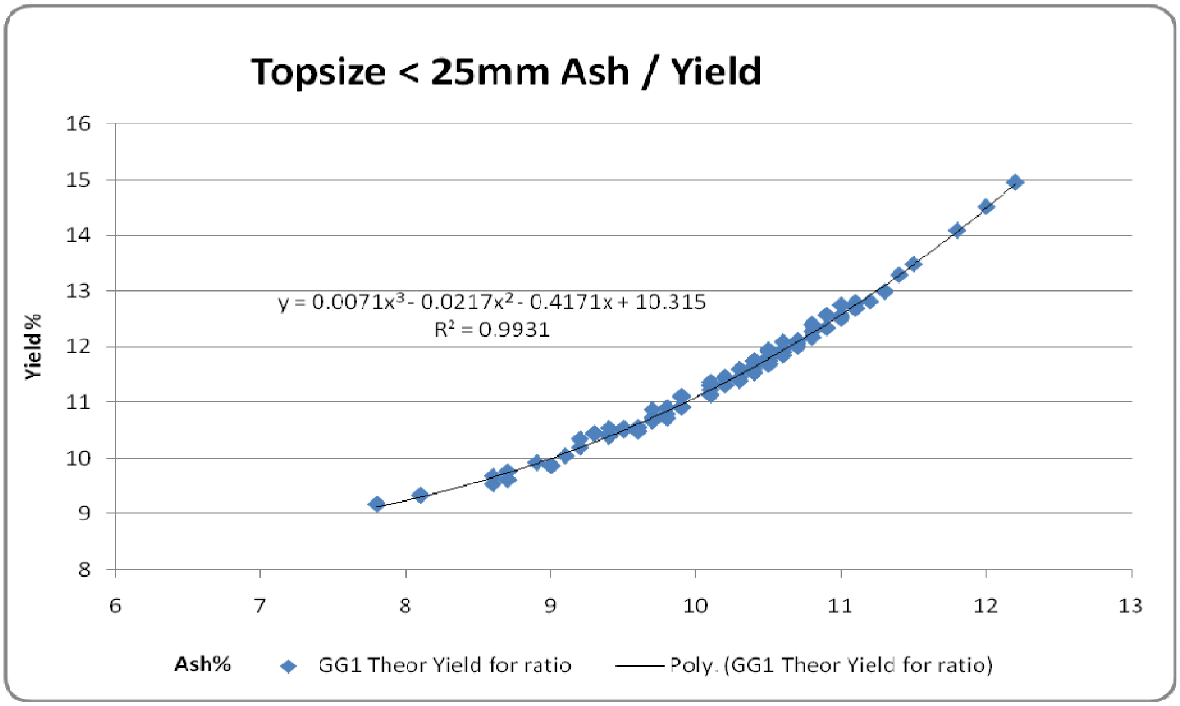


Figure 45 Represents a baseline regression for <25mm top size

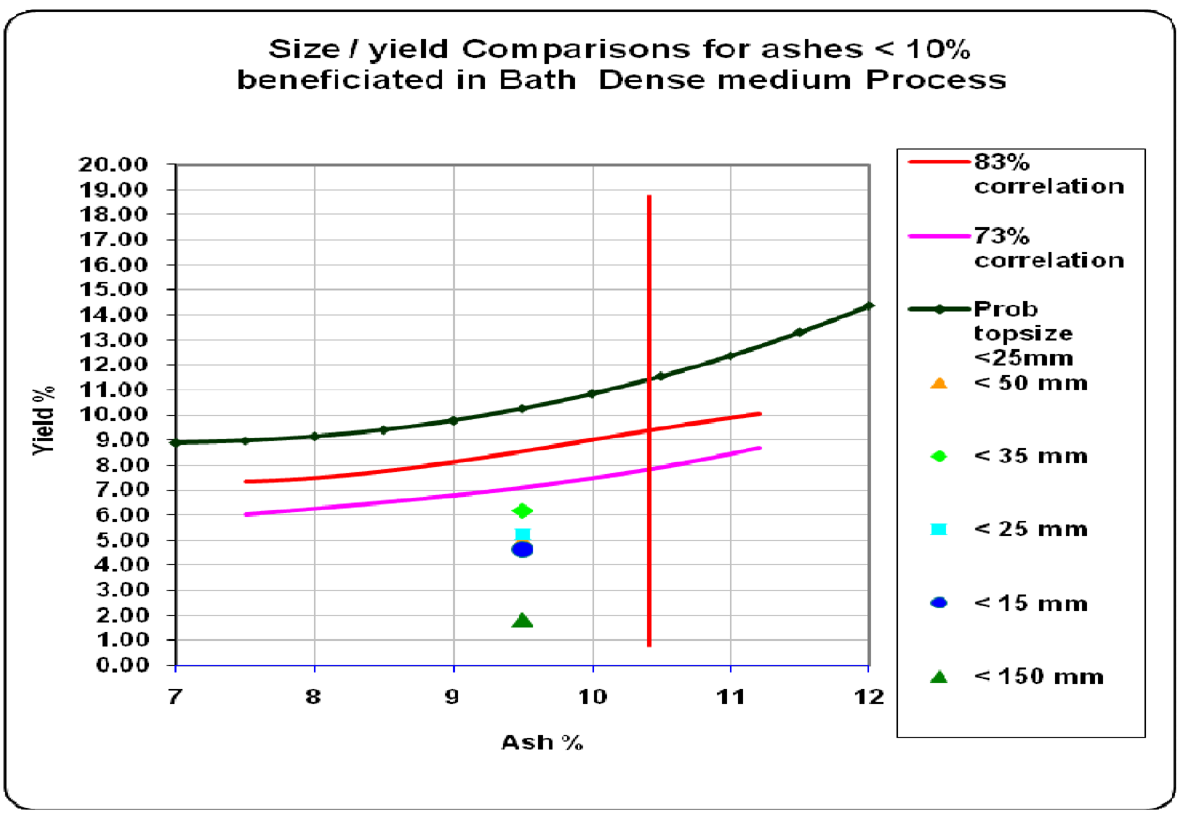


Figure 46 Plot of different size fractions behaviour in a bath dense medium process compared with yield prediction limits and correlation factor limits.

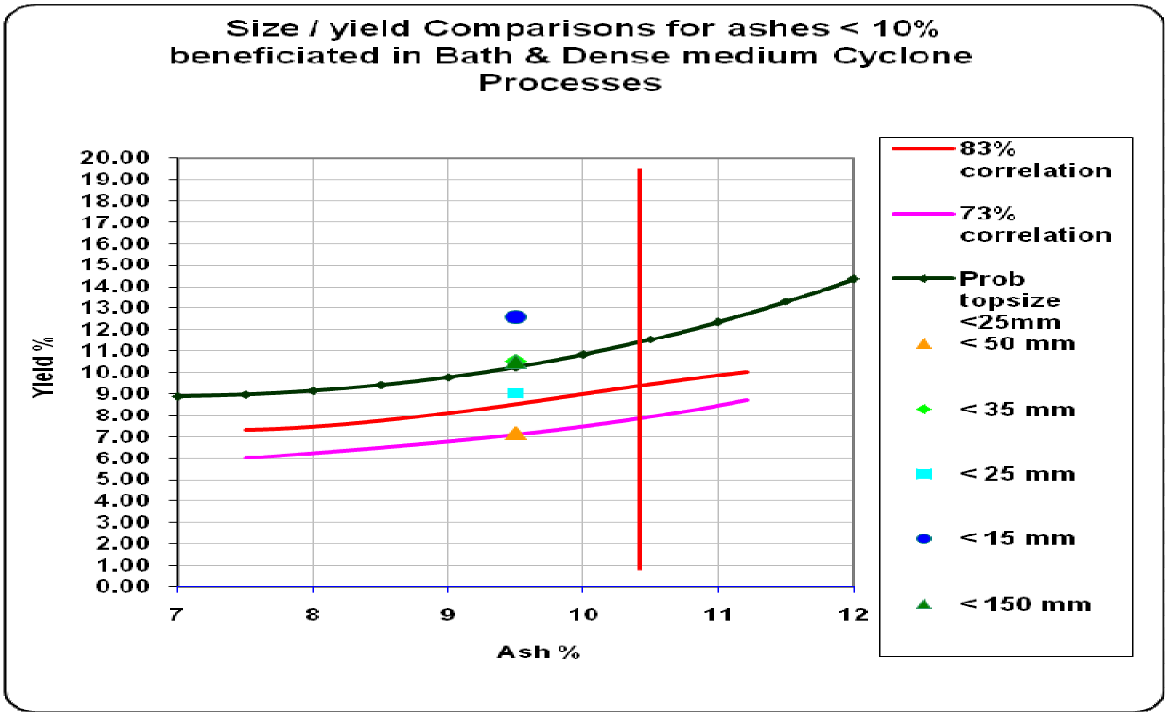


Figure 47 Plot of different size fractions behaviour in a bath and cyclone dense medium processes compared with yield prediction limits and correlation factor limits.

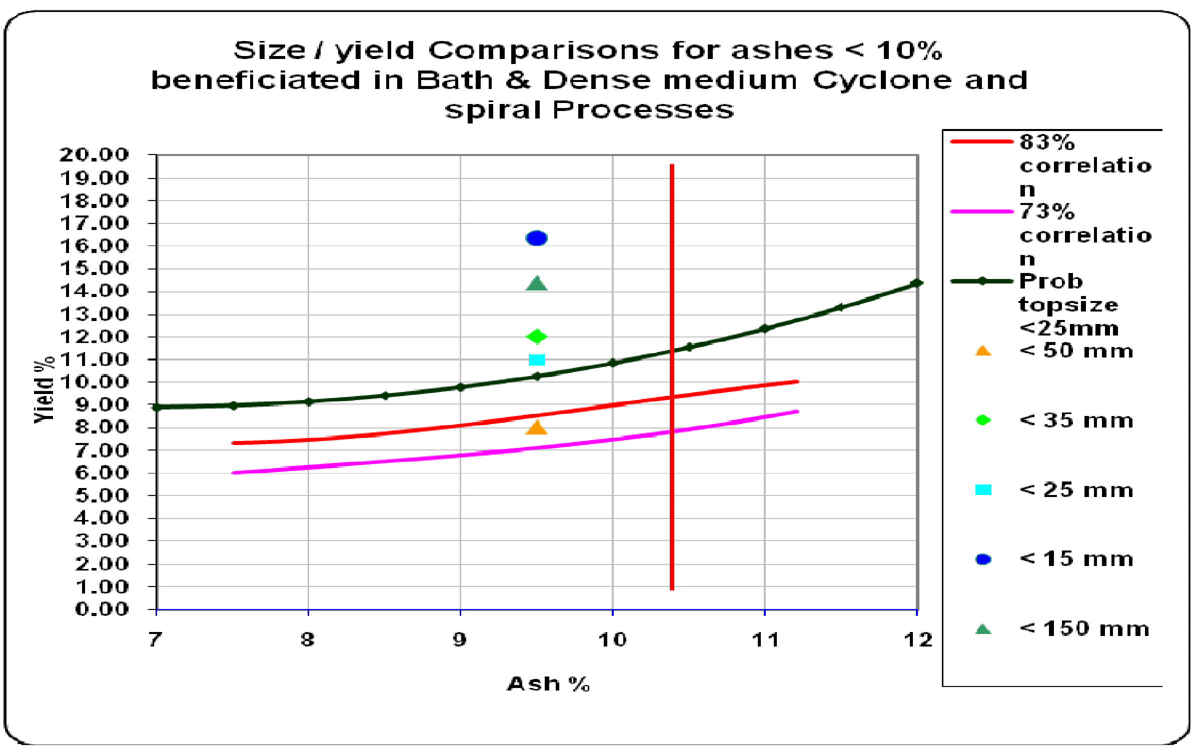


Figure 48 Plot of different size fractions behaviour in bath, cyclone dense medium and spiral processes compared with yield prediction limits and correlation factor limits.

Figures 46, 47 and 41 are a visual portrayal of the cumulative effects of the beneficiation processes starting with the drum/bath dense medium process, combining this with dense medium cyclones and lastly introducing spirals. Feed in the 25mm to 35mm fractions exhibits a 1.5% to 2% yield improvement, while the 15mm fractions show a dramatic increase from 4.5% to 12.5% when only the drum and cyclone dense medium separation is considered and a further increase to approximately 16%+ when spirals are introduced. This represents another 3.5% increase in yield due to better liberation of low density material in the smaller size fraction. Most of the low ash coals are in the density range of 1.305g/cc and 1.334g/cc, this being lower than a 10.3% ash at 1.338g/cc.

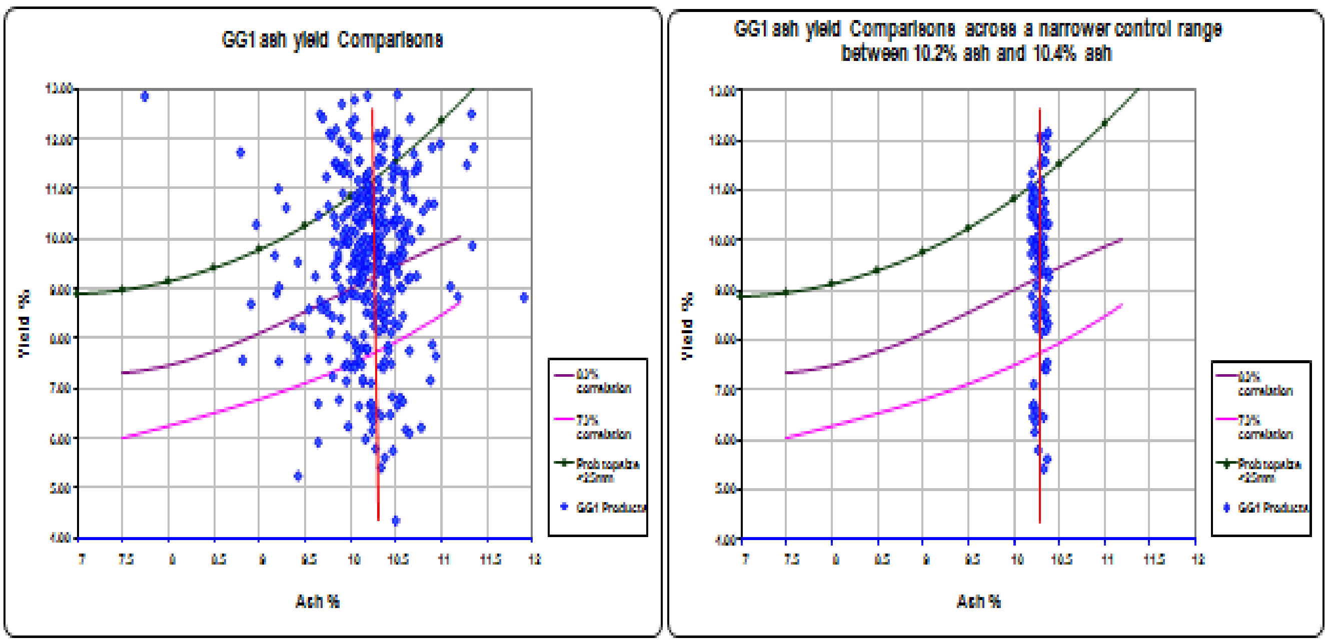


Figure 49 GG1 beneficiation plant results portrayed on the same basis.

The current production results portrayed in Figure 49 for GG1 production shows the highest concentration of consistent results to be greater than an 83% correlation on the theoretical predicted yield. Comparing this with the data from the sized material investigation and the processes used, the products obtained were mostly due to the top size of the feed being < 25mm.

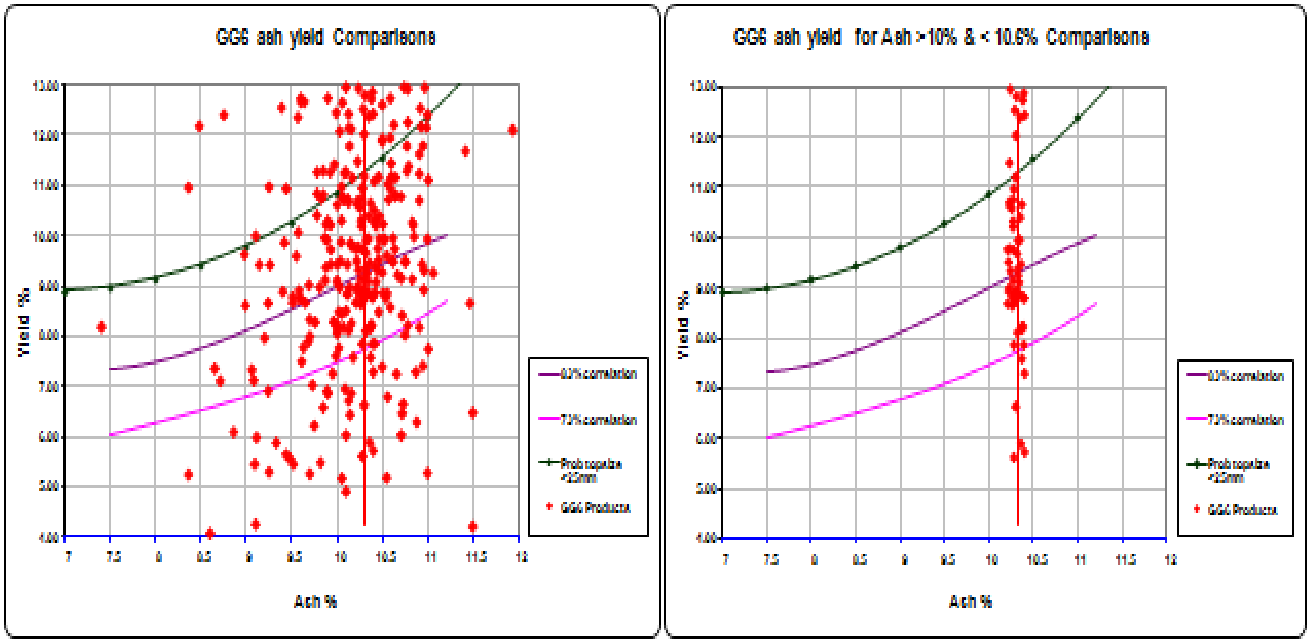


Figure 50 GG6 plant results compared on the same basis.

The results for GG6 however appear more randomly distributed with a slightly higher concentration around the 83% correlation, closer probably to a 78% correlation. This is more apparent when the range for the ash control specification is reduced to a range between 10% ash and 10.6% ash. Comparing this with the size fraction plots the range of sized material is too large, material falling in the smaller size ranges i.e. <25mm provides reasonable yields while the larger material is misplaced to the middling coal product (power station coal).

Assessing the foregoing, GG6 plant cannot do any better than it currently is and a 73% correlation factor applied to predicted yields is attainable and justifiable given the top size distribution at present, some smaller fractions generated within the process may compliment the yields being obtained and result in higher than predicted yields. A reduction in top size would definitely benefit and if this could be reduced to the same top size as the exploration borehole cores or as close as possible to this, i.e. to 15mm, then an acceptable loss of approximately 2% to super fines can be accommodated and predicted yields for this plant would not require a correlation factor. The same can be said for GG1, which is currently using an 83% correlation factor and has a top size of 20mm.

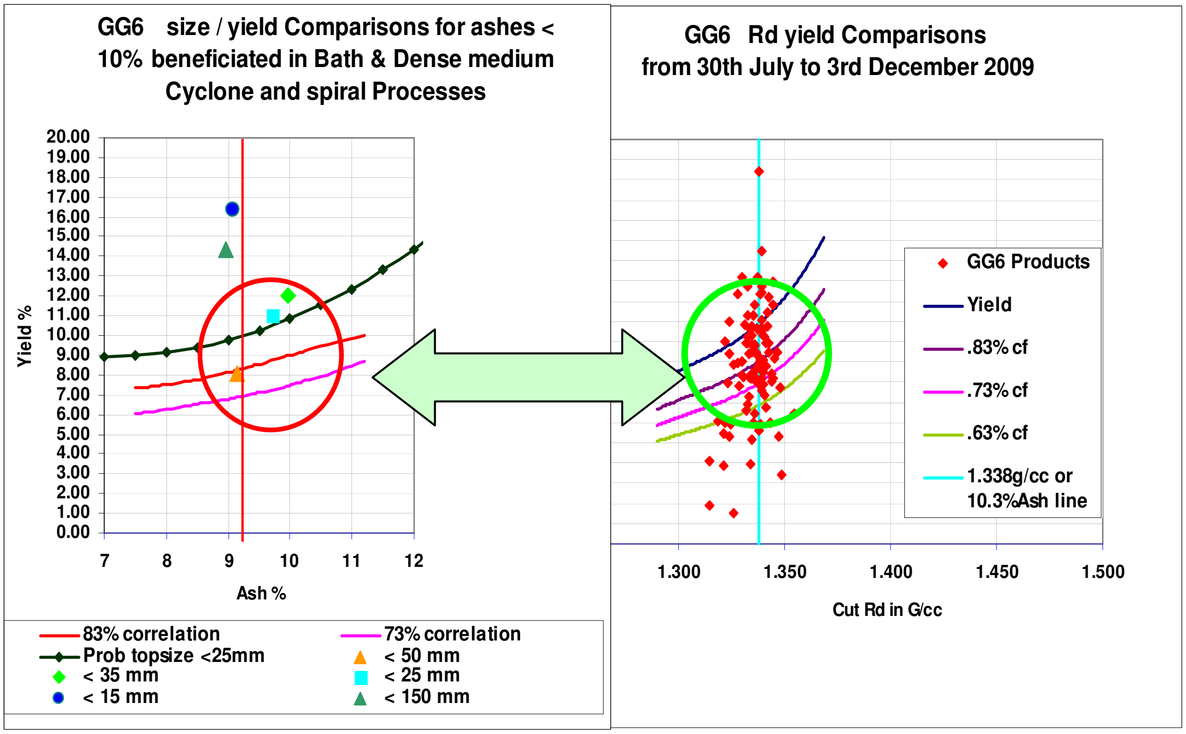


Figure 51 GG6 comparisons highlighting the effect of sized material.

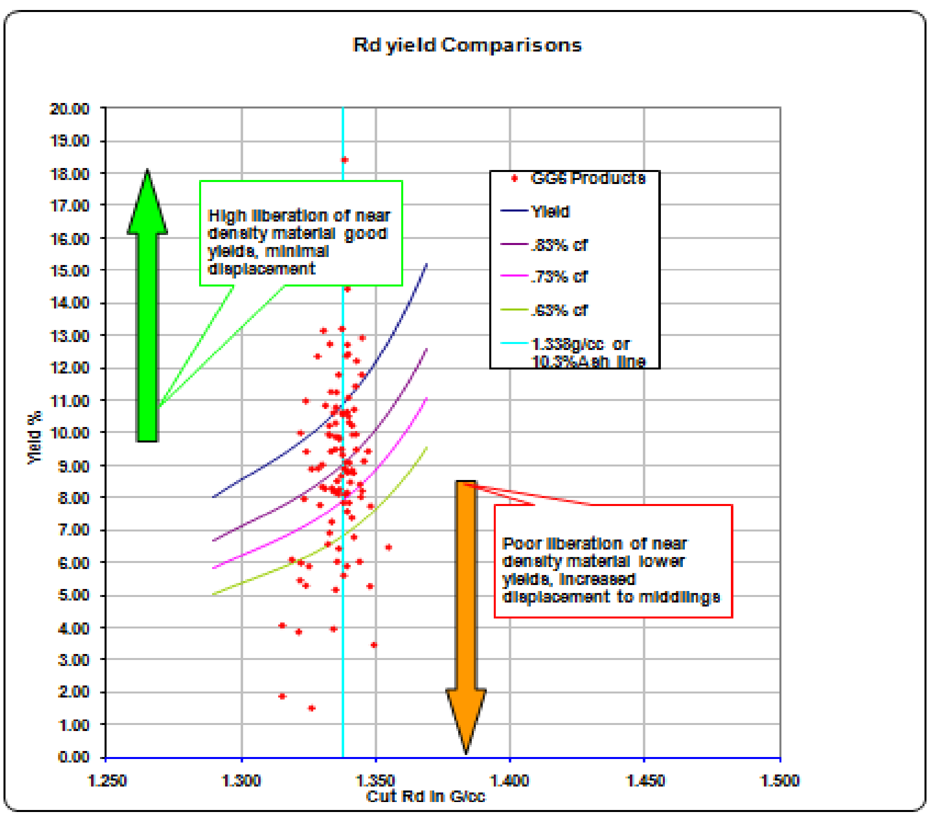


Figure 52 Graphic depicting yield based on liberation of sized material

The foregoing proves conclusively that the top size of the feed material has a major impact on the liberation of low ash semi soft coking coal in this deposit.

5.3 HISTORICAL YIELD PREDICTIONS FOR PLANNING, PRODUCTION AND GRADE CONTROL PURPOSES IN THE BENEFICIATION ENVIRONMENT

Historically, semi soft coking coal and middling (power station coal) yields were based on product extractions done on the defined bench parameters using the closest exploration borehole's analytical results for the bench, or rather the vertical geological sequence and area being mined, this being the only control prior to modelling of the ore deposit.($_1$Dreyer, 1991)

Since mining changed from fixed elevations to defined geological contacts delineating the respective benches into well defined cycles with certain associated metallurgical properties and the advent of early seam modelling, greater improvements have been made to evaluate the process from raw run-of-mine, through the beneficiation process to final saleable products.($_2$Dreyer, 1994)

The inverted pyramid structure for reconciliation as proposed by Riske et al (2007) can be applied to indicate the areas of relevance used for the evaluation of the correlation factors derived for both estimation and production through the process value chain. During the earlier years the emphasis was mainly on, partial spatial, more temporal and physical reconciliation, than on the entire package.

Planning and scheduling, grade control, mining and final products formed the basis of the reconciliation system. Factors obtained from this were then applied to theoretical geological model predictions, for budgeting and forecasting purposes.

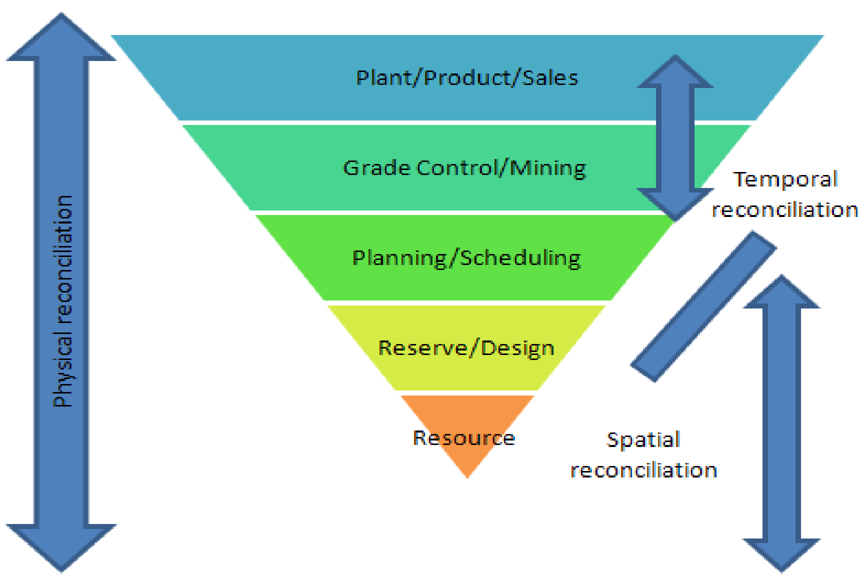


Figure 53 Schematic of the reconciliation process.

A geological model comprised of the various mining benches, qualities of raw materials as well as probable extractable products and their associated properties was built and is updated on a regular basis as new information is acquired.

The mines sequentially scheduled blast blocks given in defined polygons for the respective strips on the various benches are then populated with the relevant metallurgical data for planning and production purposes.

These blocks thus have an idealistically predicted yield for the various products based on the theoretically defined block, between set floor and roof boundaries and of a specific aerial extent defined by the polygons.

Tonnages of the various products can be determined in-situ. Reconciling this data with the final products after beneficiation presented a multitude of problems due to extraneous uncontrollable factors, which resulted in the introduction of correlation factors to account for the inexplicable differences (Dreyer, 1994).

Relatively accurate correlation factors were determined per mining bench, provided that the material being beneficiated was consistently supplied from the same source and the same vertical sequence. The behaviour of material from a particular bench, mined over a relatively long period consistently, was assessed and values adjusted via the determined correlation factors to ascertain the products from a particular source.(Roux, 2006) The probable yield of this raw material was then determined.

An important aspect was that the correlation factors derived were suitable while the beneficiation process remained the same, thus these factors would have to be adjusted after any changes or improvements within the beneficiation environment were implemented.

An example of such a change would be the introduction of spiral modules to improve overall efficiency and recovery.

Conversely changes also had to be made if and when the nature of the raw run of mine material changed, examples being related to oxidation and weathering or lateral facies changes within the depositional environment.

Four sets of factors had to be determined to accommodate the different materials for each product required as well as for grade control and budgeting purposes.

Modelled values (2007 correlation factors) had to be adjusted for the 4 different sources of raw material. Bench 2 weathered with a coking coal correlation factor of 62% and middling (power station coal) correlation factor of 94.57%, normal bench 2 materials, 71.95% and 95.65% respectively, bench 3, 74.77% and 143.07% and bench 4 with 70.24% and 113.20% for middling (Power station coal).

It is relevant to note that the discussed values are only relevant to one of the beneficiation plants, in this case GG1 (Grootegeluk 1, semi soft coking coal and power station coal beneficiation plant).

Each respective plant with its unique string of products and top sizes of material broken for beneficiation has their own unique set of correlation factors.

The included table below illustrates some of these correlation factors used historically.

Table 4 Correlation factors derived historically for grade control and model adjustments.

Correlation Factor Percentages - Grade Control Model

Coking Coal

Bench	2000/2001	2001/2002	2002/2003	2003/2004	2005	2006	2007
Bench 2 Weathered	55.91	55.91	67.53	65.11	64.31	60.60	59.66
Bench 2	67.52	67.52	81.55	78.63	77.66	73.18	72.05
Bench 3	66.76	66.76	80.64	81.02	76.70	72.28	71.16
Bench 4	65.95	65.95	79.66	80.04	76.00	71.62	70.51
Ash	10.0%	10.0%	10.0%	10.0%	10.3%	10.3%	10.3%
RD							
Sulphur					102.32	100.76	100.51

Middlings

Bench	2000/2001	2001/2002	2002/2003	2003/2004	2005	2006	2007
Bench 2 Weathered	118.88	118.88	88.14	114.67	111.31	116.32	115.17
Bench 2	109.06	109.06	80.86	105.20	102.12	106.71	105.66
Bench 3	128.98	128.98	95.63	121.30	136.20	142.33	140.92
Bench 4	126.56	126.56	93.83	119.02	118.40	123.73	122.51
Ash			35.0%				
RD	1.80	1.80		1.80	1.80	1.80	1.80

Correlation Factor Percentages - Geological Model

Coking Coal

Bench	2000/2001	2001/2002	2002/2003	2003/2004	2005	2006	2007
Bench 2 Weathered					61.72	61.90	62.00
Bench 2					77.87	72.60	71.95
Bench 3					81.74	75.39	74.77
Bench 4					74.76	72.39	70.24
Ash					10.3%	10.3%	10.3%
RD							
Sulphur					102.32	100.76	100.51

Middlings

Bench	2000/2001	2001/2002	2002/2003	2003/2004	2005	2006	2007
Bench 2 Weathered					97.81	97.70	95.35
Bench 2					95.00	95.94	95.65
Bench 3					137.79	144.56	143.07
Bench 4					113.28	115.32	113.73
Ash							
RD					1.80	1.80	1.80

The following plots Figures 54, 55 & 56 illustrate differences firstly of the type of raw feedstock, its origin and its typified behaviour within the beneficiation environment. Theoretical semi soft coking coal yields for Bench 2 weathered areas are exceptionally high, due to the composition of bench 2 material since the samples with the highest vitrinite content are found in zone 10 which is the lower section of bench 2. The highest concentration of lower density material falls in the range between, 1.40 g/cc and approximately 1.57 g/cc from the standard float sink analysis. The remainder of bench 2, a more homogeneous blend, shows lower, more consistent theoretical yields. Yields obtained in the beneficiation process however where an attempted ash control of 10.3% is maintained resulted in the derived correlation factors reflecting low plant efficiency with respect to weathered bench 2 material and an improved efficiency in the full succession bench 2 materials. Reasonably constant values were obtained for benches 3 and 4.

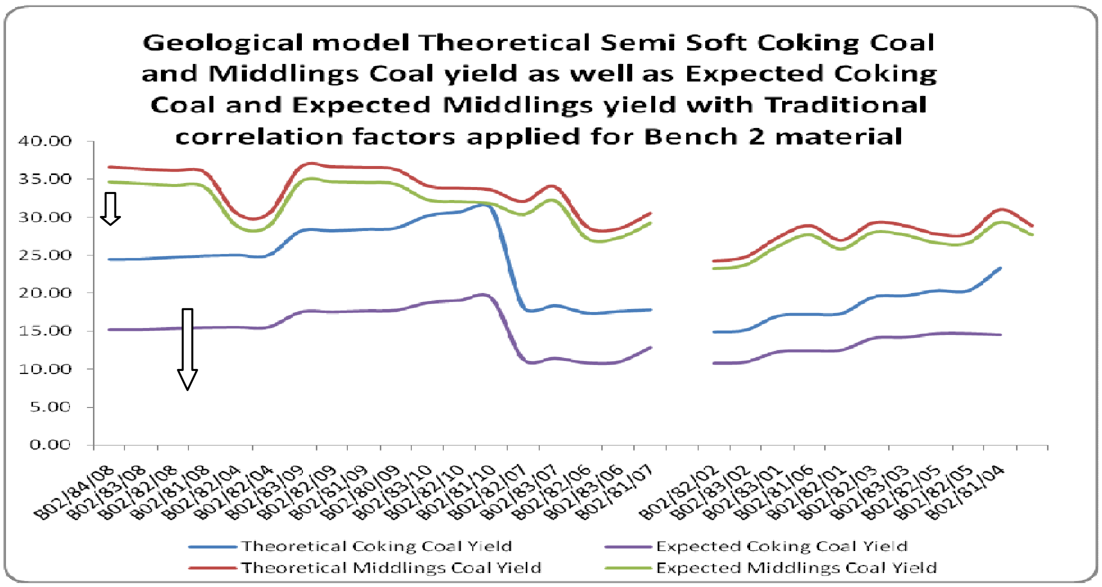


Figure 54 Depicts geological model theoretical coking coal and middling yields as well as the expected yields after application of traditionally determined correlation factors for Bench 2 Blast Blocks.

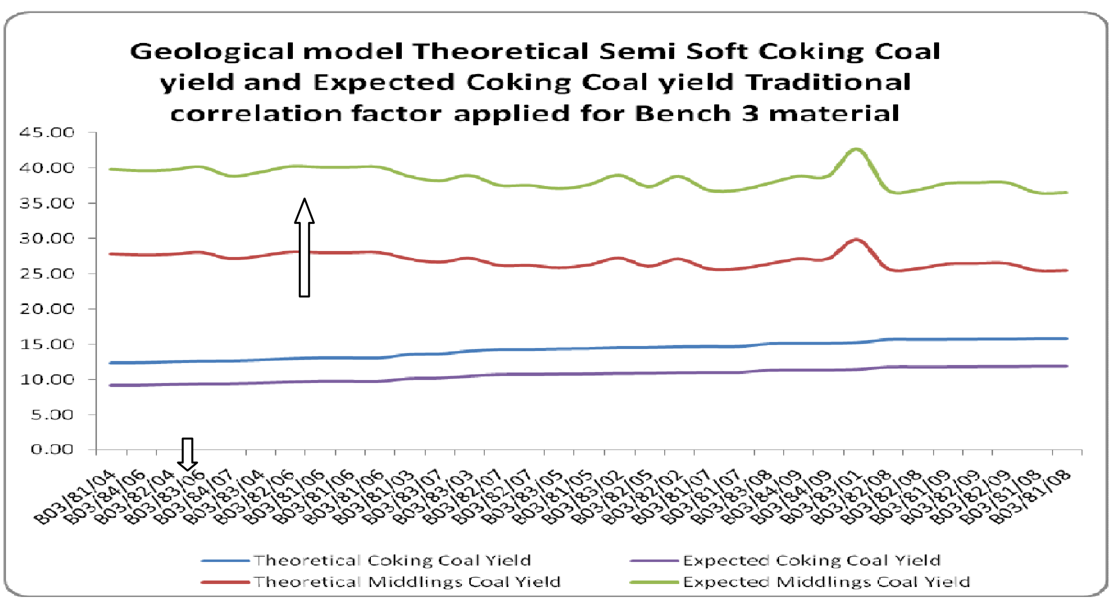


Figure 55 Depicts geological model theoretical coking coal and middling's yields as well as the expected yields after application of traditionally determined correlation factors for Bench 3 Blast Blocks.

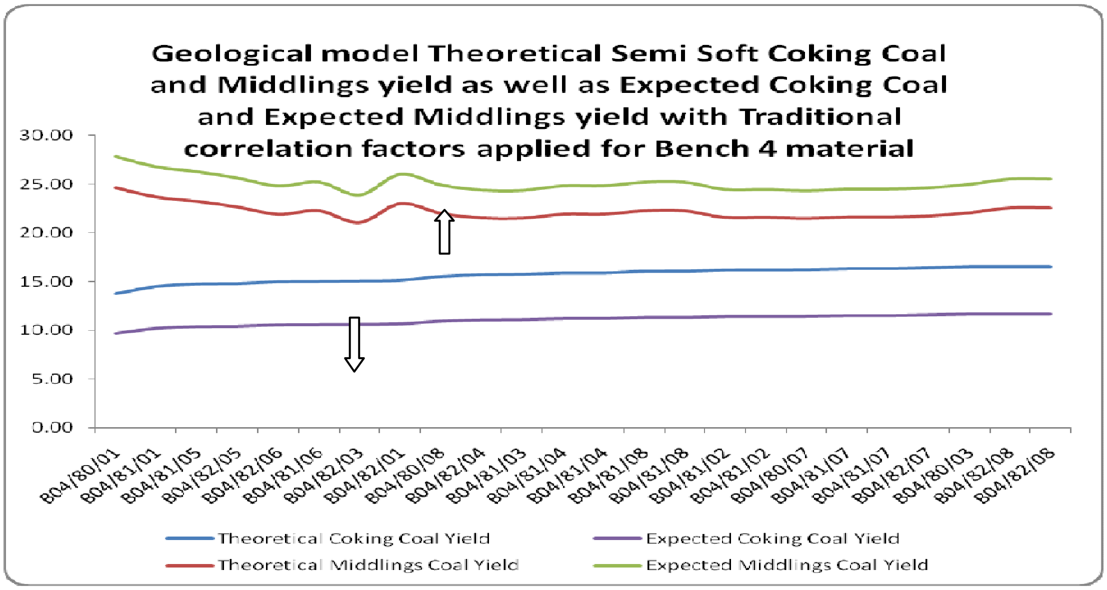


Figure 56 Depicts geological model theoretical coking coal and middling's yields as well as the expected yields after application of traditionally determined correlation factors for Bench 4 Blast Blocks.

Due to increased demand, greater volumes of material being required and mining pit geometry factors having to be honoured, the practice of selectively mining one bench or portions of a bench over a reasonable period of time to sustain the methodology of controlling correlation factors for the various benches could not be sustained.

Material from two or more locations from the various mining benches had of necessity to be blended as raw feedstock to the beneficiation plant. Predictions of probable product for budgeting and forecasting purposes became nigh impossible since the old system of correlation factor application failed miserably and predicted cut densities for the various products were nowhere near the controls within the plant to maintain specific ash values required for the end products.

Now the only feasible value that could be used was based on the beneficiation plant's organic efficiency. The monitoring period's data, starting January 2008 to late 2010 will be used to illustrate the problem and the differences. Yield values have been condensed to monthly averages.

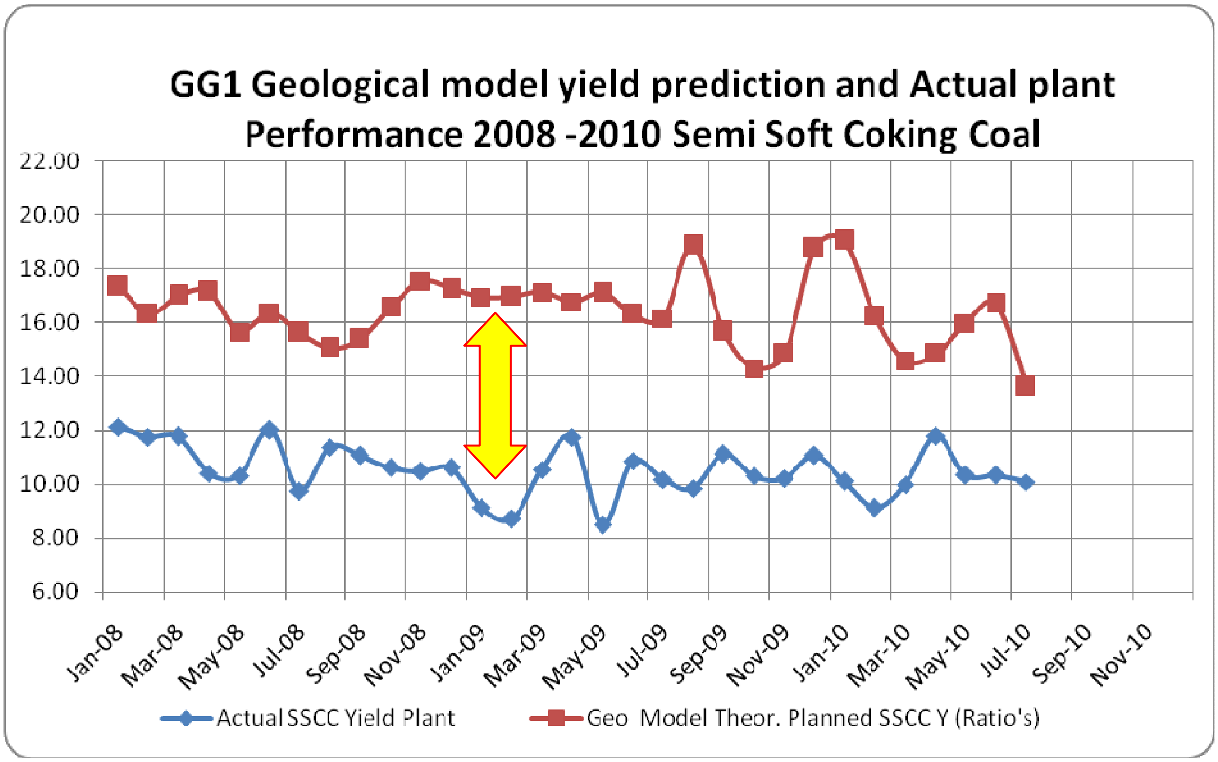


Figure 57 Difference between Geological Model yields and Actual beneficiation plant results.

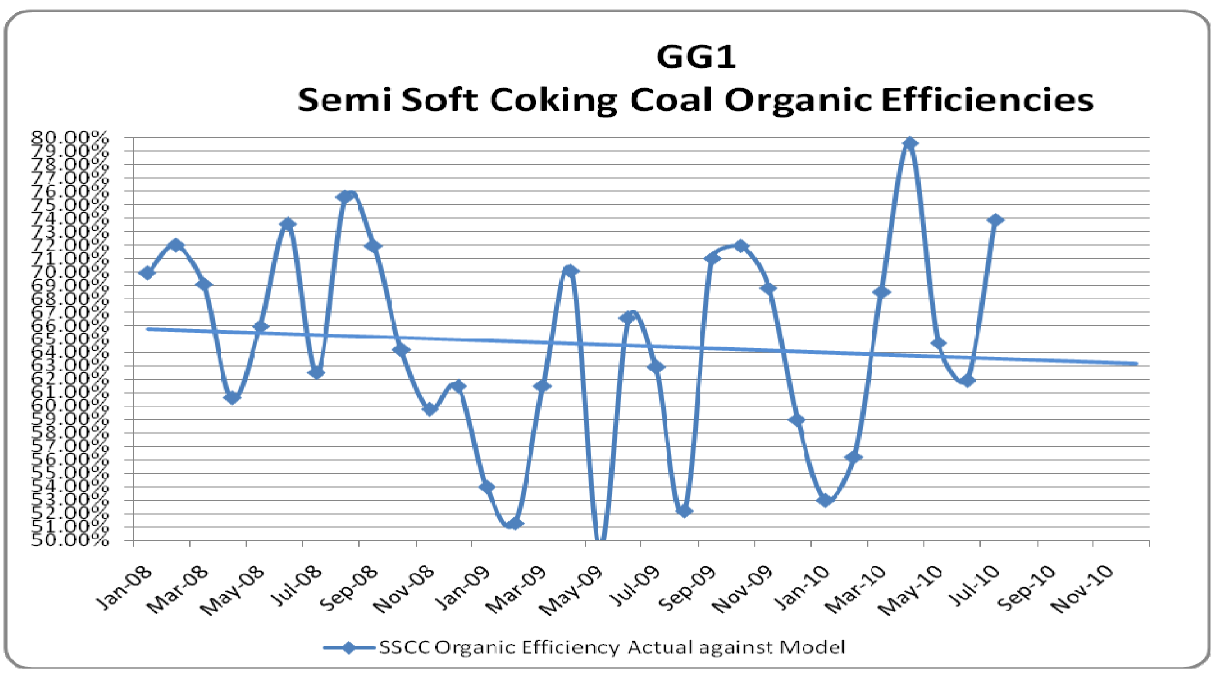


Figure 58 Semi soft coking coal recoveries, plant organic efficiency.

The beneficiation plant's efficiency over previous periods was used to determine a correlation factor on which the budget and forecast yields could be determined. The linear regression portrays values between 63% and 66%. This however did not give satisfactory results since the plant's reported efficiency now only increased to between 85% and 88% of the predicted yields, shown in Figure 51.

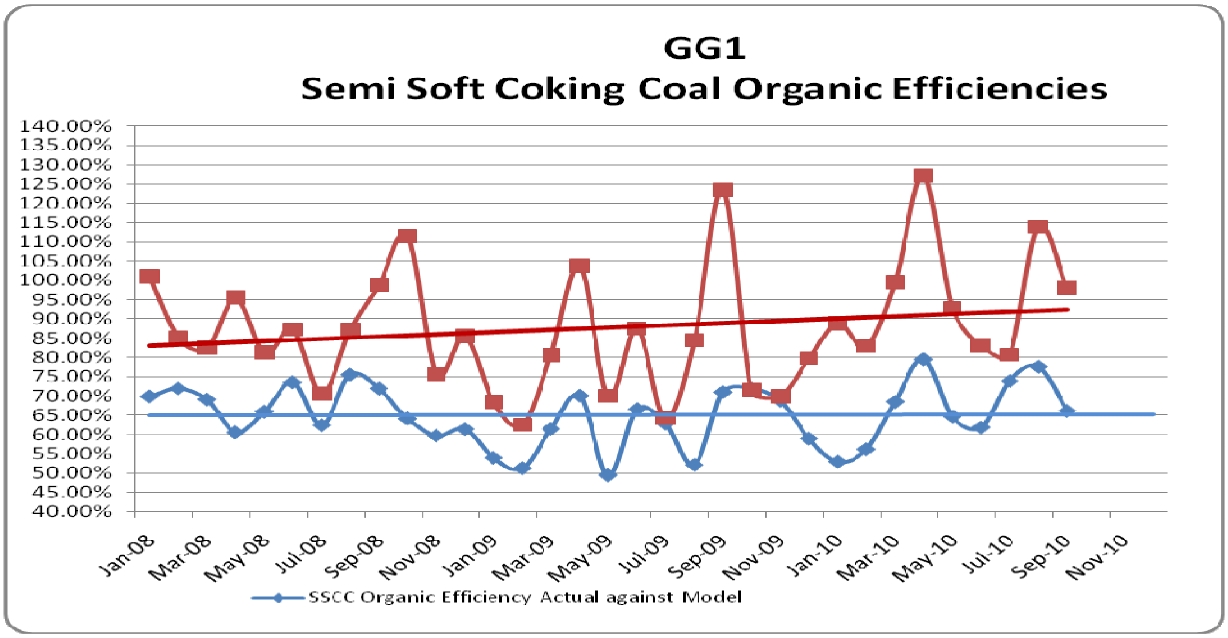


Figure 59 GG1 Organic efficiencies before and after correlation factor adjustments.

At this stage the results obtained from the ash density relationship were introduced into the system.

5.4 APPLICATION OF ASH DENSITY CORRECTED WASH DATA AND COMPARISONS WITH ACTUAL DATA

Initially all test work with regard to the application of this theory was conducted in Excel spreadsheets, since no other alternative was available. The original data however, was obtained from the composite data and compiled for a representative borehole representing the block of interest. This in turn had been compiled from interpolative results of individual blast-hole interpolations within a mini modelling environment and generated from exploration borehole data with analyses as found in the geological model. This data was extracted from the Sable database and imported into a predefined Excel template designed for this exercise (Roux, 2007)

In order to understand the origin of the data, blast-holes are geophysically logged, interpreted and correlated to delineate the vertical sample sequence represented in the blast-hole within a specific blast block on a mining bench. These blast holes are then used to define the roof and floor contacts for that specific bench. The samples involved are recognised and the analytical data for the individual samples in the vertical succession can then be extracted from exploration boreholes in close proximity to the relevant blast block (Roux L. 1988)

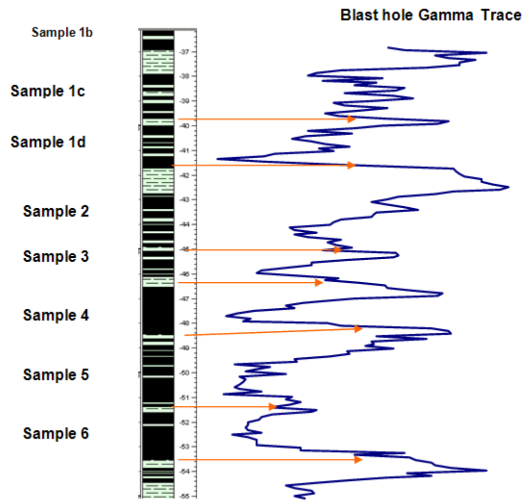
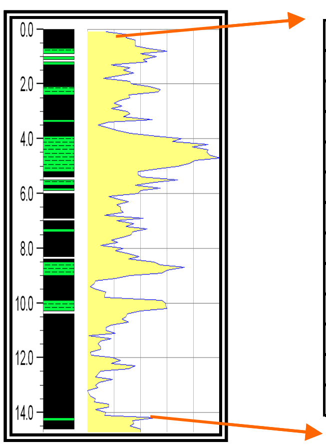


Figure 60 Interpreted and correlated blasthole

Log Profile **Typical Washability Table**



Bench 2									
Depth F	Rd	YIELD	MOIS	ASH	VOL	SWELL	ROGA	S	CV
39.71	1.35	10.03	3.36	6.21	35.09	3.5	48	0.8	30
39.71	1.4	23.85	2.99	11.46	34.88	2.92	40	0.89	28.42
39.71	1.5	42.18	2.82	16	33.67	2.68	31	1.04	26.94
39.71	1.6	49.13	2.74	18.01	33	2.43	28	1.12	26.29
39.71	1.7	52.14	2.71	19.19	32.56	2.29	26	1.18	25.89
39.71	1.8	54.29	2.69	20.19	32.23	2.2	25	1.22	25.55
39.71	1.9	56.13	2.67	21.23	31.87	2.13	24	1.26	25.2
39.71	2	58.25	2.65	22.57	31.44	2.05	24	1.28	24.75
39.71	2.1	60.91	2.6	24.54	30.68	1.96	23	1.28	24.1
39.71	2.2	64.76	2.54	27.47	29.54	1.84	21	1.26	23.14
39.71	9.99	100	2.11	48.03	22.12	1.19	14	1.17	16.42

Figure 61 A compiled wash table for the blasthole showing fractional yields and associated qualities.

Having defined the vertical succession represented Figure 60, this is then used to extract analytical data from the four closest exploration boreholes Figure 61, relevant to the vertical succession being sampled, from which washability tables are compiled. The washability tables for the individual representative exploration borehole are then used in an inverse distance interpolation to determine a representative wash table for the blasthole.

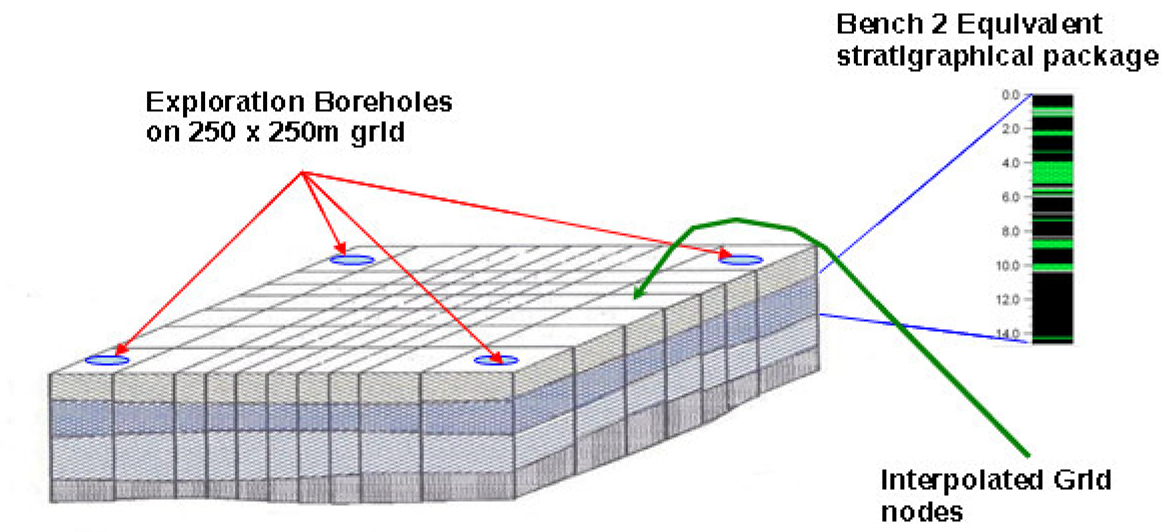


Figure 62 Spatial image of modelling concept.

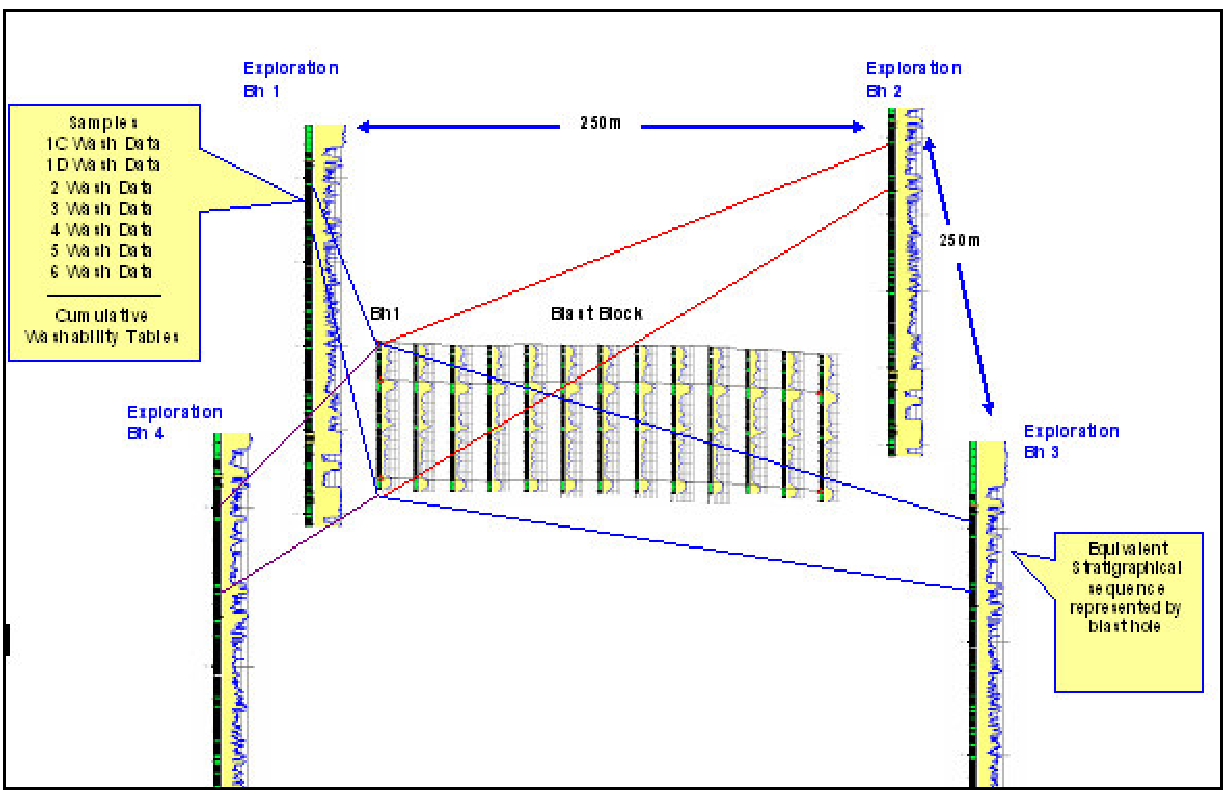


Figure 63 Mini-Modelling schematic.

Once this has been done for all the blast holes in the blast block, a representative borehole is constructed for the blast block. This is cumulated to provide a single cumulative wash table for the blast block from which the relevant products can be extracted. The following table, Table 5 represents such data in its final stage after cumulating.

The last four rows included in this table represent the products extracted at various values as shown. For example, cut 1 refers to the 35% ash product with its concomitant analytical parameters. Cut 2 refers to the primary cut at 1.80g/cc and cut 3, a 10.3% ash product while cut 4 indicates the power station or middling yield after the 10.3% ash product has been taken.

Table 5 Table representing yields for a blast block to prescribed mining elevations.

GRADECON : PREDICTED MINING ELEVATIONS

STANDARD CUT SUMMARY REPORT

DATE: 2007/04/25

BLASTBLOCK : B2/81/08

Composite Method: FLOAT_SINK, Analysis Type: PROX
Primary Cut: ASH = 35.00
Secondary Cut: RD_2 = 1.80
Tertiary Cut: ASH = 10.30

BLOCK: REP_BOREHOLE

FRA	RD1	RD2	YIEL	MOIST	ASH	VOLA	SWEL	ROGA	SULP	CV	PHOS
F	0.00	1.35	9.98	2.35	7.50	36.66	4.87	64.93	1.01	29.85	0.00
F	0.00	1.40	18.50	2.25	10.03	36.16	4.59	61.96	1.06	28.94	0.00
F	0.00	1.50	31.10	2.14	14.42	34.72	3.87	49.87	1.14	27.33	0.00
F	0.00	1.60	37.26	2.11	17.18	33.69	3.38	41.70	1.17	26.27	0.00
F	0.00	1.70	43.29	2.09	20.08	32.61	2.98	35.89	1.21	25.14	0.00
F	0.00	1.80	47.06	2.09	22.23	31.77	2.75	33.02	1.22	24.29	0.00
F	0.00	1.90	49.79	2.10	24.03	31.09	2.60	31.21	1.23	23.55	0.00
F	0.00	2.00	52.14	2.11	25.73	30.46	2.48	29.80	1.25	22.85	0.00
F	0.00	2.10	54.55	2.13	27.57	29.79	2.37	28.49	1.26	22.08	0.00
F	0.00	2.20	59.34	2.20	31.40	28.45	2.18	26.19	1.23	20.47	0.00
S	2.20	2.50	99.99	1.94	52.66	21.30	1.29	15.54	1.12	12.51	0.00
Cut 1:	2.20	2.25	66.22	2.16	35.00	27.24	2.03	24.39	1.21	19.12	0.00
Cut 2:	1.80	1.80	47.06	2.09	22.23	31.77	2.75	33.02	1.22	24.29	0.00
Cut 3:	1.40	1.41	19.27	2.25	10.30	36.07	4.55	61.23	1.07	28.84	0.00
Midd:	1.41	1.80	27.79	1.98	30.50	28.79	1.50	13.46	1.32	21.13	0.00

The template was designed to accept the raw data taken directly from the SABLE geological database and cumulate it into a wash table from which product extractions could be made. The basic fractional data was then altered through the application of the ash density adjustment algorithm and re-cumulated into a usable wash table.

This illustrates the differences as a result of the adjustment and the effect that this could have on yield predictions related to specific control parameters. The following schematic illustrates the table which would be used for the initial evaluation of the wash data for a singular blast block. Table 6 represents the same block as Table 4, i.e. Blast B02/81/08(Bench 2 Weathered). In this table the float and sink fractions are at specific density ranges as depicted in the RD2 column, where the first float value is shown as 1.35g/cc, the next at 1.40g/cc and then at 0.1g/cc increments to a final float of 2.20g/cc.

Figure 64 represents the raw composite data and the cumulative table for product extraction.

Gradcon original fractional data

FRACT	RD_1	RD_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	SULPHUR	CV	PHOS
F	0.00	1.35	9.98	2.35	7.50	36.66	4.87	64.00	1.01	29.85	0.00
F	0.00	1.40	8.52	2.14	13.00	35.58	4.26	58.00	1.12	27.88	0.00
F	0.00	1.50	12.59	1.97	20.87	32.59	2.80	32.00	1.24	24.95	0.00
F	0.00	1.60	6.17	1.98	31.10	28.54	0.92	0.00	1.32	20.94	0.00
F	0.00	1.70	6.03	1.94	37.97	25.89	0.54	0.00	1.45	18.19	0.00
F	0.00	1.80	3.77	2.09	46.94	22.19	0.04	0.00	1.38	14.44	0.00
F	0.00	1.90	2.72	2.28	55.13	19.35	0.00	0.00	1.50	10.90	0.00
F	0.00	2.00	2.35	2.37	61.78	17.14	0.00	0.00	1.51	7.97	0.00
F	0.00	2.10	2.41	2.53	67.47	15.15	0.00	0.00	1.44	5.38	0.00
F	0.00	2.20	4.79	2.98	75.01	13.20	0.00	0.00	0.89	2.12	0.00
S	2.20	2.50	40.65	1.57	83.69	10.87	0.00	0.00	0.98	0.90	0.00

Cumulative data

Rd_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	SULPHUR	CV	PHOS
1.35	9.98	2.35	7.50	36.66	4.87	64.00	1.01	29.85	0.00
1.40	18.50	2.25	10.03	36.16	4.59	61.24	1.06	28.94	0.00
1.50	31.10	2.14	14.42	34.72	3.87	49.40	1.14	27.33	0.00
1.60	37.26	2.11	17.18	33.69	3.38	41.22	1.17	26.27	0.00
1.70	43.29	2.09	20.08	32.61	2.98	35.48	1.21	25.14	0.00
1.80	47.06	2.09	22.23	31.77	2.75	32.64	1.22	24.29	0.00
1.90	49.79	2.10	24.03	31.09	2.60	30.85	1.23	23.55	0.00
2.00	52.14	2.11	25.73	30.46	2.48	29.46	1.25	22.85	0.00
2.10	54.55	2.13	27.57	29.79	2.37	28.16	1.26	22.08	0.00
2.20	59.34	2.20	31.40	28.45	2.18	25.89	1.23	20.47	0.00
2.50	99.99	1.94	52.66	21.30	1.29	15.36	1.12	12.51	0.00

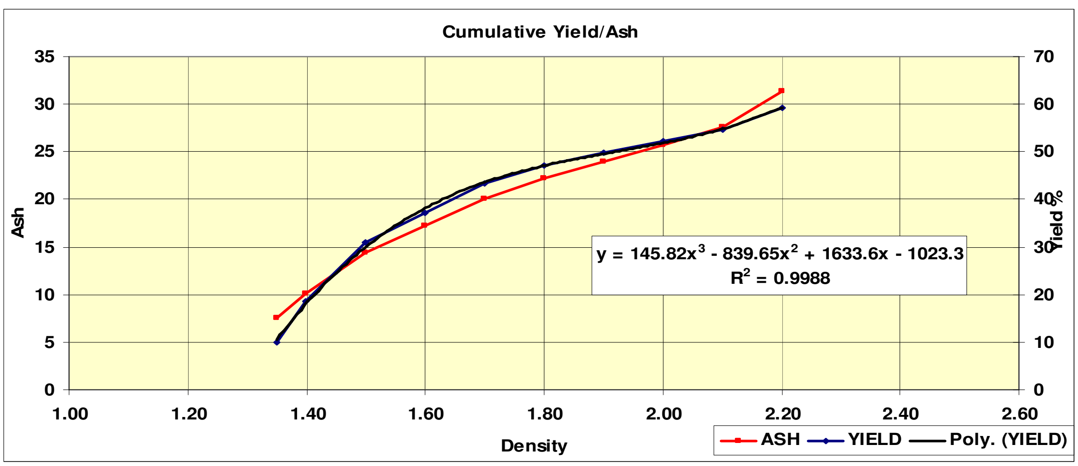


Figure 64 Combination table and graphic depicting the fractional wash table and the cumulative wash table of this as well as the extraction curves on the cumulative values.

The ash adjusted table takes the existing tables data and then uses the ash adjusted density algorithm to recalculate the true density of the float fraction based on the ash analysis at that fraction shown again in the RD_2 column. This new data is then cumulated for product extraction. Sample extraction is based on a 4th order polynomial interpolation of the relevant ash density adjusted data.

Adjusted Data									
RD_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	SULPHUR	CV	PHOS
1.30	9.98	2.35	7.50	36.66	4.87	64.00	1.01	29.85	0.00
1.37	8.52	2.14	13.00	35.58	4.26	58.00	1.12	27.88	0.00
1.48	12.59	1.97	20.87	32.59	2.80	32.00	1.24	24.95	0.00
1.62	6.17	1.98	31.10	28.54	0.92	0.00	1.32	20.94	0.00
1.71	6.03	1.94	37.97	25.89	0.54	0.00	1.45	18.19	0.00
1.84	3.77	2.09	46.94	22.19	0.04	0.00	1.38	14.44	0.00
1.95	2.72	2.28	55.13	19.35	0.00	0.00	1.50	10.90	0.00
2.04	2.35	2.37	61.78	17.14	0.00	0.00	1.51	7.97	0.00
2.12	2.41	2.53	67.47	15.15	0.00	0.00	1.44	5.38	0.00
2.22	4.79	2.98	75.01	13.20	0.00	0.00	0.89	2.12	0.00
2.34	40.65	1.57	83.69	10.87	0.00	0.00	0.98	0.90	0.00

Calculated Cumulative data									
Rd_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	SULPHUR	CV	PHOS
1.30	9.98	2.35	7.50	36.66	4.87	64.00	1.01	29.85	0.00
1.37	18.50	2.25	10.03	36.16	4.59	61.24	1.06	28.94	0.00
1.48	31.10	2.14	14.42	34.72	3.87	49.40	1.14	27.33	0.00
1.62	37.26	2.11	17.18	33.69	3.38	41.22	1.17	26.27	0.00
1.71	43.29	2.09	20.08	32.61	2.98	35.48	1.21	25.14	0.00
1.84	47.06	2.09	22.23	31.77	2.75	32.64	1.22	24.29	0.00
1.95	49.79	2.10	24.03	31.09	2.60	30.85	1.23	23.55	0.00
2.04	52.14	2.11	25.73	30.46	2.48	29.46	1.25	22.85	0.00
2.12	54.55	2.13	27.57	29.79	2.37	28.16	1.26	22.08	0.00
2.22	59.34	2.20	31.40	28.45	2.18	25.89	1.23	20.47	0.00
2.34	99.99	1.94	52.66	21.30	1.29	15.36	1.12	12.51	0.00

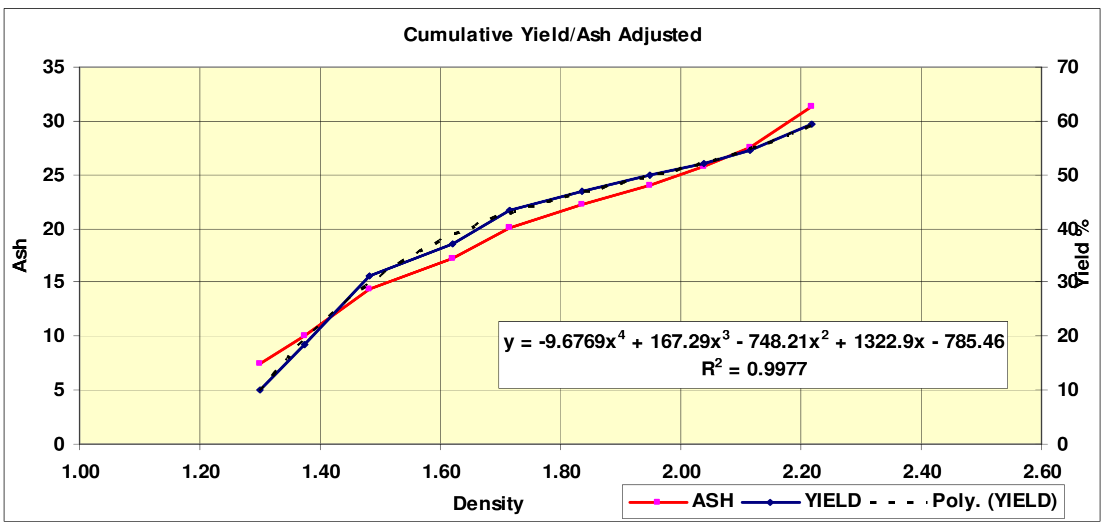


Figure 65 The ash-Density adjusted fractional wash table and the cumulated, adjusted wash table for product extraction for the same material as in Figure 64.

The two sets of extractions can then be compared. The table below is a comparison of three sets of extracted data. The upper table showing the 4th order polynomial interpolation on the original cumulated wash data, values as extracted utilizing the CAB feature of SABLE Data Warehouse software and the 4th order polynomial interpolation of the ash adjusted density data cumulated. The lower table represents values adjusted by correlation factors currently in use, for the SABLE generated data and a pseudo correlation factor of 80% plant efficiency in the case of the polynomials.

Table 6 Comparisons of three methods of product prediction.

	Yields		
	4th Order polynomial on normal wash data	SABLE Derived products	4th Order polynomial on Ash/Density adjusted wash data
35% Ash Product	73.53	66.22	96.57
1.80 g/cc Rd Primary Cut Product	47.15	47.06	47.34
10.3% Ash Product	16.25	19.27	15.67
Power Station product (Middlings)	30.86	27.79	31.68
Coking coal cut Rd	1.39	1.41	1.35
	Expected Yields		
Bench 2 North (Weathered) Coking coal correlation factor 59.66%, Middlings coal correlation factor 115.17%	4th Order polynomial on normal wash data assuming 80% efficiency	SABLE Derived products adjusted by correlation factors currently used	4th Order polynomial on Ash/Density adjusted wash data assuming 80% efficiency
35% Ash Product	73.53	66.22	96.57
1.80 g/cc Rd Primary Cut Product	47.15	47.06	47.34
10.3% Ash Product	13.00	11.50	12.54
Power Station product (Middlings)	37.03	32.01	38.02

The most relevant, and interesting value to emerge from this adjustment and comparison, is that of the coking coal cut density, both from the SABLE and initial 4th order polynomial cut densities are unrealistically high, while the ash adjusted density value conforms with the range within which the beneficiation plant is operating.

The foregoing verifies the hypothesis that the application of derived algorithms relevant to the ash density relationship to correct wash data to reflect true density of the raw material can be ascertained. This will result in improved predictions of qualities and serves to illustrate the application of this methodology.

The true value to be realized would be obtained from the inclusion of this predictive methodology to all the raw material planned from the respective benches. This would be done in their planned ratios to the beneficiation plants, requiring the basic method to be expanded to cope with multiple blast block scenario's from which a single wash table for the material passing through the plant can be obtained. A template has been made to accommodate up to 8 blast blocks per day per week if necessary. The wash table information is derived from a weighting of the proximate parameters based on the ratio of those blocks' contribution to the total table. Once all relevant blocks' raw fractional data has been entered, the ash density adjustment is done and the wash table cumulated for product extraction.

The same process can be followed using the as-mined ratios, since blocks that are planned in certain ratios are not necessarily dispatched to the plant as per plan. The major advantage, however, is that the data for the material, irrespective of its source can be accommodated and utilized in an ongoing method to improve the prediction of probable products at their various controls. Not only will yield values be accordingly adjusted, but other important properties can be derived since a working wash table of the proximate analysis of the raw material is being utilized for the derivation of these values.

As reasonable results were obtained from the Beta testing of the ash density adjustment methodology, this method was implemented on a trial basis from the beginning of November 2007. The advantages of using this methodology negated the need for bench correlation factors, which could not be adequately updated or renewed as a result of the mining operation having to honour pit geometry.

The implication is that individual benches could not be mined exclusively to obtain the necessary data for the evaluation of bench correlation factors. The raw feed material from the mine, now represented by a daily changing blend of material from the various benches, can be accommodated. This disallows the determination of behavioural properties of the individual constituents to ascertain acceptable correlation factors for the individual benches. An acceptable correlation between predicted and actual yields reflecting overall plant efficiency can now be obtained.

5.5 PARTIAL IMPLEMENTATION OF PROPOSED METHOD

The notion of partial implementation stems from the fact that only the grade control contribution to short term planning was addressed in this phase. Full implementation necessitates the application of this methodology to the geological model parameters as well (Roux, 2008).

In order to assess the application of this methodology, the use of new values obtained through the AAD method was introduced on the grade control predictions derived from the geophysically logged blast-holes and the theoretical yield values were used in mine planning activities from the beginning of November 2007**.**

The plant's operation was thus measured against theoretical yields determined for the blends of material dispatched from the mine, irrespective of the bench of origin. This provided a good reflection of the plant's efficiency (see below). Monitored over a reasonable period of time, this method would allow the derivation of more accurate correlation factors for predictive, scheduling, budgeting and forecasting purposes based on the plants efficiency.

The evaluation of the data from the GG1 beneficiation plant has been used for this exercise and has once again been subdivided into the two main products derived from this material. The main products being semi soft coking coal at a control ash of 10.3% and the remaining middlings (power station product) left after the SSCC product has been extracted from the primary product, obtained from the run of mine material at a cut density of 1.80 g/cc.

5.5.1 SEMI SOFT COKING COAL EVALUATION

The monitoring period's data starting January 2008 to late 2010 will be used to illustrate the differences. Yield values have been condensed to monthly averages and the detailed evaluation of this phase is covered in an internal report (Roux, 2008).

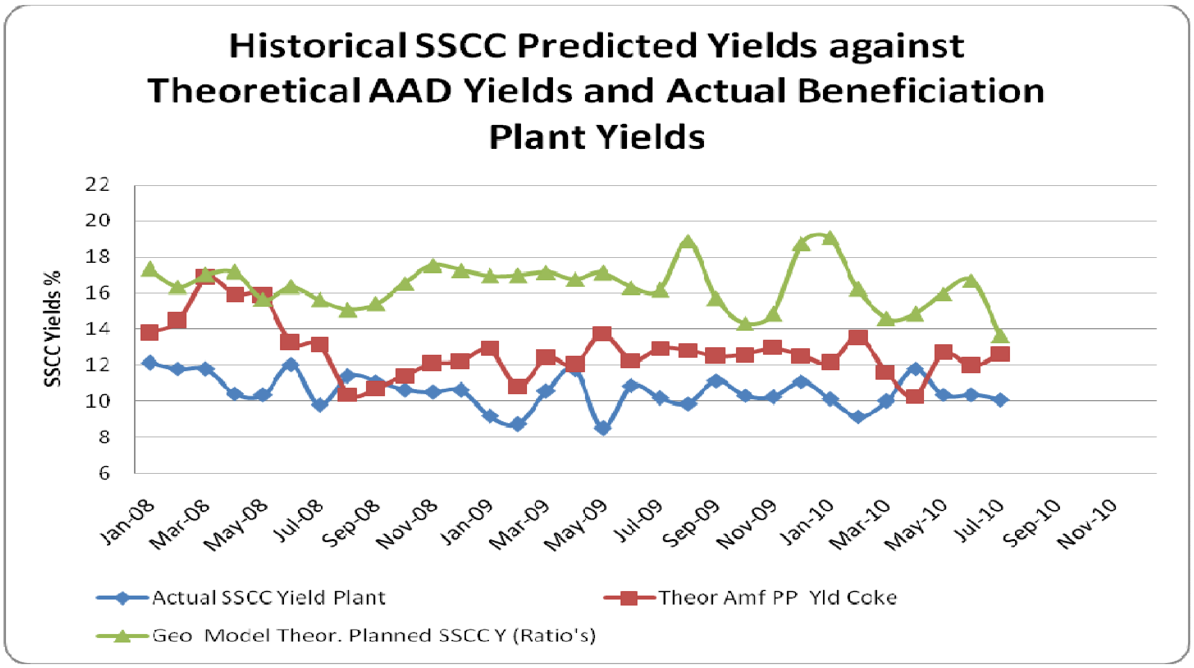


Figure 66 Historical SSCC monthly yields compared with theoretical AAD monthly yields and the actual beneficiation plant yields.

(The abbreviations used in this figure are as follows: Actual SSCC Yield Plant, referring to the actual production of semi soft coking coal, Geo Model Theor. Planned SSCC Y (Ratio's) referring to the original planned geological model values derived from the old product prediction methods for semi soft coking coal with the ratio's of admixtures from different sources being taken into account and the Theor. Amf. PP Yld. Coke referring to the value obtained after mine floor deviations from the predicted mining elevations had been taken into consideration and product extraction based on the same controlling parameters used in the plant for that period.)

Figure 66 highlights the old system values as well as the pitch of the theoretical ash adjusted density determined yields for the same period, notably the ash adjusted theoretical values are lower than the historically determined values, but substantially closer in value to the actual yields obtained in the beneficiation plant. There is no discernable correlation between the old set of values and the set derived from ash adjusted density determination with the exception of the period representative of production during October 2007(not shown in Figure 66). Thereafter the ash adjusted density derived values and the traditionally determined values do not correlate at all.

The only valid observation is that the ash adjusted values are predominantly lower than the historical theoretical yields. Introducing the actual plant yields obtained illustrates an improved trend association suggesting correlation between the ash adjusted values and actual plant yields, evident in Figure 66.

In assessing beneficiation plant efficiency, consideration should also be given to process losses and misplacements of product that are bound to occur. In a typical beneficiation plant, due to mechanical actions in the process, fines are generated, these are invariably lost to slimes, and sizes of broken material may not be optimal to allow maximum liberation of near density material thus creating the possibility of misplacement of material to both products. This implies that coking coal can be misplaced to the middling product and vice versa, as well as the probable loss of fine and ultra fine material to slimes which invariably are discarded. The actual plant yield In Figure 66 tending to follow the AAD plot may well be representative of the plant's efficiency.

In order to test this assumption a 90% correlation factor was applied to the data for this period to accommodate possible misplacements to middling and the result plotted in Figure 67, verifies a better correlation than any previously obtained.

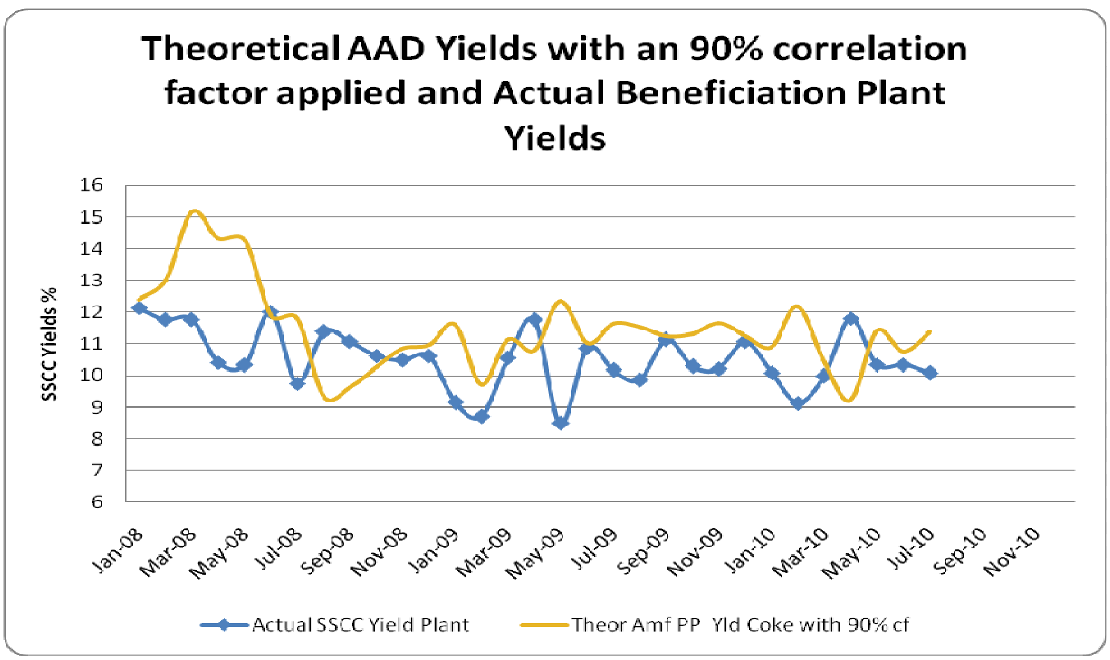


Figure 67 Theoretical AAD yield with 90% correlation factor applied to accommodate possible misplacement of SSCC to middling.

(The abbreviations used in this figure are as follows: Actual SSCC Yield Plant, referring to the actual production of semi soft coking coal, the Theor. Amf. PP Yld. Coke referring to the value obtained after mine floor deviations from the predicted mining elevations had been taken into consideration and product extraction based on the same controlling parameters used in the plant for that period and cf refers to the correlation factor.)

At this point however it may be prudent to include information from the middlings evaluation pertinent to the coking coal yield.

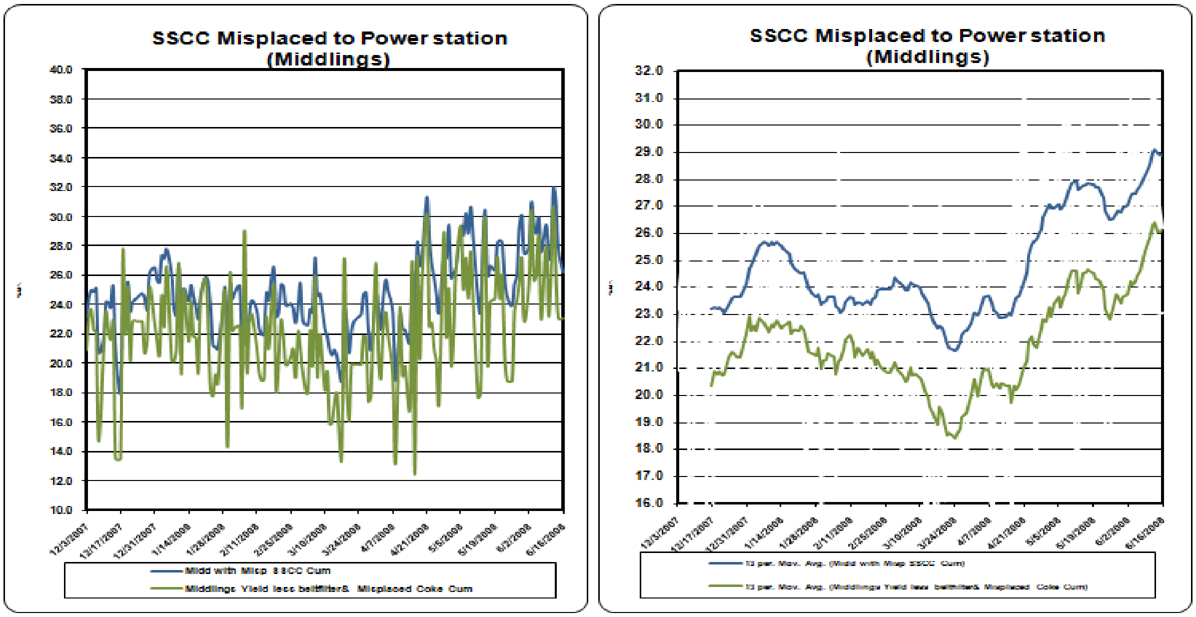


Figure 68 Semi-soft coking coal misplacement to middlings

Analysis of the middling product to ascertain the amount of misplaced coking coal shown in Figure 68 with a 5 point moving average applied to this data gives a rough average of 2.25% coking coal inclusion. Referring this back to theoretical coking coal yield, it represents a loss of 10% to 15% of the semi soft coking coal product.

A detailed extract from a graphic covering a six day period from 30th June to the 5th July illustrates problems experienced with regard to controls relating to spot ash values done on an hourly basis. A further complication to the entire scenario arises from the supply of raw material to the plant. The ratios of material supplied from mining may be vastly different from the planned ratios or they may be quite accurate. The problem stems from the fact that five silos are fed from the drum breaker and that the silo levels are maintained automatically. Only three feed streams however are operational at any particular time, so the initial ratios that the material was delivered in are firstly upset by the distribution of feedstock to the various silos and the streams feeding the plant are also controlled with regard to silo levels. The net result is that the feedstock now has an entirely different composition with its own composite wash table which could be totally different from the original planned scenario.

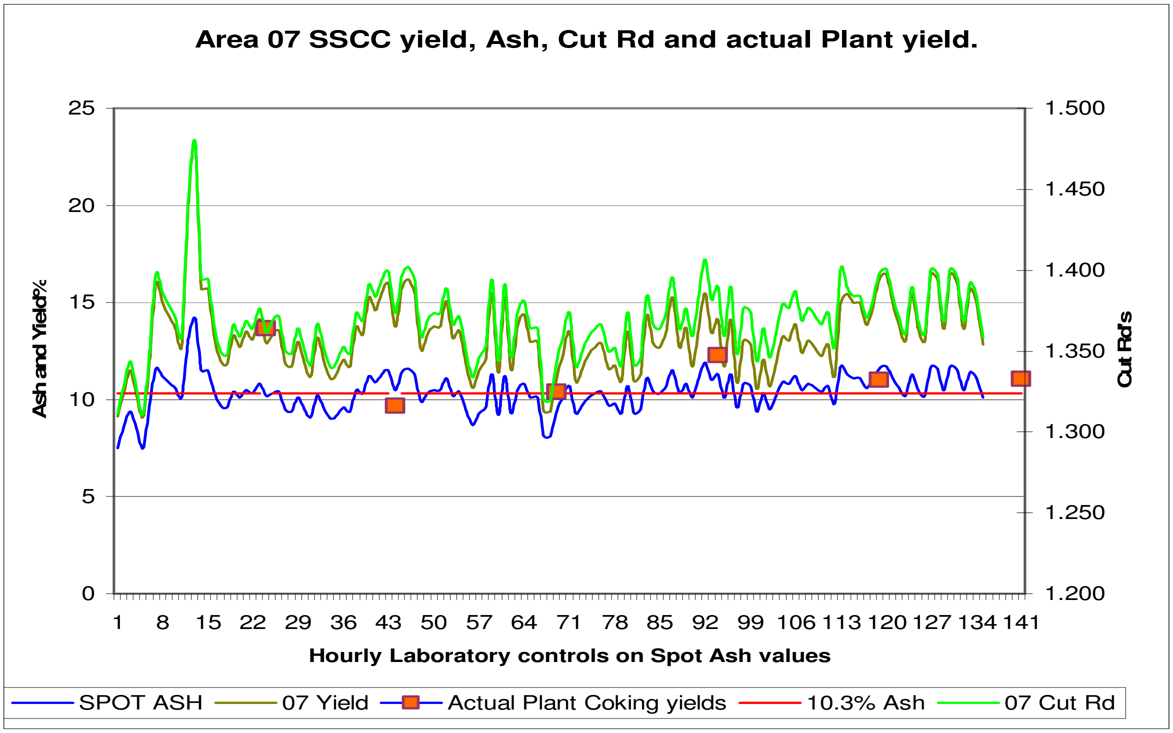


Figure 69 Final Semi soft Coking Coal product fluctuations as a result of changing conditions in the plant and raw feedstock ratios.

Assessing the trends for Area 07 Cut Rd and the Area 07 Yield (area 07 represents the final semi soft coking coal product stream) in Figure 69, the spot ash and cut Rd trends are mirror images while the effect of near density material is pronounced in areas where the two trends diverge indicating that a higher cut Rd is required to produce a yield at the control ash value. This implies a greater contribution of slightly higher density material to compliment the amount yielded by the correct density fraction for that specific ash control. Condensing the information from Figure 69 to a daily averaged value highlights misplacement of semi soft coking coal product to the middling product as shown in Figure 70. The first day's actual plant yield and determined average yield derived from hourly ash analysis are accurate, while the second and third day's values show a lower actual yield than the hourly results appear to indicate. This may reflect misplacement of coking coal to middling or changes in feed ratios as a result of silo and feed blends, the fourth day's results are again in agreement, while the last two days give a lower yield than the laboratory results seem to indicate.

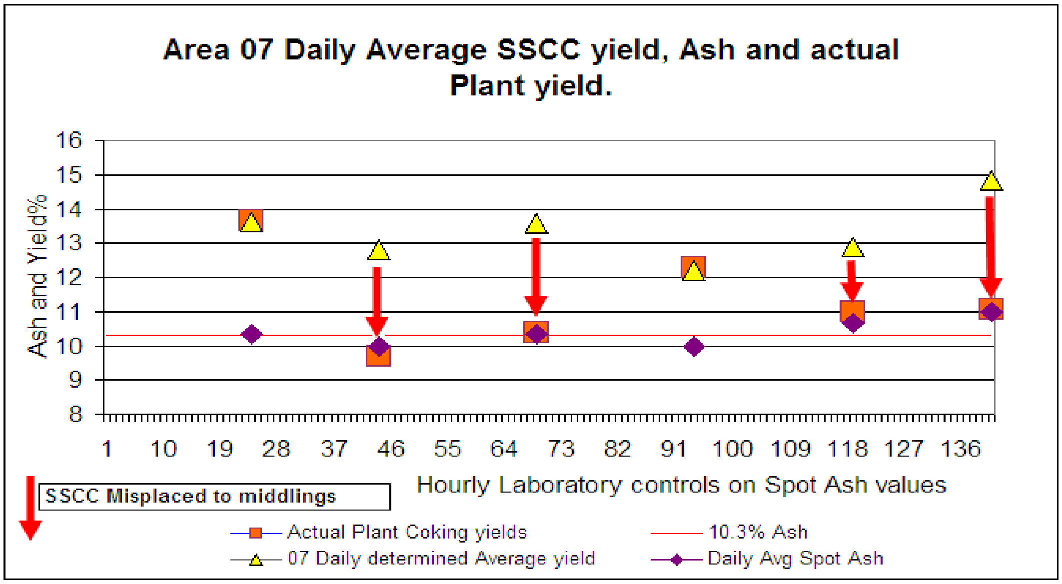


Figure 70 Daily averaged yields and ash controls for area 07 and probable misplacement of SSCC product.

The noted variations around the laboratory determined spot ash values are indicative of changes to cut density controls, illustrating constant variations on the modules to try and maintain a 10.3% ash control. A further adjustment was then made to decrease the correlation factor to 83% allowing for the misplacement of near density material to the middlings product.

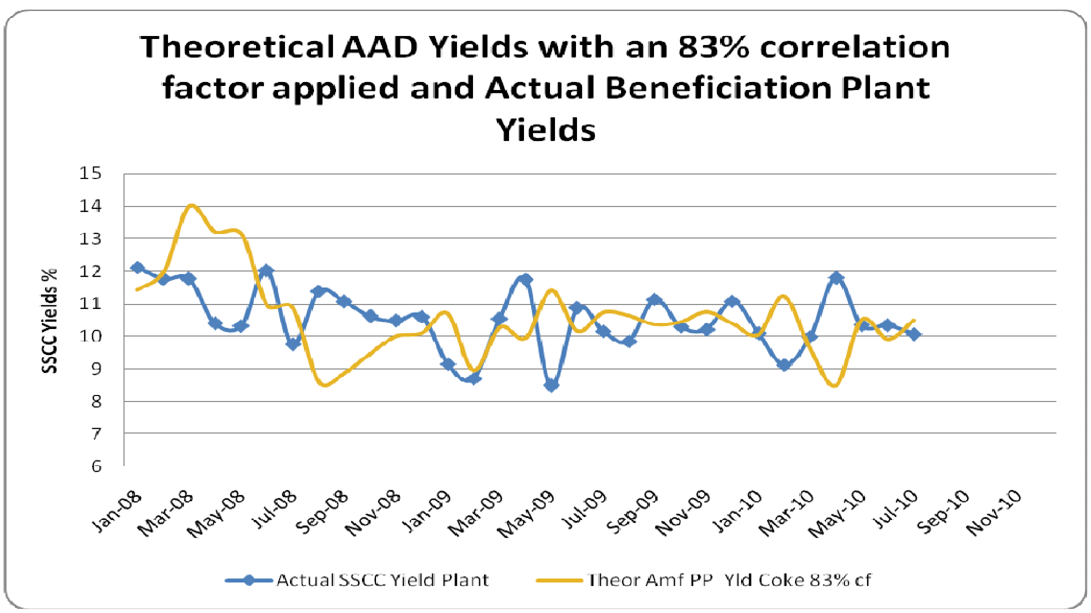


Figure 71 Theoretical AAD yield with an 83% correlation factor adjustment, correlation with actual plant yields.

The effect of constant changes to the cut densities in order to control the end products ash are also very evident in Figure 72, where the ash controls have been reduced to a monthly representative value and plotted on a secondary scale. Noticeably the yield trend dips in accordance with the lower ash control values, indicative that in all probability, only the vitrinite fraction is being extracted.

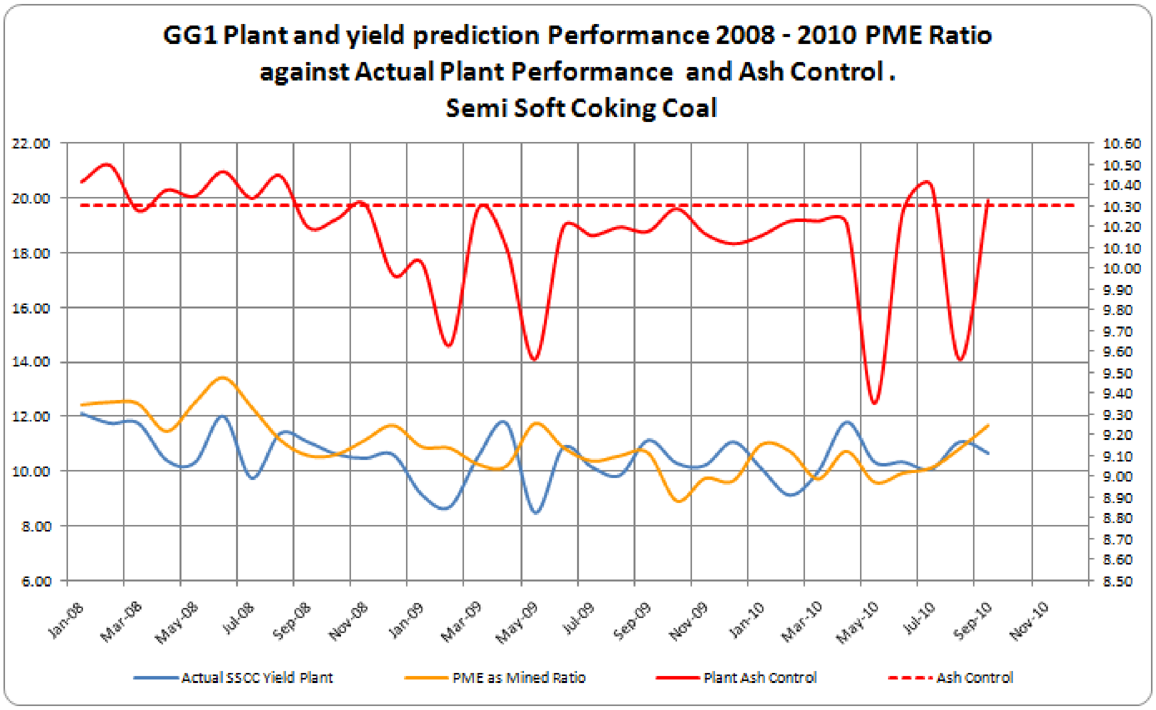


Figure 72 Plant ash control values illustrating effect on yield obtained.

(The abbreviations used in this figure are as follows: Actual SSCC Yield Plant, referring to the actual production of semi soft coking coal, PME as mined ratio refers to the predicted mining elevation yields adjusted to accommodate the block ratios from the mine.)

The following points were observed with regard to semi-soft coking coal

- Ash adjusted density values for semi soft coking coal align below the old theoretical yield values used for predictions.
- Ash adjusted density predicted and theoretical yields and actual plant yields appear to follow a similar trend.
- An assessment of semi soft coking coal misplaced to middling over this period has resulted in a value of approximately 10% to a max of 15% of the original yield value determined. Taking the conservative value of 10% and adapting this as a correlation factor between the theoretical yield and the probable expected yield has resulted in a reasonable correlation between the plant actual yields and the determined values.

- This factor however may be more closely related to the material size distribution and as such should not be seen as a plant efficiency factor. Calculations of planned, predicted and as mined yields have also taken yield determination methods into account, but are not used here since the objective is primarily to do away with correlation factors. (Refer to Appendix D)

- Variance in control ash values can play havoc with the end product. Predictions are done at 10.3% ash, while the period under consideration has yielded very few point values equal to this control. A substantial amount of material is lost due to fluctuations with regard to ash control.

- Deviations between mine planned blocks and the actual blocks sent to the plant result in discrepancies in determined yields.

- Actual plant yields with the misplaced semi soft coking coal taken into account correlate relatively well with the as mined floor and plant parameter adjusted yields. Here floor deviations as well as the controlling parameters at which the plant is being operated are taken into account.

- Products extracted at a 1,338g/cc cut density are representative of the free vitrinite available and if predictions, budgeting and forecasting were based on this, no correlation factor would be required. Should the 10.3% ash extraction on the cumulative curve however be used the values should be adjusted by a correlation factor of 83% taking the misplaced semi soft coking coal and the top size of the feed material into account.

5.5.2 MIDDLINGS COAL EVALUATION

The middlings coal or power station coal product will always be dependent on the initial or primary separation density in a double stage beneficiation plant, the primary cut being the first stage separation of waste and wash product from which the coking coal product can be extracted. The remaining material after the coking coal product has been taken is then classified as middlings coal which is used for a power station product.

The primary separation density was selected in such a way that the properties of the remaining products would still be within power station product specifications, i.e. with reference to the ash and calorific value of the product.   The evaluation would therefore follow the same criteria as applied to the semi soft coking coal evaluation. The original power station yields derived from empirical data compared with the ash adjusted density theoretical value and actual plant yields are shown in Fig 73.

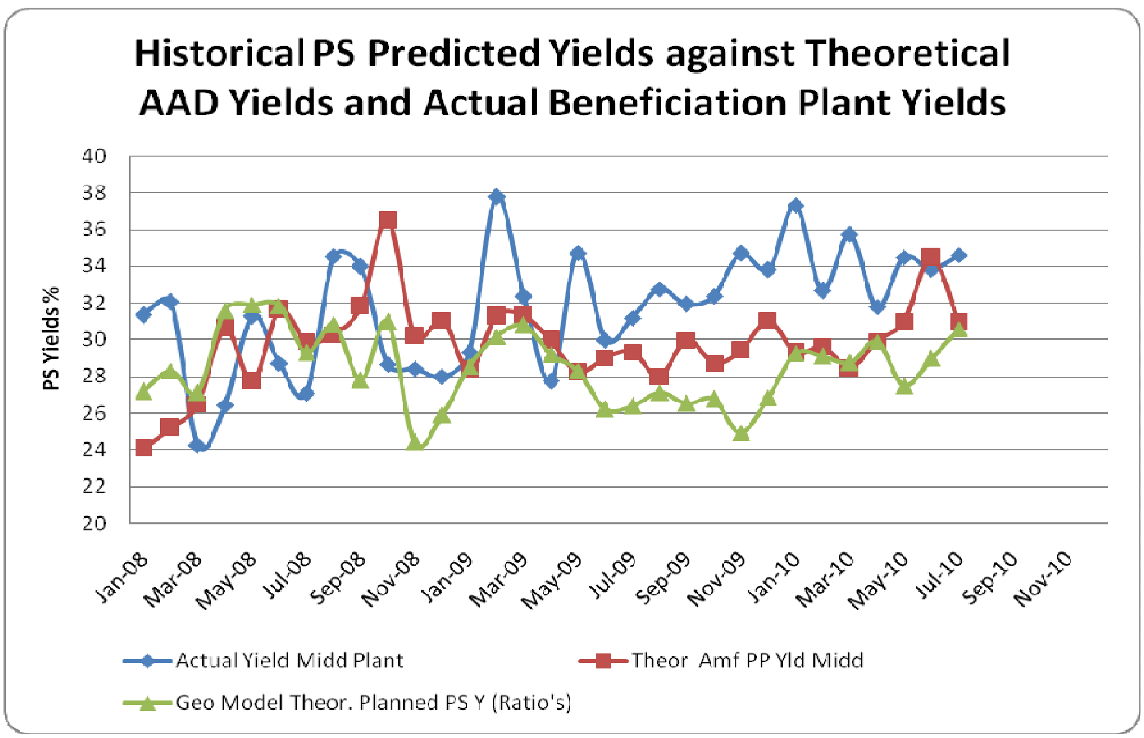


Figure 73 Power station yields for planned and expected as mined values based on the old system.

(The abbreviations used in this figure are as follows: Actual Yield Midd Plant, referring to the actual production of power station coal, Geo Model Theor. Planned PS Y (Ratio's) referring to the original planned geological model values derived from the old product prediction methods for power station coal with the ratio's of admixtures from different sources being taken into account and the Theor. Amf. PP Yld. Midd referring to the value obtained after mine floor deviations from the predicted mining elevations had been taken into consideration and product extraction based on the same controlling parameters used in the plant for that period.)

In order to understand the power station product better, it should be broken down into its main components, being the material remaining after the semi soft coking coal product has been removed, the total power station yield less the misplaced coking coal and the belt-filter recovered slimes. The following graphic Fig 74 shows the plant power station yield, less the misplaced material against the theoretical yield obtained from the original wash tables before ash adjusted density had been applied.

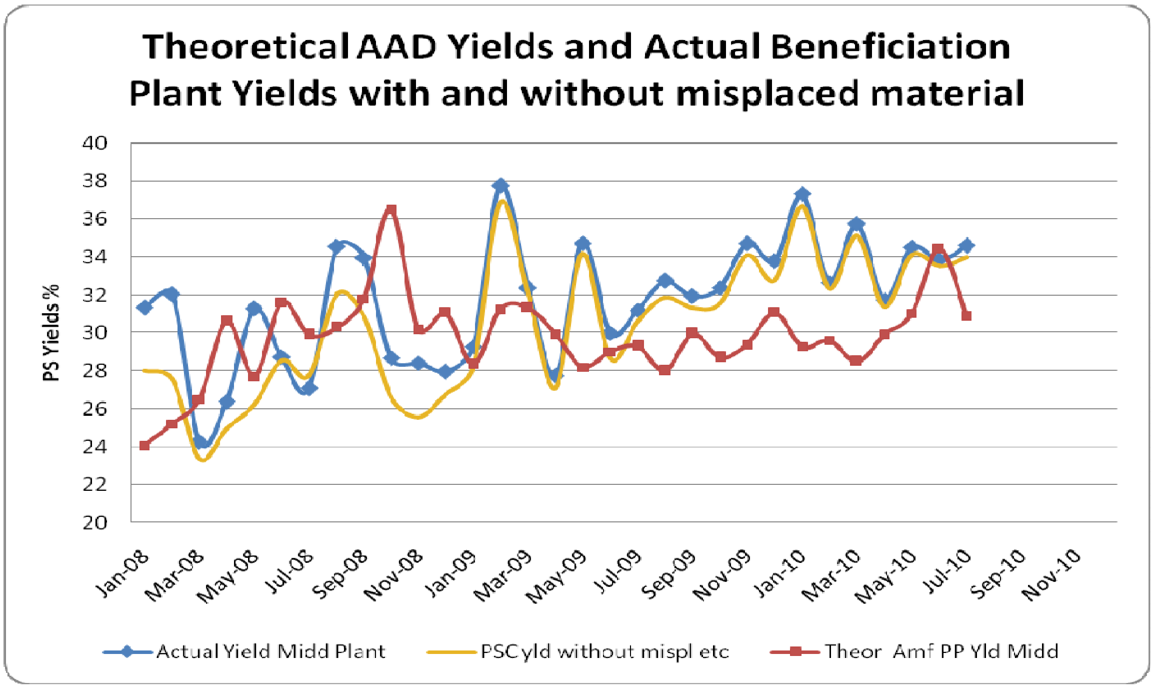


Figure 74 Theoretical yields from original wash tables against plant yield without any misplaced or additional recovered material.

(The abbreviations used in this figure are as follows: Actual Yield Midd Plant, referring to the actual production of power station coal, the PSC yld without mispl etc referring to power staion coal without misplaced semi soft coking coal added and the Theor. Amf. PP Yld. Midd referring to the value obtained after mine floor deviations from the predicted mining elevations had been taken into consideration and product extraction based on the same controlling parameters used in the plant for that period.)

This should be representative of the fraction remaining after floating at 1.80g/cc Rd and extracting the coking coal product at a 10.3%ash equivalent.

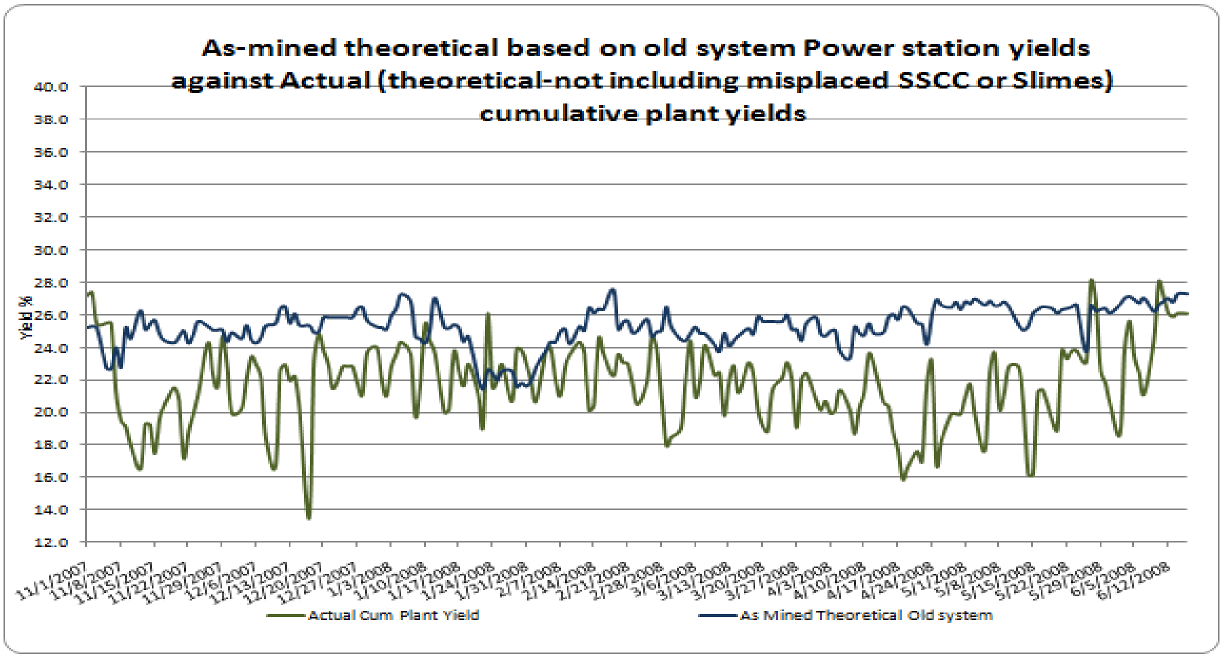


Figure 75 Refers to the as mined correlation factor adjusted yield, against the base plant power station yield.

In Figure 76 the ash adjusted density theoretical yield value, pitches below the expected as mined yield from the old system and appears to be more stable over this period.

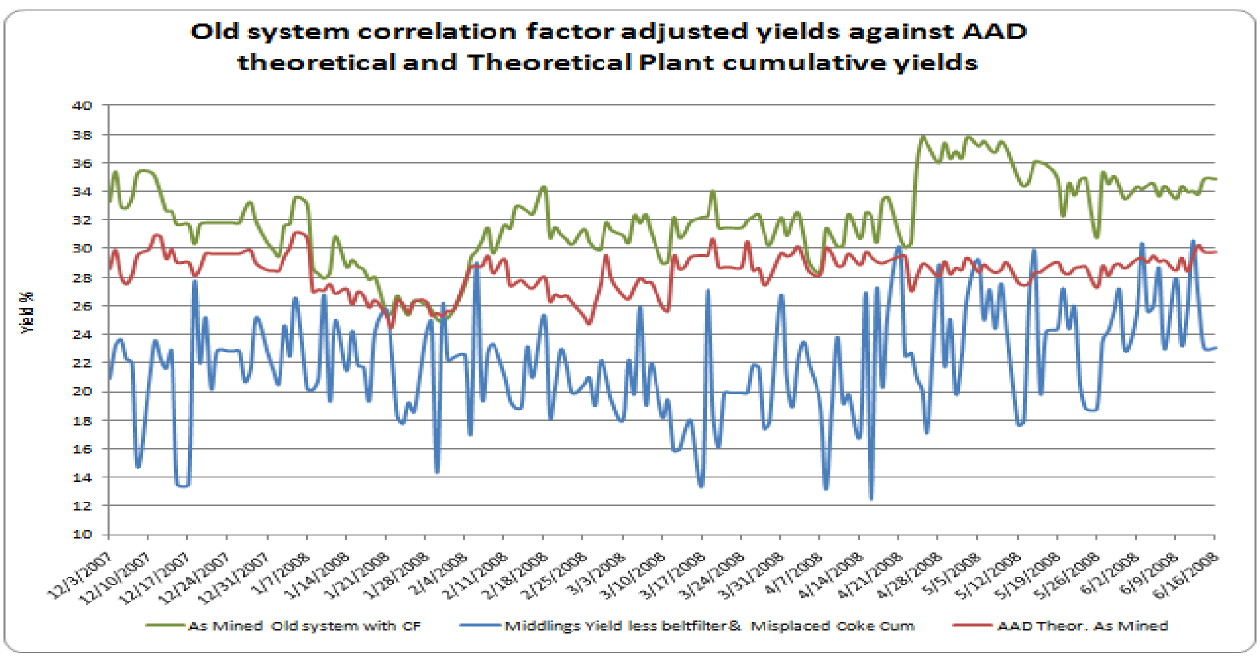


Figure 76 AAD theoretical against old expected and plant base yield.

Generally the predicted yield appears to be around an average of 28% with a standard deviation of approximately 1.95%. In order to gain a better understanding of the configuration of the power station end product, the total yield has been broken down into its individual components in Figure 77.

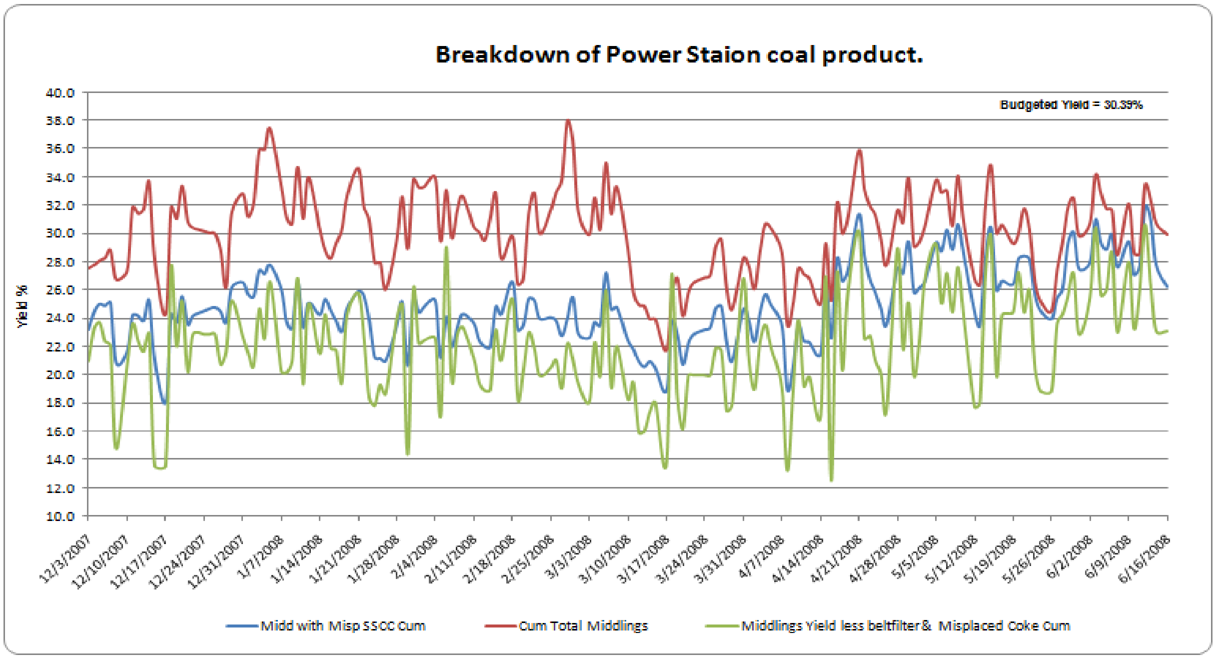


Figure 77 Breakdown of power station products individual yield components.

The value reported by the plant includes the misplaced coking coal and the belt-filter recovered slimes and as such is substantially higher than the values predicted from the wash table product extractions.

In the past, individual bench correlation factors were determined in an attempt to accommodate this increase in yield. In much the same way, the ash adjusted density values will also need to be adjusted to accommodate this change. Thus an initial adjustment to correct the middling yield to accommodate the misplaced coking coal would effectively need the predicted yield to be raised by the amount of semi soft coking coal misplaced. This however does not take the recovered slimes from the belt filter into account.

During the evaluation of the semi soft coking coal product and its behaviour, a reasonably constant deviation in the amount of coking coal displaced to middling as a result of the size distribution of the finer materials was obtained, This was illustrated in Figure 68. Due to the almost parallel trends, the value could be adopted with reasonable certainty. The semi soft coking coal yield value was then adjusted by a 90% correlation factor, although the range indicated was between 10% and 15% of the product. The 10% value has given a reasonable correlation with the actual plant data and should be attainable. This results in the first adjustment to the middling value which should be in the order of a correlation factor of 110%.

Assessing the belt-filter recovery however is an entirely different matter, since no constant trend over the investigation period can be established. Values vary between 2% and 9% as can be seen in Figure 78. The 13 point moving average does not show any near parallel trends that can be used to justify a correlation amount with any degree of confidence.

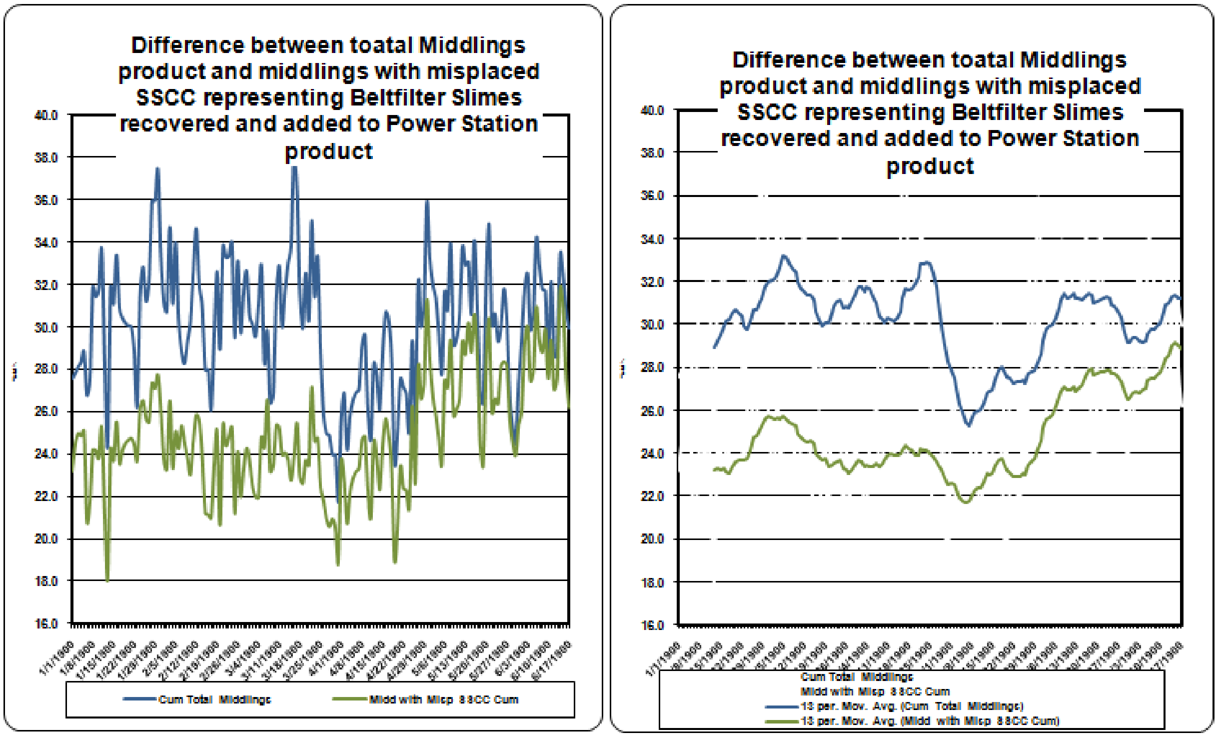


Figure 78 Cumulative Power station coal less belt-filter recovered slimes.

These fluctuations may be as a result of either, changes in the primary cut density ranges due to variations in the coarse to fine ratio, or, due to variations in raw run of mine feed ratios from the respective mining benches, or a combination of both.

The following points were observed with regard to Power station coal (middlings)

- The actual plant middling yields, stripped of misplaced semi soft coking coal and belt-filter recovered material are generally lower than the original theoretical middling yields derived from the unaltered wash tables.
- The ash adjusted density theoretical value is less than the old expected value and appears more constant with a smaller standard deviation over the same period.
- A better understanding of the overall composition of the middling product is obtained by breaking it down into its various components. The basic theoretical value followed by this same value including misplaced semi soft coking coal product and lastly the addition of slimes recovered in the belt filter plant to portray the final power station product.

- A correlation factor derived for middling yield would have to take the foregoing into consideration.

5.5.3 EFFECTIVE DIFFERENCES BETWEEN ASH ADJUSTED DENSITY DATA, THE OLD WASH TABLES AND THE GEOLOGICAL MODEL EXTRACTED PRODUCTS.

The following sets of figures, Figure's 79, 80 and 81, illustrate the differences between the three methods for product extraction. Note however that the geological model values are based on the perfect defined block, i.e. the roof and floor contacts conform to the geological model definitions, while the remaining methods address the practical situation in the open pit to a prescribed floor elevation equivalent to the geological model. The roof elevations for the respective blocks however have taken the previous, or actual floor as mined from the previous bench into account, thus they do not conform to the model values.

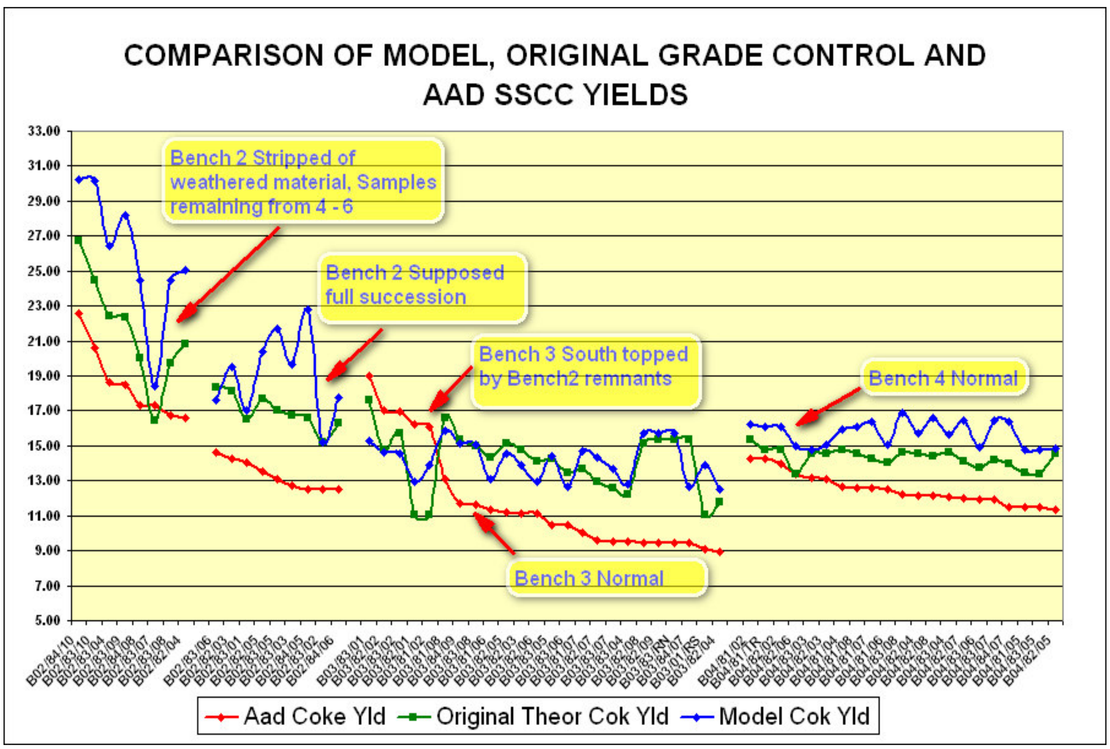


Figure 79 Comparison of geological model, grade control and AAD SSCC yields for individual blast blocks on the different benches.

The semi soft coking coal comparison plot shows the ash adjusted density approach to be the most conservative and in all probability the closest to the actual semi soft coking coal product that can be obtained at a 10.3% ash control. This also verifies the overall misleading effect of the near density material previously included in the product extractions at higher cut densities not representative of the material sought. The higher concentrations of vitrinite in especially bench 2 and the upper portion of bench 3 contribute to this phenomenon.

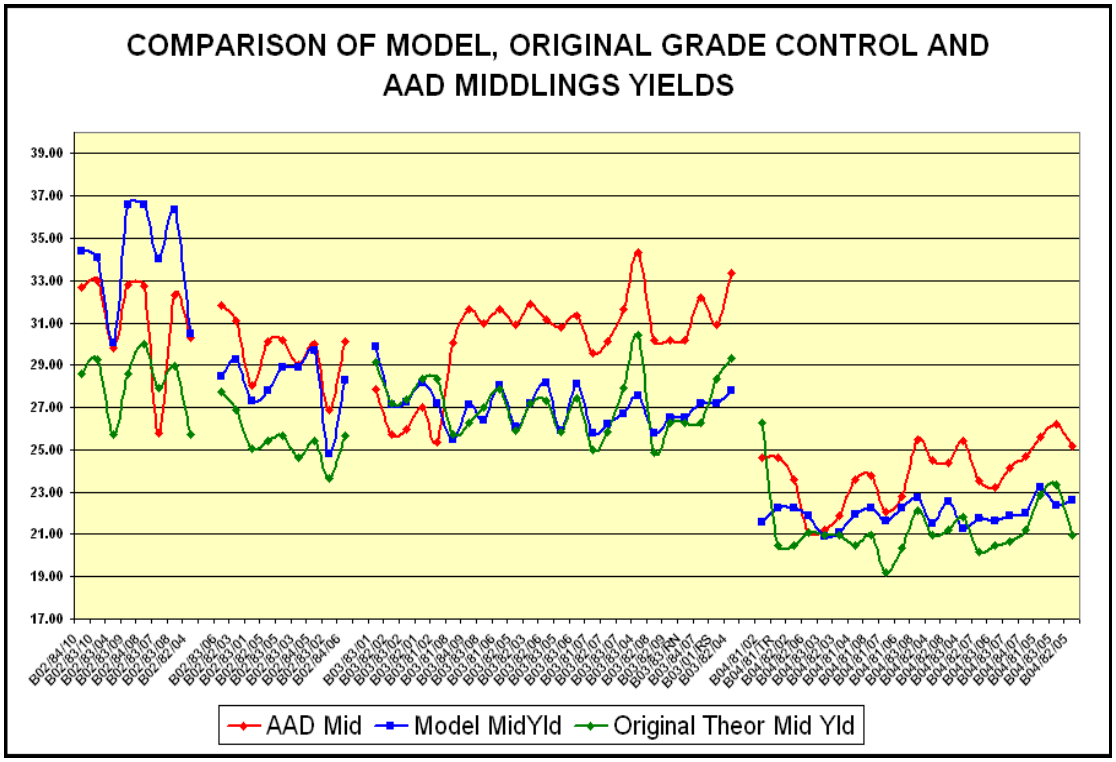


Figure 80 Comparison of geological model, grade control and AAD Middling yields for individual blast blocks on the different benches.

The middling coal plots show the ash adjusted density values to be substantially higher than the original grade control theoretically derived values in most cases. This too would be as a result of the adjustments brought about by the application of ash adjusted density to give a more representative ash/density correlation of the products extracted from the initial 1.80g/cc primary cut. The proof though, that the major changes to the ash density range have been limited to the lower near density material is obvious when a comparison is done on the total yield obtainable from the 1.80g/cc cut.

The plot of total yields shows both the original wash table extraction and the ash adjusted density 4^{th} order polynomial extraction products almost parallel over benches 3 and 4 with a minor deviation of approximately 1% that the ash adjusted density value is higher than the original value.

The bench 2 trends however are almost identically superimposed. The large differences between the geological model values and the other can be attributed to the differences between the ideal modelled block parameters and reality. The plots also reflect the variable nature of the individual blocks in relation to each other on the different benches as a result of the sedimentary, depositional environment.

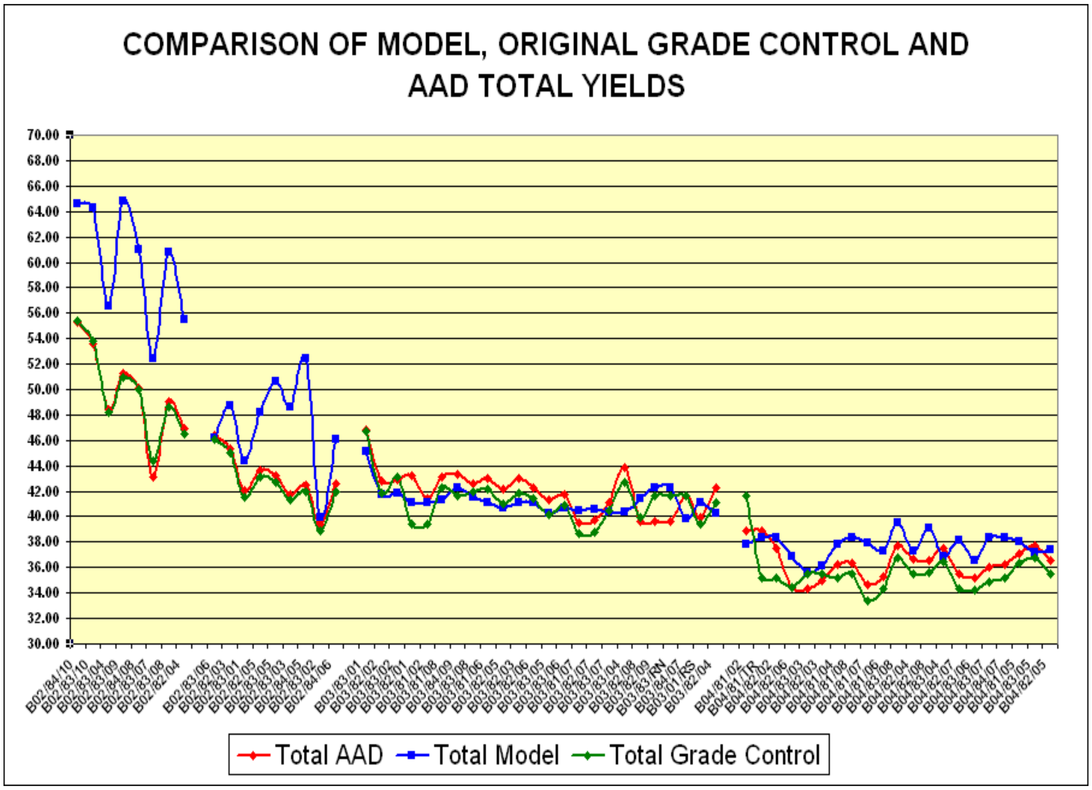


Figure 81 Comparison of total yields from the 3 methods.

5.5.4 The conclusions based on observations with regard to semi soft coking coal and power station coal evaluation are the following:

- The application of ash adjusted density to the raw composite wash table data has resulted in more representative wash tables also accommodating the lower density regions for more accurate interpolation in these regions. Previously the wash data ranged from 1.35g/cc to 2.2g/cc at fixed density intervals. Now the tables can range from as low as 1.25g/cc to 2.2g/cc, the density values are derived from the absolute ash value.

- Overall and applied to the mining blocks, this has resulted in lower more representative theoretical semi soft coking coal yields for the individual blocks.

- A more accurate constant for the semi soft coking coal misplaced to middlings has been determined, since this is directly related to the size fraction of the material being beneficiated as opposed to the empirical size fractions used on the borehole core analysis at the pilot plant. This constant has been implemented as a correlation factor on the theoretical value. The correlation factor now being used is 83% of the theoretical value.

- The converse of the above would then necessitate the difference being used for the middlings correlation factor. This however does not compensate for the addition of recovered slimes or variations in the initial primary cut from which the semi soft coking coal product has been extracted. Due to the inconsistency of the variations in slimes recovered and the variations in primary cut density a median value with a slight additional compensation has been applied. The closest approximation is roughly 113.5%, which has been further adjusted to the value currently in use, namely 115%.

- The variability of the power station product's composition therefore does not allow for a specific correlation factor being applied with confidence apart from the misplaced semi soft coking coal which forms a part of the product.

- Variations in the ratios of the blends being sent to the plant impact profoundly on the representative wash tables used for product extraction. If the planned values are not adhered to, the material being beneficiated will have totally different properties compared to those used for planning purposes.

- Although blast block yields are determined using ash adjusted density and wash table information for the specific products required, the admixture of blocks planned by short term mine planning are based on arithmetical composites. The daily as mined ratio adjustments to ascertain the blends actually dispatched from the mine are also based on arithmetical compositions.

- On comparison, discrepancies or deviations between the arithmetical approach and proper wash table construction and product extraction of the blend material do exist. These deviations have been addressed and a plant constant formulated.

6 TECHNO-ECONOMIC EVALUATIONS USING AAD

6.1 AAD COMPARED AGAINST GEOLOGICAL MODEL PREDICTED VALUES, BUDGETED VALUES AND THE BENEFICIATION PLANTS ACTUAL PERFORMANCE.

The ash adjusted density algorithm was implemented on short term mine planning. Grade control predictions from January 2008 were condensed to monthly based values and used for comparative and evaluation purposes.

The data used here spans a period from January 2008 to approximately September 2010. Data for these comparisons was extracted from the monthly Geology, Grade control, Mining and Beneficiation plant reconciliation reports.

The three main datasets used in this evaluation are:

The geological model predicted theoretical yields and tonnages, based on product extractions done on empirical laboratory data, composited, cumulated and modelled for the respective benches from the exploration derived data without correlation factors taken into account.

The as mined, ratio, floor and plant parameter adjusted, reconstituted ash adjusted density corrected theoretical yields and tonnages with a correlation factor allowing minor plant in-efficiencies with regard mainly to the misplacement of near density material.

The mine planning correlation factor adjusted budget yields and tonnages. The following comparative tables represent the extracted datasets mentioned previously for the period. The values reported in these tables represent daily data condensed to a single monthly representative value for each dataset.

Table 7 Condensed monthly representative values for GG1 plant production compared with theoretical geological yields.

ACTUAL BENEFICIATION PLANT VALUES AGAINST GEOLOGICAL MODEL YIELDS ON ACTUAL ROM

MONTH	Beneficiation reported ROM tons	Actual SSCC Yield Plant	Actual SSCC Tons	Actual Yield Midd Plant	Actual PS Tons	Beneficiation reported ROM tons	Geo Model Theor. Planned SSCC	Model SSCC Tons Theor	Geo Model Theor. Planned PS Y (Ratio's)	Model PS Tons Theor
Jan-08	1,350,807	12.12	163,770	31.34	423286	1,350,807	17.34	234,230	27.20	367,420
Feb-08	1,217,959	11.76	143,264	32.05	390365	1,217,959	16.34	199,015	28.30	344,682
Mar-08	1,059,717	11.77	124,683	24.25	256956	1,059,717	17.02	180,364	27.13	287,501
Apr-08	1,382,602	10.40	143,844	26.39	364886	1,382,602	17.17	237,393	31.59	436,764
May-08	1,513,214	10.32	156,231	31.26	473073	1,513,214	15.65	236,818	31.90	482,715
Jun-08	1,227,107	12.02	147,499	28.72	352375	1,227,107	16.34	200,509	31.85	390,834
Jul-08	1,421,358	9.76	138,699	27.10	385188	1,421,358	15.62	222,016	29.30	416,458
Aug-08	1,318,344	11.39	150,115	34.54	455343	1,318,344	15.07	198,674	30.82	406,314
Sep-08	1,410,722	11.07	156,219	33.98	479398	1,410,722	15.39	217,110	27.78	391,899
Oct-08	1,372,514	10.62	145,780	28.66	393312	1,372,514	16.55	227,151	30.97	425,068
Nov-08	1,216,485	10.48	127,529	28.41	345582	1,216,485	17.55	213,493	24.42	297,066
Dec-08	1,255,632	10.61	133,247	27.96	351089	1,255,632	17.27	216,848	25.93	325,585
Jan-09	1,332,795	9.15	121,995	29.30	390460	1,332,795	16.95	225,909	28.54	380,380
Feb-09	1,129,841	8.70	98,348	37.75	426503	1,129,841	16.97	191,734	30.17	340,873
Mar-09	1,237,445	10.54	130,484	32.35	400327	1,237,445	17.15	212,222	30.79	381,009
Apr-09	1,337,593	11.76	157,244	27.74	370984	1,337,593	16.77	224,314	29.19	390,443
May-09	1,569,828	8.49	133,246	34.74	545297	1,569,828	17.13	268,912	28.29	444,104
Jun-09	1,324,848	10.87	143,983	29.99	397370	1,324,848	16.32	216,215	26.22	347,375
Jul-09	1,132,417	10.17	115,124	31.18	353144	1,132,417	16.17	183,112	26.40	298,958
Aug-09	1,172,739	9.85	115,554	32.73	383895	1,172,739	18.89	221,530	27.14	318,281
Sep-09	1,506,168	11.14	167,779	31.92	480780	1,506,168	15.68	236,167	26.54	399,737
Oct-09	1,399,025	10.30	144,075	32.39	453191	1,399,025	14.31	200,200	26.77	374,519
Nov-09	1,313,443	10.22	134,173	34.71	455857	1,313,443	14.84	194,915	24.93	327,441
Dec-09	1,231,857	11.08	136,481	33.79	416305	1,231,857	18.78	231,343	26.86	330,877
Jan-10	1,355,900	10.10	136,918	37.30	505794	1,355,900	19.06	258,435	29.27	396,872
Feb-10	1,262,063	9.13	115,175	32.66	412214	1,262,063	16.24	204,959	29.12	367,513
Mar-10	1,381,988	9.99	138,110	35.73	493733	1,381,988	14.58	201,494	28.75	397,322
Apr-10	1,320,264	11.80	155,853	31.75	419170	1,320,264	14.84	195,927	29.92	395,023
May-10	1,331,595	10.34	137,648	34.49	459272	1,331,595	15.98	212,789	27.49	366,055
Jun-10	1,276,858	10.34	132,048	33.82	431863	1,276,858	16.71	213,363	28.98	370,033
Jul-10	1,351,191	10.08	136,197	34.60	467522	1,351,191	13.64	184,302	30.58	413,194
Aug-10	1,371,395	11.08	151,955	31.63	433799	1,371,395	14.27	195,698	26.46	362,871
Sep-10	1,221,859	10.67	130,368	28.55	348852	1,221,859	16.12	196,964	26.27	320,982
Oct-10										
Nov-10										
Dec-10										
	43,307,573		4,563,638		13717185	43,307,573		7,054,125		12,296,169

ROM Difference	0
SSCC Difference	-2,490,487
PS Difference	1,421,016

Overall Correlation Factor SSCC	64.69
Overall Correlation Factor PS	111.56

-1352190383

Table 7 is a summary of actual plant production and the historical geological model values for the period Jan 2008 to Sept 2010. Run of mine tonnages were used to determine the semi soft coking coal and power station products, thus, since there are no differences with regard to the baseline run of mine, the comparisons are essentially on the products. The beneficiation plants performance only realized 64.69% of the geological model predicted yields for semi soft coking coal, while the power station coal was marginally higher at 111.54%. In terms of tonnages this may not appear that significant, but considering that the semi soft coking coal product's value during this period was approximately six times higher than the power station coal, the loss in forecast revenue as a result is substantial.

Table 8 Beneficiation plant values compared with as mined ash adjusted density values.

ACTUAL BENEFICIATION PLANT VALUES AGAINST As Mined Floor and Plant operating Parameters AAD TONNAGES with an 83% cf applied

MONTH	Beneficiation reported ROM tons	Actual SSCC Yield Plant	Actual SSCC Tons	Actual Yield Midd Plant	Actual PS Tons	Beneficiation reported ROM tons	Theor Amf PP Yld Coke	Theor AMF PP SSCC Tons Theor	Theor Amf PP Yld Midd	Theor Amf PP PS Tons Theor
Jan-08	1,350,807	12.12	163770	31.34	423286	1,350,807	11.43	154,345	24.06	325,004
Feb-08	1,217,959	11.76	143264	32.05	390365	1,217,959	12.00	146,140	25.2	306,926
Mar-08	1,059,717	11.77	124683	24.25	256956	1,059,717	13.99	148,249	26.50	280,825
Apr-08	1,382,602	10.40	143844	26.39	364886	1,382,602	13.22	182,737	30.61	423,214
May-08	1,513,214	10.32	156231	31.26	473073	1,513,214	13.15	199,037	27.72	419,463
Jun-08	1,227,107	12.02	147499	28.72	352375	1,227,107	10.97	134,634	31.62	388,011
Jul-08	1,421,358	9.76	138699	27.10	385188	1,421,358	10.90	154,913	29.91	425,128
Aug-08	1,318,344	11.39	150115	34.54	455343	1,318,344	8.60	113,366	30.29	399,326
Sep-08	1,410,722	11.07	156219	33.98	479398	1,410,722	8.88	125,285	31.80	448,610
Oct-08	1,372,514	10.62	145780	28.66	393312	1,372,514	9.47	130,002	36.54	501,517
Nov-08	1,216,485	10.48	127529	28.41	345582	1,216,485	10.00	121,636	30.2	367,378
Dec-08	1,255,632	10.61	133,247	27.96	351089	1,255,632	10.11	126944	31.06	389999
Jan-09	1,332,795	9.15	121995	29.30	390460	1,332,795	10.70	142,609	28.33	377,581
Feb-09	1,129,841	8.70	98348	37.75	426503	1,129,841	8.96	101,234	31.26	353,188
Mar-09	1,237,445	10.54	130484	32.35	400327	1,237,445	10.28	127,209	31.32	387,568
Apr-09	1,337,593	11.76	157244	27.74	370984	1,337,593	9.95	133,091	29.94	400,475
May-09	1,569,828	8.49	133246	34.74	545297	1,569,828	11.41	179,117	28.20	442,691
Jun-09	1,324,848	10.87	143983	29.99	397370	1,324,848	10.17	134,737	29.01	384,338
Jul-09	1,132,417	10.17	115124	31.18	353144	1,132,417	10.73	121,508	29.32	332,025
Aug-09	1,172,739	9.85	115554	32.73	383895	1,172,739	10.63	124,662	28.01	328,484
Sep-09	1,506,168	11.14	167779	31.92	480780	1,506,168	10.37	156,190	29.97	451,399
Oct-09	1,399,025	10.30	144075	32.39	453191	1,399,025	10.44	146,058	28.71	401,660
Nov-09	1,313,443	10.22	134173	34.71	455857	1,313,443	10.74	141,064	29.4	386,152
Dec-09	1,231,857	11.08	136,481	33.79	416305	1,231,857	10.39	127,990	31.06	382,615
Jan-10	1,355,900	10.10	136,918	37.30	505794	1,355,900	10.05	136,268	29.29	397,143
Feb-10	1,262,063	9.13	115,175	32.66	412214	1,262,063	11.24	141,856	29.62	373,823
Mar-10	1,381,988	9.99	138,110	35.73	493733	1,381,988	9.61	132,809	28.49	393,728
Apr-10	1,320,264	11.80	155,853	31.75	419170	1,320,264	8.50	112,222	29.92	395,023
May-10	1,331,595	10.34	137,648	34.49	459272	1,331,595	10.51	139,951	31.01	412,928
Jun-10	1,276,858	10.34	132,048	33.82	431863	1,276,858	9.92	126,664	34.46	440,005
Jul-10	1,351,191	10.08	136,197	34.60	467522	1,351,191	10.49	141,740	30.90	417,518
Aug-10	1,371,395	11.08	151,955	31.63	433799	1,371,395	9.54	130,831	25.22	345,866
Sep-10	1,221,859	10.67	130,368	28.55	348852	1,221,859	9.83	120,109	27.60	337,233
Oct-10										
Nov-10										
Dec-10										
	43,307,573		4,563,638		13717185	43,307,573		4,555,207		12,816,846

ROM Difference	0
SSCC Difference	8,431
PS Difference	900,339

Overall Correlation SSCC	100.19
Overall Correlation PS	107.02

95092632

Table 8 on the other hand, reflecting the differences between actual plant production and the AAD derived values is substantially more accurate, considering that the actual yield is 100.19%, better than the predicted AAD value for semi soft coking coal as well as for power station coal at 107.02%.

Table 9 Comparisons between plant production and budget values.

ACTUAL BENEFICIATION PLANT VALUES AGAINST BUDGETED VALUES

MONTH	Beneficiation reported ROM tons	Actual SSCC Yield Plant	Actual SSCC Tons	Actual Yield Midd Plant	Actual PS Tons	Budget ROM tons	Budgeted SSCC Yield	Budget SSCC Tons	Budgeted PS Yield	Budget PS Tons
Jan-08	1,350,807	12.12	163770	31.34	423286	1,473,001	11.02	162297	31.47	463533
Feb-08	1,217,959	11.76	143264	32.05	390365	1,424,833	11.80	168061	32.69	465714
Mar-08	1,059,717	11.77	124683	24.25	256956	1,380,562	10.95	151206	33.53	462834
Apr-08	1,382,602	10.40	143844	26.39	364886	1,399,386	10.76	150519	33.46	468285
May-08	1,513,214	10.32	156231	31.26	473073	1,629,122	11.79	192038	33.84	551310
Jun-08	1,227,107	12.02	147499	28.72	352375	1,480,054	11.41	168879	33.12	490147
Jul-08	1,421,358	9.76	138699	27.10	385188	1,698,962	11.57	196552	31.61	537042
Aug-08	1,318,344	11.39	150115	34.54	455343	1,557,881	11.06	172266	33.22	517560
Sep-08	1,410,722	11.07	156219	33.98	479398	1,488,942	10.61	157927	31.88	474729
Oct-08	1,372,514	10.62	145780	28.66	393312	1,193,714	10.96	130809	34.09	406882
Nov-08	1,216,485	10.48	127529	28.41	345582	1,556,303	10.82	168367	31.23	485997
Dec-08	1,255,632	10.61	133247	27.96	351089	1,462,202	10.66	155836	32.49	475057
Jan-09	1,332,795	9.15	121995	29.30	390460	1,634,736	10.90	178230	29.19	477149
Feb-09	1,129,841	8.70	98348	37.75	426503	1,460,320	10.76	157202	30.32	442777
Mar-09	1,237,445	10.54	130484	32.35	400327	1,460,310	11.07	161682	33.01	482046
Apr-09	1,337,593	11.76	157244	27.74	370984	1,395,872	10.86	151597	30.33	423350
May-09	1,569,828	8.49	133246	34.74	545297	1,644,664	11.58	190381	30.22	496943
Jun-09	1,324,848	10.87	143983	29.99	397370	1,575,119	10.44	164501	28.46	448309
Jul-09	1,132,417	10.17	115124	31.18	353144	1,728,046	10.38	179288	28.35	489895
Aug-09	1,172,739	9.85	115554	32.73	383895	1,286,624	10.63	136768	30.12	387545
Sep-09	1,506,168	11.14	167779	31.92	480780	1,318,711	10.31	135929	31.24	411915
Oct-09	1,399,025	10.30	144075	32.39	453191	1,736,310	11.61	201590	29.49	512088
Nov-09	1,313,443	10.22	134173	34.71	455857	1,669,298	11.50	191922	29.28	488813
Dec-09	1,231,857	11.08	136,481	33.79	416305	1,542,629	11.09	171001	30.87	476182
Jan-10	1,355,900	10.10	136,918	37.30	505794	1,332,795	11.56	154125	31.31	417274
Feb-10	1,262,063	9.13	115,175	32.66	412214	1,289,741	10.77	138924	29.27	377543
Mar-10	1,381,988	9.99	138,110	35.73	493733	1,411,264	9.83	138717	29.48	416037
Apr-10	1,320,264	11.80	155,853	31.75	419170	1,188,710	10.32	122657	28.76	341833
May-10	1,331,595	10.34	137,648	34.49	459272	1,365,959	10.84	148100	29.53	403324
Jun-10	1,276,858	10.34	132,048	33.82	431863	1,376,832	11.52	158635	30.73	423072
Jul-10	1,351,191	10.08	136,197	34.60	467522	1,500,969	11.24	168686	29.32	440024
Aug-10	1,371,395	11.08	151,955	31.63	433799	1,320,200	10.10	133340	31.10	410582
Sep-10	1,221,859	10.67	130,368	28.55	348852	1,289,047	10.30	132772	29.10	375113
Oct-10										
Nov-10										
Dec-10										
	43,307,573		4,563,638		13717185	48,273,118		5,290,804		14,940,904

ROM Difference	-4,965,545
SSCC Difference	-727,166
PS Difference	-1,223,719

Overall Correlation Factor SSCC	86.26
Overall Correlation Factor PS	91.81

-558671512

Table 10 Comparison between plant production and budget adjusted to ROM tons.

ACTUAL BENEFICIATION PLANT VALUES AGAINST BUDGETED YIELDS AND ROM TONS

MONTH	Beneficiation reported ROM tons	Actual SSCC Yield Plant	Actual SSCC Tons	Actual Yield Midd Plant	Actual PS Tons	Budget ROM tons	Budgeted SSCC Yield	Budget SSCC Tons	Budgeted PS Yield	Budget PS Tons
Jan-08	1,350,807	12.12	163770	31.34	423286	1,350,807	11.02	148834	31.47	425080
Feb-08	1,217,959	11.76	143264	32.05	390365	1,217,959	11.80	143660	32.69	398096
Mar-08	1,059,717	11.77	124683	24.25	256956	1,059,717	10.95	116065	33.53	355271
Apr-08	1,382,602	10.40	143844	26.39	364886	1,382,602	10.76	148714	33.46	462668
May-08	1,513,214	10.32	156231	31.26	473073	1,513,214	11.79	178375	33.84	512086
Jun-08	1,227,107	12.02	147499	28.72	352375	1,227,107	11.41	140017	33.12	406379
Jul-08	1,421,358	9.76	138699	27.10	385188	1,421,358	11.57	164436	31.61	449291
Aug-08	1,318,344	11.39	150115	34.54	455343	1,318,344	11.06	145779	33.22	437981
Sep-08	1,410,722	11.07	156219	33.98	479398	1,410,722	10.61	149630	31.88	449790
Oct-08	1,372,514	10.62	145780	28.66	393312	1,372,514	10.96	150402	34.09	467827
Nov-08	1,216,485	10.48	127529	28.41	345582	1,216,485	10.82	131604	31.23	379880
Dec-08	1,255,632	10.61	133247	27.96	351089	1,255,632	10.66	133850	32.49	407944
Jan-09	1,332,795	9.15	121995	29.30	390460	1,332,795	10.90	145310	29.19	389018
Feb-09	1,129,841	8.70	98348	37.75	426503	1,129,841	10.76	121626	30.32	342574
Mar-09	1,237,445	10.54	130484	32.35	400327	1,237,445	11.07	137007	33.01	408479
Apr-09	1,337,593	11.76	157244	27.74	370984	1,337,593	10.86	145268	30.33	405675
May-09	1,569,828	8.49	133246	34.74	545297	1,569,828	11.58	181718	30.22	474331
Jun-09	1,324,848	10.87	143983	29.99	397370	1,324,848	10.44	138363	28.46	377077
Jul-09	1,132,417	10.17	115124	31.18	353144	1,132,417	10.38	117490	28.35	321036
Aug-09	1,172,739	9.85	115554	32.73	383895	1,172,739	10.63	124662	30.12	353242
Sep-09	1,506,168	11.14	167779	31.92	480780	1,506,168	10.31	155252	31.24	470469
Oct-09	1,399,025	10.30	144075	32.39	453191	1,399,025	11.61	162430	29.49	412613
Nov-09	1,313,443	10.22	134173	34.71	455857	1,313,443	11.50	151009	29.28	384610
Dec-09	1,231,857	11.08	136,481	33.79	416305	1,231,857	11.09	136552	30.87	380252
Jan-10	1,355,900	10.10	136,918	37.30	505794	1,355,900	11.56	156797	31.31	424508
Feb-10	1,262,063	9.13	115,175	32.66	412214	1,262,063	10.77	135943	29.27	369441
Mar-10	1,381,988	9.99	138,110	35.73	493733	1,381,988	9.83	135839	29.48	407407
Apr-10	1,320,264	11.80	155,853	31.75	419170	1,320,264	10.32	136231	28.76	379664
May-10	1,331,595	10.34	137,648	34.49	459272	1,331,595	10.84	144374	29.53	393177
Jun-10	1,276,858	10.34	132,048	33.82	431863	1,276,858	11.52	147116	30.73	392352
Jul-10	1,351,191	10.08	136,197	34.60	467522	1,351,191	11.24	151853	29.32	396115
Aug-10	1,371,395	11.08	151,955	31.63	433799	1,371,395	10.10	138511	31.10	426504
Sep-10	1,221,859	10.67	130,368	28.55	348852	1,221,859	10.30	125851	29.10	355561
Oct-10										
Nov-10										
Dec-10										
	43,307,573		4,563,638		9744966	43,307,573		4,740,571		13,416,396

ROM Difference	0
SSCC Difference	-176,933
PS Difference	-3,671,430

Overall Correlation Factor SSCC	96.27
Overall Correlation Factor PS	72.63

The last two, Table's 9 and 10 are comparisons between actual plant production and in Table 9, the budgeted production derived from the application of correlation factors originating from historical data and plant performance, applied to geological model derived yields used for medium term scheduling. The same data in the last table adjusted to negate the effect of run of mine tonnages not attained. Table 9 results show actual production of 86.26% SSCC against budget SSCC tons and 91.21% power station coal against budget. Removing the effect of ROM tonnages not realized the actual plant production of SSCC is 96.27% of the adjusted budget value while the power station coal is 72.63%.

If one were to consider a nominal amount of R100/ton for power station coal and Semi Soft Coking Coal at 6 times the power station coal value, i.e. R600/ton then the information portrayed above translates into phenomenal amounts over this 33 month period representing a 14% improvement on the total budget. Table 11 below indicates that the AAD methodology has resulted in the closest monetary value to actual production income versus the predictions provided by the geological model and the mine planning budgetary values.

Table 11 Techno economical breakdown on nominal values.

			Rand Value	Total Value
Actual against Geological Model		ROM Tons Difference	0	
Overall Correlation Factor SSCC	64.69	SSCC Difference	R -1,494,291,990.18	
Overall Correlation Factor PS	111.56	PS Difference	R 142,101,607.63	R -1,352,190,382.55
Actual against As Mined AAD PP		ROM Tons Difference	0	
Overall Correlation Factor SSCC	100.19	SSCC Difference	R 5,058,732.57	
Overall Correlation Factor PS	107.02	PS Difference	R 90,033,899.06	R 95,092,631.63
Actual against Budget		ROM Tons Difference	-1,998,501	
Overall Correlation Factor SSCC	86.26	SSCC Difference	R -436,299,624.60	
Overall Correlation Factor PS	91.81	PS Difference	R -122,371,887.70	R -558,671,512.30
Actual against Adjusted Budget		ROM Tons Difference	0	
Overall Correlation Factor SSCC	96.27	SSCC Difference	R -106,159,551.08	
Overall Correlation Factor PS	102.24	PS Difference	R 30,078,900.09	R -76,080,650.99

		Act as % of Predicted
Actual Total Yield Value	R 4,109,901,300.00	
Geological Model Total Yield value	R 5,462,091,682.55	75.24
As Mined AAD Total Yield Value	R 4,014,808,668.37	102.37
Budget Total Yield Value	R 4,668,572,812.30	88.03

The As Mined AAD value represents a 14% improvement on the budgeted amount which translates into approximately R653.6m over this 33 month monitoring period

6.2 ELIMINATION OF CORRELATION FACTORS

Sufficient evidence has been obtained to prove that material top size especially with regard to the production of a semi soft coking coal product at a low ash influences the eventual result dramatically due to liberation of the low ash material not realizing. If this one factor could be remedied to obtain the optimal top size, no correlation factor between the predicted values and the beneficiation result would be necessary. Table 12 below is final proof that yields can be predicted without a correlation factor being applied.

Table 12 Geological model 1.338g/cc theoretical product extraction on ash adjusted density compared with actual beneficiation plant results.

ACTUAL BENEFICIATION PLANT VALUES AGAINST 1338g/cc Pred SSCC YIELDS

MONTH	Beneficiation reported ROM tons	Actual SSCC Yield Plant	Actual SSCC Tons	Actual Yield Midd Plant	Actual PS Tons	Beneficiation reported ROM tons	1338 AAD Theor SSCC	PME Ratio SSCC Tons	PME As Mined PS	PME Ratio PS Tons
Jan-08	1,350,807	12.12	163,770	31.34	423286	1,350,807	11.20	151,290	27.05	365,393
Feb-08	1,217,959	11.76	143,264	32.05	390365	1,217,959	11.51	140,187	27.49	334,817
Mar-08	1,059,717	11.77	124,683	24.25	256956	1,059,717	11.25	119,218	28.46	301,595
Apr-08	1,382,602	10.40	143,844	26.39	364886	1,382,602	11.33	156,649	31.93	441,465
May-08	1,513,214	10.32	156,231	31.26	473073	1,513,214	10.95	165,697	31.32	473,939
Jun-08	1,227,107	12.02	147,499	28.72	352375	1,227,107	11.44	140,381	31.57	387,398
Jul-08	1,421,358	9.76	138,699	27.10	385188	1,421,358	10.41	147,963	30.28	430,387
Aug-08	1,318,344	11.39	150,115	34.54	455343	1,318,344	11.41	150,423	30.58	403,150
Sep-08	1,410,722	11.07	156,219	33.98	479398	1,410,722	11.21	158,142	29.45	415,458
Oct-08	1,372,514	10.62	145,780	28.66	393312	1,372,514	10.58	145,212	28.81	395,421
Nov-08	1,216,485	10.48	127,529	28.41	345582	1,216,485	10.51	127,853	28.71	349,253
Dec-08	1,255,632	10.61	133,247	27.96	351089	1,255,632	11.99	150,550	27.94	350,824
Jan-09	1,332,795	9.15	121,995	29.30	390460	1,332,795	11.25	149,939	29.27	390,109
Feb-09	1,129,841	8.70	98,348	37.75	426503	1,129,841	10.99	124,170	31.17	352,171
Mar-09	1,237,445	10.54	130,484	32.35	400327	1,237,445	11	136,119	32.63	403,778
Apr-09	1,337,593	11.76	157,244	27.74	370984	1,337,593	10.83	144,861	30.45	407,297
May-09	1,569,828	8.49	133,246	34.74	545297	1,569,828	11.40	178,960	30.43	477,699
Jun-09	1,324,848	10.87	143,983	29.99	397370	1,324,848	11.82	156,597	29.55	391,493
Jul-09	1,132,417	10.17	115,124	31.18	353144	1,132,417	10.37	117,432	32.65	369,734
Aug-09	1,172,739	9.85	115,554	32.73	383895	1,172,739	10.84	127,125	30.67	359,679
Sep-09	1,506,168	11.14	167,779	31.92	480780	1,506,168	10.46	157,545	30.48	459,080
Oct-09	1,399,025	10.30	144,075	32.39	453191	1,399,025	11.30	158,090	31.40	439,294
Nov-09	1,313,443	10.22	134,173	34.71	455857	1,313,443	11.11	145,924	31.28	410,845
Dec-09	1,231,857	11.08	136,481	33.79	416305	1,231,857	10.55	129,961	30.95	381,260
Jan-10	1,355,900	10.10	136,918	37.30	505794	1,355,900	11.34	153,759	29.50	399,991
Feb-10	1,262,063	9.13	115,175	32.66	412214	1,262,063	10.92	137,817	29.10	367,260
Mar-10	1,381,988	9.99	138,110	35.73	493733	1,381,988	10.89	150,498	30.51	421,645
Apr-10	1,320,264	11.80	155,853	31.75	419170	1,320,264	10.13	133,743	29.72	392,382
May-10	1,331,595	10.34	137,648	34.49	459272	1,331,595	9.32	124,105	30.63	407,868
Jun-10	1,276,858	10.34	132,048	33.82	431863	1,276,858	10.32	131,772	28.71	366,586
Jul-10	1,351,191	10.08	136,197	34.60	467522	1,351,191	10.70	144,577	30.59	413,329
Aug-10	1,371,395	11.08	151,955	31.63	433799	1,371,395	11.22	153,871	29.13	399,487
Sep-10	1,221,859	10.67	130,368	28.55	348852	1,221,859	10.32	126,096	28.32	346,030
Oct-10										
Nov-10										
Dec-10										
	43,307,573		4,563,638		13717185	43,307,573		4,736,526		13,006,116

ROM Difference	0
SSCC Difference	-172,888
PS Difference	711,069

Overall Correlation Factor SSCC	96.35
Overall Correlation Factor PS	105.47

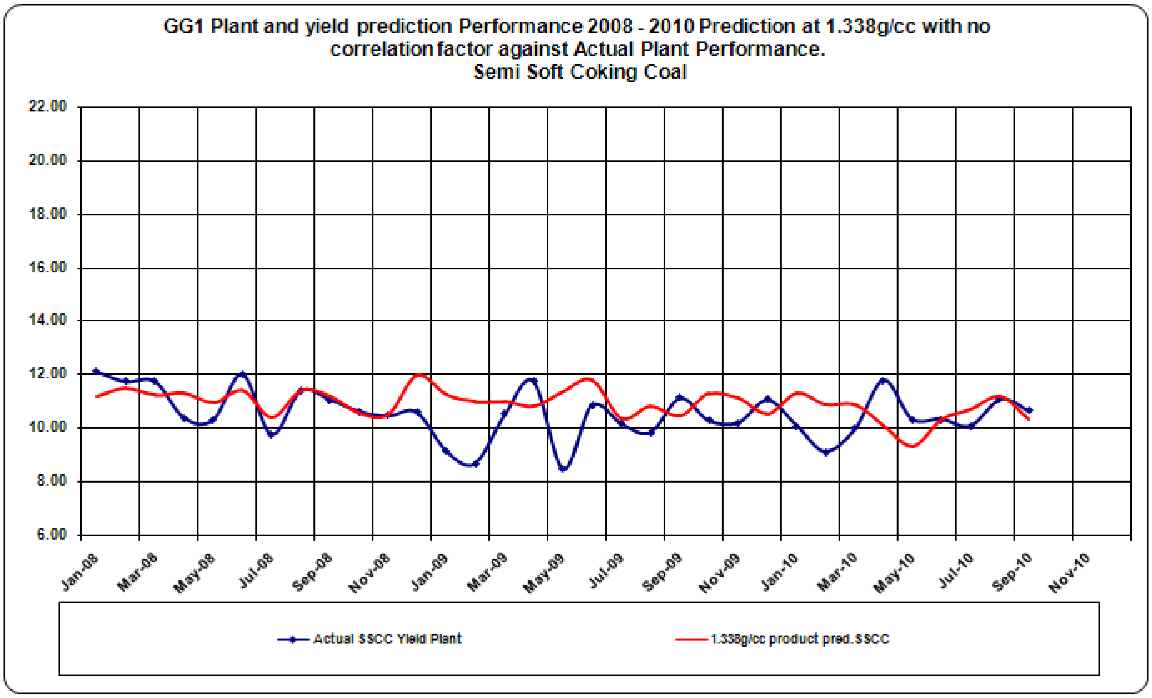


Figure 82 portrays the modelled 1.338g/cc product extraction values applied to the 33 month monitoring period against actual plant results to obtain an effective correlation without having to utilize correlation factors in the yield predictions.

The ash adjusted density algorithm was used on the raw data from the Grootegeluk geological database for the formulation of this year, 2010's geological model. Product extractions were done and modelled in Minex, thereafter the mine planning scheduled blast blocks for the relevant benches from which a semi soft coking coal product is produced, were populated with the relevant data. These blocks were identical to the previously generated model blocks so that a comparison could be made between the actual mined material over the past 33 months and the predicted results should this model have been implemented. This applies to both GG1 and GG6 beneficiation plants at Grootegeluk coal mine.

7 SUMMARY AND CONCLUSIONS

The primary objective of this dissertation was to develop a methodology that would provide a credible association between geological exploration-derived empirical analyses of the resource materials and the yields of products derived from a beneficiation plant with specific reference to semi soft coal.

This was achieved by undertaking the following:

- The methodology was developed to provide a more accurate prediction of yields within the beneficiation plant from borehole data through the application of ash adjusted density (AAD) calculations.

This methodology has achieved the following:

- The negation of irrelevant correlation factors and replacing these with a common correlation factor which is beneficiation plant specific and applicable to all material irrespective of its source, vertically or laterally throughout the deposit.
- Accounting for only one parameter, namely, the size fraction of the beneficiated product related to the initial empirical wash table fractions and analysis.
- Accommodation of the reconciliation of the process with the beneficiation plant's end result and enhanced the accuracy of predicted yields for budgetary and forecasting purposes.
- Allowing a more credible definition and quantification of saleable reserves and reconciliation of beneficiation results with geologically modelled predictions.

Four hypotheses were postulated in the development of this methodology and have been proven correct and applicable in the foregoing sections. These hypotheses will be revisited in relation to the overall methodology.

7.1 The determination of a relationship between ash and density in coal samples.

An evaluation of approximately 31,000 sets of fractional wash data revealed a near linear relationship between ash and density. Statistical analysis, sample composites and additional analysis at fractions lower than the norm verified this relationship. An algorithm was developed to establish the true density of a wash fraction based on its ash analysis.

The relationship was also not unique to a specific stratigraphical unit, but in the case of the Waterberg coalfield was applicable to both the Volksrust Formation coals (intercalated coal shale cycles typically delta plain type environment) and the Vryheid Formation, representative of Middle Ecca coals in a fluvial environment.

The major difference here being that the Volksrust Formation coals are considered to be autochthonous (formed in-situ, syndepositional) while the Vryheid Formation coals are considered to be allochthonous (sediment transported into the basin from an external source).

A further implication of this is that the relationship between density and ash in coal may be relevant to coal deposits globally.

7.2. The evaluation of the distribution of low density material related to depositional environment

Interpretation and comparison of the wash table data for individual samples in the vertical stratigraphy of the depositional sequence has confirmed and typified the individual samples as discreet minor sedimentary cycles.

Combinations of these sample composites representing larger cycles in terms of the defined zones or mining benches which would be a combination of zones, clearly indicate the expected distribution of low density material in these various combinations allowing optimal selection should new mining benches be formulated.

A better perspective of the distribution of low density material was obtained after the application of the ash adjusted density algorithm, presenting a reflection of true density and density distribution within these delineated cycles.

7.3 The application of derived algorithms in the evaluation of predicted, as mined and model values against actual beneficiation plant performance resulting in improved prediction and reconciliation providing more credible measures.

The development of a methodology to adapt the wash data of relevant blast blocks being planned and mined has through the application of AAD to the raw composite wash table data resulted in more representative wash tables accommodating the lower density regions for more accurate interpolation in these regions.

This has resulted in lower more representative theoretical semi soft coking coal yields for the individual blocks comparable with the beneficiation plants performance.

A more accurate constant for the semi soft coking coal misplaced to middling in the GG1 plant has been determined, since this is directly related to the size fraction of the material being beneficiated as opposed to the empirical size fractions used on the borehole core analysis at the pilot plant.

This constant has been implemented as a correlation factor on the theoretical value. The correlation factor is 90% of the theoretical value. Since blast block yields are determined using AAD and wash table information for the specific products required, the admixture of blocks planned by short term mine planning as well as the daily as mined ratio adjustments to ascertain the blends planned for beneficiation or being actually dispatched from the mine are based on arithmetical compositions.

Discrepancies or deviations between the arithmetical approach and wash table reconstruction for product extraction of the blend material do exist, and as such an additional correction has been introduced to assist the mine planning function since there is a distinct difference between a calculated yield and yields obtained from a reconstructed wash table further reducing the correlation factor for GG1 to 83%. This however is only applicable if an arithmetical yield is generated for a blend of different blocks with predetermined yield values, if a wash table of the blended blocks has been generated the correlation factor reverts to 90%.

The assessment of GG1 semi soft coking coal beneficiation plant results has shown that 90%- 94% recovery has been attainable, thus the factor being used for power station coal or middling product has been fixed at approximately 106% since this does not compensate for the addition of recovered slimes or variations in the initial primary cut from which the semi soft coking coal product has been extracted.

Due to the inconsistency of the variations in slimes recovered and the variations in primary cut density the 106% correlation factor should compensate primarily for possible misplacements of coking coal in the middlings, additional product realized as a result of slimes recovery is a positive benefactor. The variability of the power station product's composition therefore does not allow for a specific correlation factor being applied with any relative confidence apart from the misplaced semi soft coking coal which forms a part of the product.

Variations in the ratios of the blends being sent to the plant impact profoundly on the representative wash data used for product extraction. If however the planned values are not adhered to, the material being beneficiated will have totally different properties compared to those used for planning purposes.

The ash adjusted density values noted during these evaluation periods were closer to the actual plant values than the original budget values derived from the application of various correlation factors based on overall plant performance in respect to material from the varied sources over time. After an adjustment had been effected to negate the run of mine tonnage losses opposed to the budget tonnages planned the values obtained were worse.

7.4. The elimination of correlation factors

Sufficient evidence has been obtained to prove that material top size especially with regard to the production of a semi soft coking coal product at a low ash influences the eventual result dramatically due to liberation of the low ash material not realizing. If this one factor could be remedied to obtain the optimal top size, no correlation factor between the predicted values and the beneficiation result would be necessary. Proof that yields can be predicted without a correlation factor being applied has been verified.

The ash adjusted density algorithm was used on the raw data from the Grootegeluk geological database for the formulation of 2010's geological model. Product extractions were done and modelled in Minex. The mine planning scheduled blast blocks for the relevant benches from which a semi soft coking coal product is produced, were populated with the relevant data.

These blocks were identical to the previously generated model blocks so that a comparison could be made between the actual mined material over the 33 month monitoring period and the predicted results should this model have been implemented. The results have shown a semi soft coking coal correlation of 96.35% and a 105.47% for power station coal.

8 RECOMMENDATIONS

. The approach to the evaluation of wash data for specifically semi soft coking coal from drilled exploration core in the Waterberg along with associated economically viable products should be approached utilizing the methodology established in this dissertation for optimum results. It is therefore recommended that the AAD approach be applied to analytical data for the Waterberg:

1. This methodology should form the basis for data to be used in the propagation of the geological model.
2. Product extractions derived from this methodology be used for the population of mining blocks or units, to be used for budgeting, forecasting and scheduling purposes.
3. Grade control practices with respect to mining and beneficiation use the same methodology.
4. Resource and saleable reserve values be adapted to conform to this methodology.

Based upon the research and applications that have been done, significant financial benefit through increased confidence in predicting saleable quality products from borehole data can now be assured. It is hoped that this would lead to wide application in future for the South African coal mining industry.

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APPENDICES

APPENDIX A

A.1. EVALUATED DATA ON FLOAT FRACTIONS USED FOR AAD DETERMINATION.

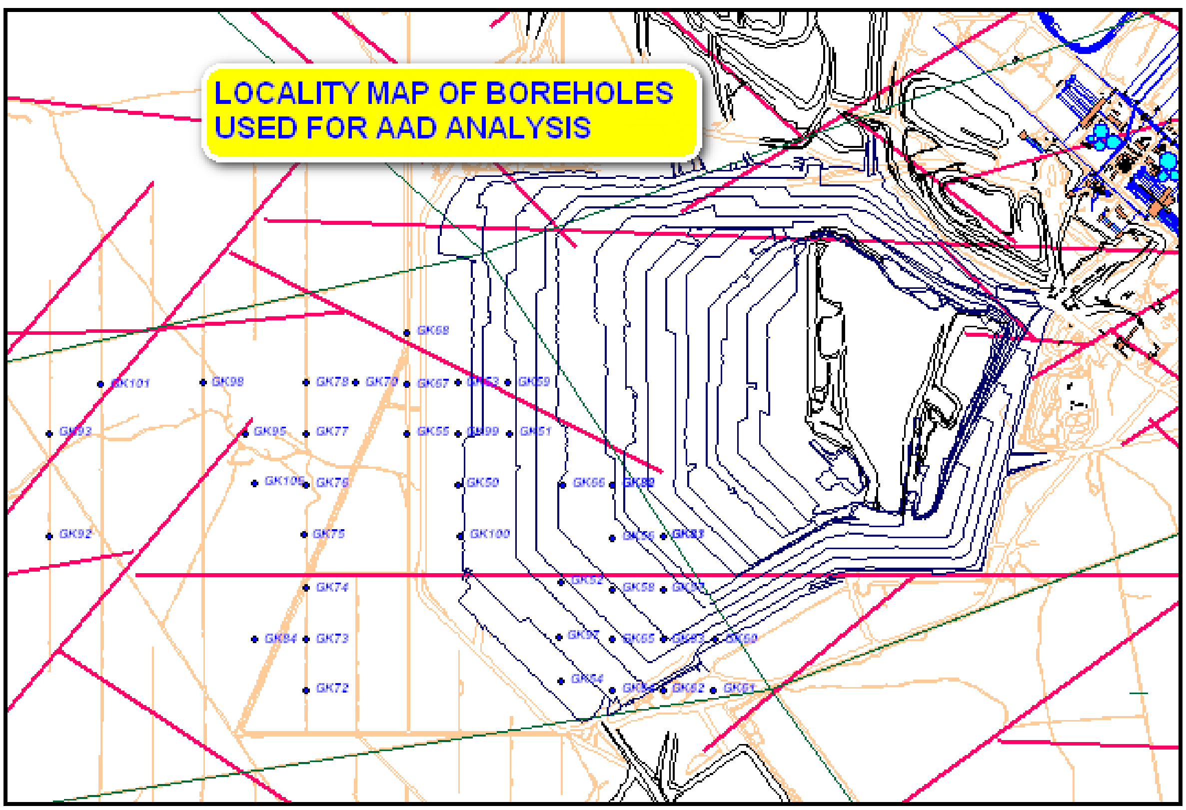


Figure A-1 Locality map showing the positions of the large diameter cored boreholes selected for the evaluation of AAD.

Borehole Id	Beginning Sample	X-Coord	Y-Coord	Collar Elev
GK100	1C	2619344.9	-53112.9	907.71
GK101	1D	2618599.83	-51357.269	913.74
GK106	1A	2619081.237	-52109.079	912.747
GK50	1A	2619092.91	-53108.92	907.91
GK51	1A	2618842.85	-53358.53	906.83
GK52	1A	2619565.8	-53607.97	904.28
GK53	1A	2618592.93	-53109.67	907.49
GK54	1A	2620047.52	-53607.81	904.07
GK55	1A	2618843.08	-52858.64	910
GK56	1A	2619349.73	-53859.32	903.71
GK57	1A	2619599.64	-54110.07	901.71
GK58	1A	2619602.09	-53859.22	903.48
GK59	1A	2618591.47	-53351.7	907.55
GK60	1C	2619841.26	-54358.76	899.89
GK61	1B	2620091.84	-54356.76	899.34
GK62	1B	2620092.09	-54108.12	900.77
GK63	1A	2619841.61	-54109.13	901.5
GK64	1B	2620091.82	-53858.05	902.11
GK65	1A	2619841.94	-53859.36	902.89
GK66	1A	2619091.12	-53618.65	905
GK67	1C	2618596.08	-52858.03	909.04
GK68	2	2618346.37	-52857.79	908.56
GK70	1D	2618590.33	-52609.15	909.77
GK72	1C	2620093.73	-52360.12	907.11
GK73	1B	2619843.71	-52360.58	909.08
GK74	1C	2619592.48	-52360.61	910.05
GK75	1D	2619338.05	-52359.01	909.48
GK76	1A	2619093.54	-52360.22	910.89
GK77	1B	2618837.13	-52359.44	911.53
GK78	1D	2618593.76	-52360.39	910.33
GK80	1A	2619090.83	-53860.04	903.34
GK81	1A	2619341.01	-54109.01	901.95
GK82	1A	2619090.93	-53863.3	903.64
GK83	1A	2619340.75	-54111.07	902.27
GK84	1C	2619841.66	-52110.02	909.06
GK92	1B	2619339.89	-51106.51	914
GK93	2	2618837.8	-51110.5	914.67
GK95	2	2618840.86	-52068.53	912.17
GK97	1A	2619840.27	-53600.21	904.9
GK98	1D	2618593.797	-51861.43	912.932
GK99	1A	2618837.37	-53111.27	908.4
GKSPES1	1A	2618837.37	-53111.27	908.4

Table A-1 List of Large diameter cored boreholes used for AAD evaluation.

A full succession borehole starting at sample 1A has approximately 72 associated samples, coal and shale and each sample is further subdivided into wash density fractions, starting at 1.35g/cc, 1.40g/cc, 1.50g/cc thru 2.20g/cc and a sink, raw and -5mm fraction for coal and from 1.50g/cc for shale.

The table below serves as an example of the separate wash tables for the individual sample components mentioned earlier, note that the R value shown in the table however is not part of the float sink analyses; this represents raw coal at 0.5mm and is not sink/floated at all.

EXTRACT FROM AN EXPLORATION BOREHOLE SHOWING INDIVIDUAL WASH TABLES FOR COAL AND SHALE

Sample	Type	FR-Type	RD1	RD2	Yield	Moist	Ash	Vol	Swell	Roga	Sulphur	CV
2	COAL	F	0	1.35	15.728	2.58	5.97	36.51	4.5	60	1.25	30.48
2	COAL	F	1.35	1.4	8.774	2.03	14.26	35.54	3.5	48	1.2	27.74
2	COAL	F	1.4	1.5	19.367	1.97	23.56	32.25	2	24	1.1	24.79
2	COAL	F	1.5	1.6	20.521	2	32.83	28.63	1	17	1.02	21.05
2	COAL	F	1.6	1.7	13.731	1.9	39.96	25.22	0.5		0.91	18.21
2	COAL	F	1.7	1.8	9.684	1.7	48.94	21.98	0		0.82	15.17
2	COAL	F	1.8	1.9	5.043	1.79	55.57	19.19			0.94	12.43
2	COAL	F	1.9	2	3.454	1.64	63.17	17.1			0.86	9.05
2	COAL	F	2	2.1	1.068	1.5	68.4	15.19			0.65	7.29
2	COAL	F	2.1	2.2	0.745	1.33	72.04	13.46			1.81	5.79
2	COAL	R	0	0.5		3.1	23.95	29.58			1.45	23.21
2	COAL	S	2.2	9.99	1.885	0.84	61.92	19.85			31.65	9.7

Sample	Type	FR-Type	RD1	RD2	Yield	Moist	Ash	Vol	Swell	Roga	Sulphur	CV
2	SHALE	F	0	1.5	9.353	3.1	16.18	32.44			1.07	26.8
2	SHALE	F	1.5	1.6	7.308	2.67	31.46	27.5			0.85	21.46
2	SHALE	F	1.6	1.7	7.679	2.76	41.35	23.34			0.77	17.76
2	SHALE	F	1.7	1.8	12.25	2.56	48.54	20.48			0.71	15.05
2	SHALE	F	1.8	1.9	19.044	3.1	55.38	18.05			0.56	12.26
2	SHALE	F	1.9	2	16.854	3.21	60.76	15.62			0.53	9.7
2	SHALE	F	2	2.1	11.768	2.92	66.92	14.08			0.45	7.88
2	SHALE	F	2.1	2.2	12.379	2.71	71.8	12.42			0.41	5.3
2	SHALE	R	0	0.5		2.08	42.47	22.89			1.12	17.54
2	SHALE	S	2.2	9.99	3.364	1.63	66.71	15.89			13.94	7.36

Sample	Type	Depth From	Depth To	Raw RD	Thickness	Coal Width	Shale Width
S2	BOTH	15.31	16.66	1.59	1.35	1.03	0.32

Table A-2 Example of shale and coal wash table for an individual sample.

The next table gives a breakdown of the combined samples, their thickness, raw RD's and coal and shale widths. Data required when compositing of the samples is undertaken.

Sample	Type	Depth From	Depth To	Raw RD	Thickness	Coal Width	Shale Width
S1A	BOTH						
S1B	BOTH						
S1C	BOTH						
S1D	BOTH						
S2	BOTH	15.31	16.66	1.59	1.35	1.03	0.32
S3	BOTH	16.66	18.16	1.74	1.5	0.73	0.77
S4	BOTH	18.16	19.36	1.68	1.2	0.84	0.36
S5	BOTH	19.36	21.65	1.63	2.29	1.86	0.43
S6	BOTH	21.65	23.46	1.54	1.81	1.53	0.28
S7	BOTH	23.46	26.19	2.25	2.73	0.49	2.24
S8	BOTH	26.19	28.04	1.68	1.85	1.19	0.66
S9	BOTH	28.04	29.55	1.58	1.51	1.35	0.16
S10	BOTH	29.55	32.73	2.23	3.18	0.38	2.8
S11	BOTH	32.73	34.29	1.74	1.56	1	0.56
S12	BOTH	34.29	35.84	1.7	1.55	0.97	0.58
S13	BOTH	35.84	37.14	1.68	1.3	0.96	0.34
S14	BOTH	37.14	39.57	1.66	2.43	1.62	0.81
S15A	BOTH	39.57	42.23	1.77	2.66	1.5	1.16
S15B	BOTH	42.23	44.31	2.09	2.08	0.57	1.51
S16	BOTH	44.31	45.82	2	1.51	0.65	0.86
S17	BOTH	45.82	49.14	1.82	3.32	1.57	1.75
S18	BOTH	49.14	50.15	1.79	1.01	0.83	0.18
S19	BOTH	50.15	52.07	1.95	1.92	0.62	1.3
S20	BOTH	52.07	53.99	2.04	1.92	0.45	1.47
S21	BOTH	53.99	56.76	1.8	2.77	1.18	1.59
S22A	BOTH	56.76	59.4	2.02	2.64	0.69	1.95
S22B	BOTH	59.4	63.22	1.99	3.82	0.95	2.87
S22C	BOTH	63.22	64.88	2.01	1.66	0.24	1.42
S22D	BOTH	64.88	68.32	1.86	3.44	1.12	2.32
S22E	BOTH	68.32	70.85	1.94	2.53	0.27	2.26
22FS	Shale	70.85	73.44	1.9	2.59	0	2.59
S23A	Coal	73.44	74.06	1.74	0.62	0.62	0
S23B	Coal	74.06	76.06	1.66	2	2	0
S23C	Coal	76.06	77.55	1.6	1.49	1.49	0
23AS	Shale	77.55	81.46	2.1	3.91	0	3.91
23BS	Shale	81.46	83.28	2.18	1.82	0	1.82
S24	Coal	83.28	84.83	1.84	1.55	1.55	0
S26	Coal	87.93	89.93	1.71	2	2	0
S27	Coal	89.93	91.29	1.41	1.36	1.36	0
S28	Coal	91.29	92.62	1.56	1.33	1.33	0
S29	Coal	92.62	94.51	1.47	1.89	1.89	0
S31	Coal	102.75	104.8	1.5	2.05	2.05	0
S32	Coal	117.37	118.69	1.52	1.32	1.32	0

Table A-3 Samples representative of a full succession exploration borehole.

Considering the aforementioned, the analytical subsets available amount to 12 fractions on coal and 10 fractions on shale, the last three previously mentioned (the sink fraction, raw fraction and the -5mm fraction) are not used, since they are not linked to a determined float density. A total of 43 large diameter cored boreholes were used for the AAD evaluation, thus giving approximately 31,000 datasets. These were then sorted into separate datasets for each fraction evaluated as coal and shale separately, then combined and later further composites representative of zones and bench definitions and lastly as stratigraphical units to ascertain that the information obtained was relevant and consistent irrespective of any selective boundaries that may have been selected within the vertical section.

A. 2. STATISTICAL DATA ON FLOAT FRACTIONS USED FOR AAD DETERMINATION

Data for each fraction from the wash table was separated into individual sheets and descriptive statistics done on the raw data, results from the descriptive statistics were then used to determine normal distribution curves for these fractions and this data is portrayed in the following sheets.

Descriptive Statistics	
ASH at 1.35g/cc	
Mean	7.342652
Standard Error	0.047552
Median	6.992778
Mode	6.1
Standard Deviation	2.08798
Sample Variance	4.359659
Kurtosis	3.029158
Skewness	1.287906
Range	17.22187
Minimum	3.278129
Maximum	20.5
Sum	14156.63
Count	1928
Largest(1)	20.5
Smallest(1)	3.278129
Confidence Level(9	0.09326

NORMAL DISTRIBUTION

Mean, μ 7.342651853
Standard Deviation, σ 2.08797967

Graph Limits

zmin -4
zmax 4

$$z = \frac{x-\mu}{\sigma}$$

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

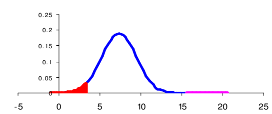
Generate Random Normal

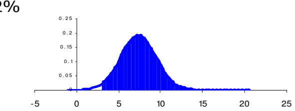
NORMINV(rand(),mean,standard_dev)
6.630521

Cumulative Probability

xmin 3.278129
xmax 20.5

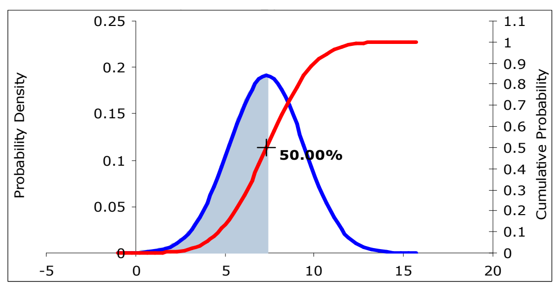
Pr(x<xmin) 2.58%
Pr(x>xmax) 0.00%
Pr(xmin<x<xmax) 97.42%





z	x	f(x)	F(x)
-4	-1.00927	6.40956E-05	3.16712E-05
-3.8	-0.59167	0.000139823	7.2348E-05
-3.6	-0.17407	0.000293059	0.000159109
-3.4	0.243521	0.000590149	0.000336929
-3.2	0.661117	0.001141816	0.000687138
-3	1.078713	0.002122553	0.001349898
-2.8	1.496309	0.003790962	0.00255513
-2.6	1.913905	0.006505317	0.004661188
-2.4	2.331501	0.010725454	0.008197536
-2.2	2.749097	0.016989913	0.013903448
-2	3.166693	0.025857994	0.022750132
-1.8	3.584288	0.037811747	0.035930319
-1.6	4.001884	0.053123522	0.054799292
-1.4	4.41948	0.071709255	0.080756659
-1.2	4.837076	0.09300189	0.11506967
-1	5.254672	0.115887491	0.158655254
-0.8	5.672268	0.138742516	0.211855399
-0.6	6.089864	0.159591881	0.274253118
-0.4	6.50746	0.176376306	0.344578258
-0.2	6.925056	0.187282807	0.420740291
1.27676E-15	7.342652	0.191066171	0.5
0.2	7.760248	0.187282807	0.579259709
0.4	8.177844	0.176376306	0.655421742
0.6	8.59544	0.159591881	0.725746882
0.8	9.013036	0.138742516	0.788144601
1	9.430632	0.115887491	0.841344746
1.2	9.848227	0.09300189	0.88493033
1.4	10.26582	0.071709255	0.919243341
1.6	10.68342	0.053123522	0.945200708
1.8	11.10102	0.037811747	0.964069681
2	11.51861	0.025857994	0.977249868
2.2	11.93621	0.016989913	0.986096552
2.4	12.3538	0.010725454	0.991802464
2.6	12.7714	0.006505317	0.995338812
2.8	13.18899	0.003790962	0.99744487
3	13.60659	0.002122553	0.998650102
3.2	14.02419	0.001141816	0.999312862
3.4	14.44178	0.000590149	0.999663071
3.6	14.85938	0.000293059	0.999840891
3.8	15.27697	0.000139823	0.999927652
4	15.69457	6.40956E-05	0.999968329

Cumulative Probability Graph



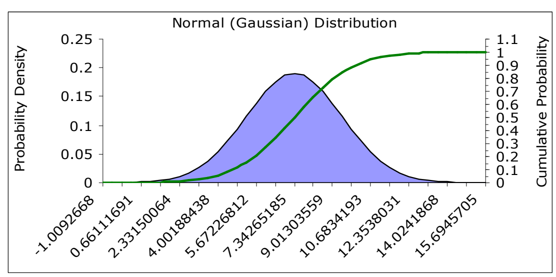


Figure A-1 1.35g/cc Float fraction Statistics.

Descriptive Statistics	
ASH at 1.40g/cc	
Mean	18.53003
Standard Error	0.073304
Median	18.50499
Mode	21.7
Standard Deviation	4.304379
Sample Variance	18.52768
Kurtosis	-0.25327
Skewness	0.229618
Minimum	6.8
Sum	63891.55
Largest(1)	35.1
Smallest(1)	6.8
Count	1932
Largest(1)	30.7
Smallest(1)	4.47
Confidence Level(95.0%	0.161322

NORMAL DISTRIBUTION

Mean, μ	18.53003113
Standard Deviation, σ	4.30437899

Graph Limits

z_{min}	-4
z_{max}	4

$$z = \frac{x-\mu}{\sigma}$$

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

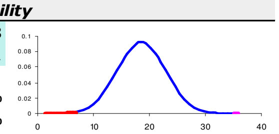
z	x	f(x)	F(x)
-4	1.312515	3.10916E-05	3.16712E-05
-3.8	2.173391	6.78256E-05	7.2348E-05
-3.6	3.034267	0.000142158	0.000159109
-3.4	3.895143	0.000286271	0.000336929
-3.2	4.756018	0.000553875	0.000687138
-3	5.616894	0.001029614	0.001349898
-2.8	6.47777	0.00183893	0.00255513
-2.6	7.338646	0.003155616	0.004661188
-2.4	8.199522	0.005202732	0.008197536
-2.2	9.060397	0.008241512	0.013903448
-2	9.921273	0.012543265	0.022750132
-1.8	10.78215	0.018341823	0.035930319
-1.6	11.64302	0.0257693	0.054799292
-1.4	12.5039	0.034784917	0.080756659
-1.2	13.36478	0.045113605	0.11506967
-1	14.22565	0.056215014	0.158655254
-0.8	15.08653	0.067301591	0.211855399
-0.6	15.9474	0.077415256	0.274253118
-0.4	16.80828	0.08555709	0.344578258
-0.2	17.66916	0.090847645	0.420740291
1.27676E-15	18.53003	0.092682889	0.5
0.2	19.39091	0.090847645	0.579259709
0.4	20.25178	0.08555709	0.655421742
0.6	21.11266	0.077415256	0.725746882
0.8	21.97353	0.067301591	0.788144601
1	22.83441	0.056215014	0.841344746
1.2	23.69529	0.045113605	0.88493033
1.4	24.55616	0.034784917	0.919243341
1.6	25.41704	0.0257693	0.945200708
1.8	26.27791	0.018341823	0.964069681
2	27.13879	0.012543265	0.977249868
2.2	27.99966	0.008241512	0.986096552
2.4	28.86054	0.005202732	0.991802464
2.6	29.72142	0.003155616	0.995338812
2.8	30.58229	0.00183893	0.99744487
3	31.44317	0.001029614	0.998650102
3.2	32.30404	0.000553875	0.999312862
3.4	33.16492	0.000286271	0.999663071
3.6	34.0258	0.000142158	0.999840891
3.8	34.88667	6.78256E-05	0.999927652
4	35.74755	3.10916E-05	0.999968329

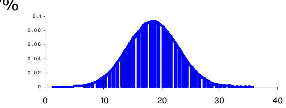
Generate Random Normal

NORMINV(rand(),mean,standard_dev)
20.79413

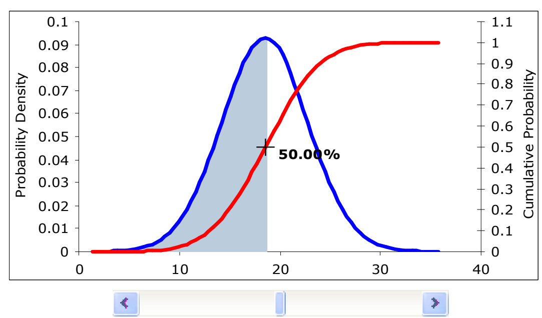
Cumulative Probability

x_{min}	6.8
x_{max}	35.1
$Pr(x<x_{min})$	0.32%
$Pr(x>x_{max})$	0.01%
$Pr(x_{min}<x<x_{max})$	99.67%





Cumulative Probability Graph



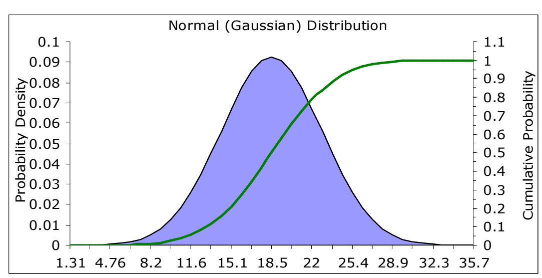


Figure A-2 1.40g/cc Float fraction Statistics.

Descriptive Statistics	
ASH at 1.50g/cc	
Mean	20.22241
Standard Error	0.094064
Median	20.99707
Mode	21.7
Standard Deviation	4.139875
Sample Variance	17.13856
Kurtosis	0.136826
Skewness	-0.31157
Range	25.4
Minimum	8.7
Maximum	34.1
Sum	39170.81
Count	1937
Largest(1)	34.1
Smallest(1)	8.7
Confidence Level(95.0%	0.184477

NORMAL DISTRIBUTION

Mean, μ	20.22240877
Standard Deviation, σ	4.139874875

Graph Limits

z_{min}	-4
z_{max}	4

$$z = \frac{x-\mu}{\sigma}$$

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

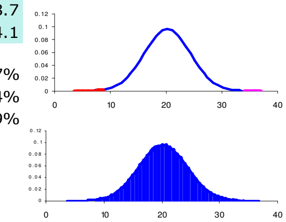
z	x	f(x)	F(x)
-4	3.662909	3.23271E-05	3.16712E-05
-3.8	4.490884	7.05207E-05	7.2348E-05
-3.6	5.318859	0.000147807	0.000159109
-3.4	6.146834	0.000297646	0.000336929
-3.2	6.974809	0.000575884	0.000687138
-3	7.802784	0.001070527	0.001349898
-2.8	8.630759	0.001912003	0.00255513
-2.6	9.458734	0.00328101	0.004661188
-2.4	10.28671	0.00540947	0.008197536
-2.2	11.11468	0.008569001	0.013903448
-2	11.94266	0.01304169	0.022750132
-1.8	12.77063	0.019070663	0.035930319
-1.6	13.59861	0.026793282	0.054799292
-1.4	14.42658	0.036167148	0.080756659
-1.2	15.25456	0.046906262	0.11506967
-1	16.08253	0.058448801	0.158655254
-0.8	16.91051	0.06997592	0.211855399
-0.6	17.73848	0.080491467	0.274253118
-0.4	18.56646	0.088956829	0.344578258
-0.2	19.39443	0.094457612	0.420740291
1.27676E-15	20.22241	0.096365782	0.5
0.2	21.05038	0.094457612	0.579259709
0.4	21.87836	0.088956829	0.655421742
0.6	22.70633	0.080491467	0.725746882
0.8	23.53431	0.06997592	0.788144601
1	24.36228	0.058448801	0.841344746
1.2	25.19026	0.046906262	0.88493033
1.4	26.01823	0.036167148	0.919243341
1.6	26.84621	0.026793282	0.945200708
1.8	27.67418	0.019070663	0.964069681
2	28.50216	0.01304169	0.977249868
2.2	29.33013	0.008569001	0.986096552
2.4	30.15811	0.00540947	0.991802464
2.6	30.98608	0.00328101	0.995338812
2.8	31.81406	0.001912003	0.99744487
3	32.64203	0.001070527	0.998650102
3.2	33.47001	0.000575884	0.999312862
3.4	34.29798	0.000297646	0.999663071
3.6	35.12596	0.000147807	0.999840891
3.8	35.95393	7.05207E-05	0.999927652
4	36.78191	3.23271E-05	0.999968329

Generate Random Normal

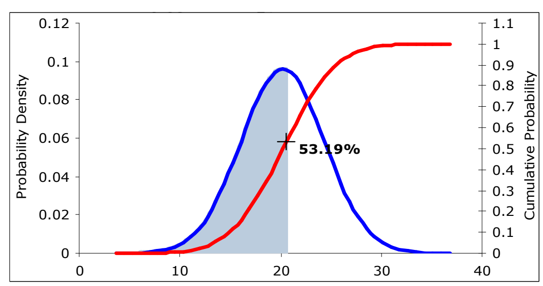
NORMINV(rand(),mean,standard_dev)
25.82547

Cumulative Probability

x_{min}	8.7
x_{max}	34.1
$Pr(x<x_{min})$	0.27%
$Pr(x>x_{max})$	0.04%
$Pr(x_{min}<x<x_{max})$	99.69%



Cumulative Probability Graph



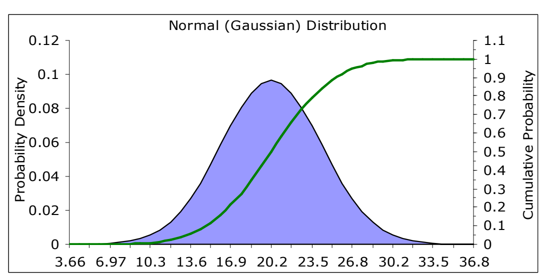


Figure A-3 1.50g/cc Float fraction Statistics.

Descriptive Statistics	
ASH at 1.60g/cc	
Mean	29.44311
Standard Error	0.069276
Median	29.92681
Mode	32
Standard Deviation	4.061939
Sample Variance	16.49935
Kurtosis	0.413358
Skewness	-0.30566
Range	34.1
Minimum	12.1
Maximum	46.2
Sum	101225.4
Count	3438
Largest(1)	46.2
Smallest(1)	12.1
Confidence Level(95.	0.135826

NORMAL DISTRIBUTION

Mean, μ	29.44311198
Standard Deviation, σ	4.061939105

Graph Limits

z_{min}	-4
z_{max}	4

$$z = \frac{x-\mu}{\sigma}$$

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

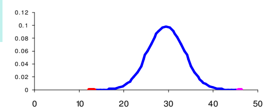
Generate Random Normal

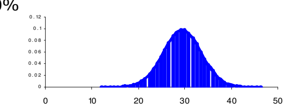
NORMINV(rand(),mean,standard_dev)

30.33315

Cumulative Probability

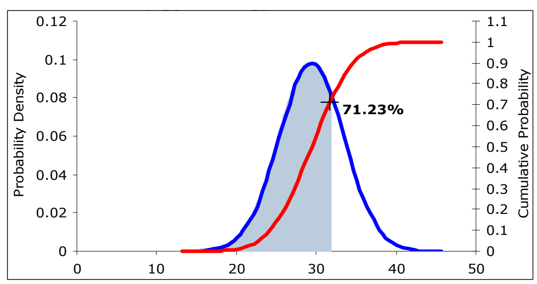
x_{min}	12.1
x_{max}	46.2
$Pr(x<x_{min})$	0.00%
$Pr(x>x_{max})$	0.00%
$Pr(x_{min}<x<x_{max})$	100.00%





z	x	f(x)	F(x)
-4	13.19536	3.29474E-05	3.16712E-05
-3.8	14.00774	7.18738E-05	7.2348E-05
-3.6	14.82013	0.000150643	0.000159109
-3.4	15.63252	0.000303357	0.000336929
-3.2	16.44491	0.000586934	0.000687138
-3	17.25729	0.001091067	0.001349898
-2.8	18.06968	0.001948688	0.00255513
-2.6	18.88207	0.003343962	0.004661188
-2.4	19.69446	0.005513261	0.008197536
-2.2	20.50685	0.008733413	0.013903448
-2	21.31923	0.013291919	0.022750132
-1.8	22.13162	0.019436569	0.035930319
-1.6	22.94401	0.02730736	0.054799292
-1.4	23.7564	0.036861081	0.080756659
-1.2	24.56879	0.047806245	0.11506967
-1	25.38117	0.059570249	0.158655254
-0.8	26.19356	0.071318537	0.211855399
-0.6	27.00595	0.082035844	0.274253118
-0.4	27.81834	0.090663629	0.344578258
-0.2	28.63072	0.096269955	0.420740291
1.27676E-15	29.44311	0.098214737	0.5
0.2	30.2555	0.096269955	0.579259709
0.4	31.06789	0.090663629	0.655421742
0.6	31.88028	0.082035844	0.725746882
0.8	32.69266	0.071318537	0.788144601
1	33.50505	0.059570249	0.841344746
1.2	34.31744	0.047806245	0.88493033
1.4	35.12983	0.036861081	0.919243341
1.6	35.94221	0.02730736	0.945200708
1.8	36.7546	0.019436569	0.964069681
2	37.56699	0.013291919	0.977249868
2.2	38.37938	0.008733413	0.986096552
2.4	39.19177	0.005513261	0.991802464
2.6	40.00415	0.003343962	0.995338812
2.8	40.81654	0.001948688	0.99744487
3	41.62893	0.001091067	0.998650102
3.2	42.44132	0.000586934	0.999312862
3.4	43.2537	0.000303357	0.999663071
3.6	44.06609	0.000150643	0.999840891
3.8	44.87848	7.18738E-05	0.999927652
4	45.69087	3.29474E-05	0.999968329

Cumulative Probability Graph



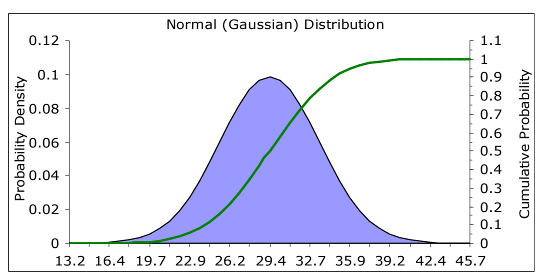


Figure A 4 1.60g/cc Float fraction Statistics

Descriptive Statistics	
ASH at 1.70g/cc	
Mean	37.30599
Standard Error	0.069544
Median	37.8
Mode	39.5
Standard Deviation	4.077088
Sample Variance	16.62265
Kurtosis	0.042637
Skewness	-0.33258
Range	28.86182
Minimum	23.73818
Maximum	52.6
Sum	128220.7
Count	3437
Largest(1)	52.6
Smallest(1)	23.73818
Confidence Level(95.(	0.136352

NORMAL DISTRIBUTION

Mean, μ	37.30598735
Standard Deviation, σ	4.077088005

Graph Limits

zmin	-4
zmax	4

$$z = \frac{x-\mu}{\sigma}$$

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

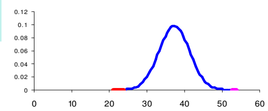
Generate Random Normal

NORMINV(rand(),mean,standard_dev)

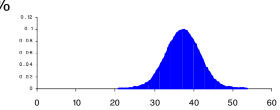
39.26637

Cumulative Probability

x_{min}	23.73818
x_{max}	52.6

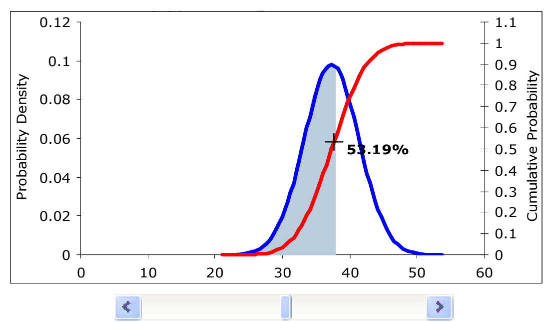


Pr($x<x_{min}$)	0.04%
Pr($x>x_{max}$)	0.01%
Pr($x_{min}<x<x_{max}$)	99.95%



z	*x*	*f(x)*	*F(x)*
-4	20.99764	3.2825E-05	3.16712E-05
-3.8	21.81305	7.16067E-05	7.2348E-05
-3.6	22.62847	0.000150083	0.000159109
-3.4	23.44389	0.00030223	0.000336929
-3.2	24.25931	0.000584753	0.000687138
-3	25.07472	0.001087013	0.001349898
-2.8	25.89014	0.001941447	0.00255513
-2.6	26.70556	0.003331537	0.004661188
-2.4	27.52098	0.005492776	0.008197536
-2.2	28.33639	0.008700963	0.013903448
-2	29.15181	0.013242532	0.022750132
-1.8	29.96723	0.01936435	0.035930319
-1.6	30.78265	0.027205897	0.054799292
-1.4	31.59806	0.036724119	0.080756659
-1.2	32.41348	0.047628615	0.11506967
-1	33.2289	0.059348909	0.158655254
-0.8	34.04432	0.071053544	0.211855399
-0.6	34.85973	0.08173103	0.274253118
-0.4	35.67515	0.090326758	0.344578258
-0.2	36.49057	0.095912252	0.420740291
1.27676E-15	37.30599	0.097849808	0.5
0.2	38.1214	0.095912252	0.579259709
0.4	38.93682	0.090326758	0.655421742
0.6	39.75224	0.08173103	0.725746882
0.8	40.56766	0.071053544	0.788144601
1	41.38308	0.059348909	0.841344746
1.2	42.19849	0.047628615	0.88493033
1.4	43.01391	0.036724119	0.919243341
1.6	43.82933	0.027205897	0.945200708
1.8	44.64475	0.01936435	0.964069681
2	45.46016	0.013242532	0.977249868
2.2	46.27558	0.008700963	0.986096552
2.4	47.091	0.005492776	0.991802464
2.6	47.90642	0.003331537	0.995338812
2.8	48.72183	0.001941447	0.99744487
3	49.53725	0.001087013	0.998650102
3.2	50.35267	0.000584753	0.999312862
3.4	51.16809	0.00030223	0.999663071
3.6	51.9835	0.000150083	0.999840891
3.8	52.79892	7.16067E-05	0.999927652
4	53.61434	3.2825E-05	0.999968329

Cumulative Probability Graph



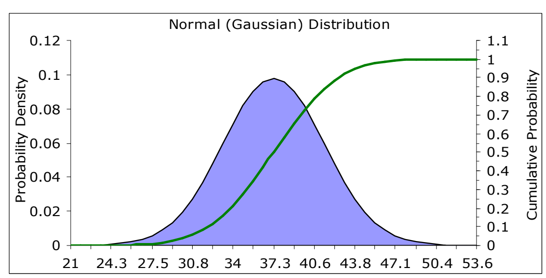


Figure A 5 1.70g/cc Float fraction Statistics

Descriptive Statistics	
ASH at 1.80g/cc	
Mean	44.04204
Standard Error	0.071722
Median	44.50161
Mode	47
Standard Deviation	4.235246
Sample Variance	17.93731
Kurtosis	-0.03337
Skewness	-0.37161
Range	30.7
Minimum	27.2
Maximum	57.9
Sum	153574.6
Count	3487
Largest(1)	57.9
Smallest(1)	27.2
Confidence Level(95.0%)	0.140621

NORMAL DISTRIBUTION

Mean, μ 44.04203986
Standard Deviation, σ 4.235246495

Graph Limits

zmin -4
zmax 4

$$z = \frac{x-\mu}{\sigma}$$

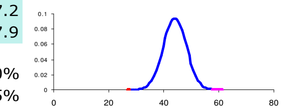
$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Generate Random Normal

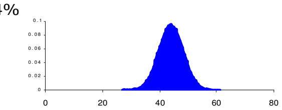
NORMINV(rand(),mean,standard_dev)
48.04107

Cumulative Probability

x_{min} 27.2
x_{max} 57.9

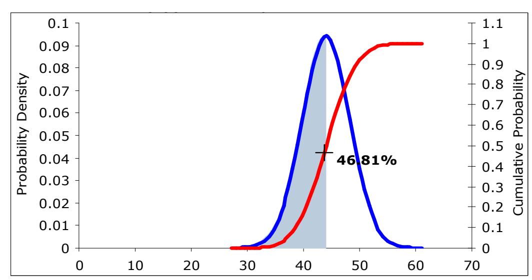


Pr($x<x_{min}$) 0.00%
Pr($x>x_{max}$) 0.05%
Pr($x_{min}<x<x_{max}$) 99.94%



z	x	f(x)	F(x)
-4	27.10105	3.15992E-05	3.16712E-05
-3.8	27.9481	6.89327E-05	7.2348E-05
-3.6	28.79515	0.000144478	0.000159109
-3.4	29.6422	0.000290944	0.000336929
-3.2	30.48925	0.000562916	0.000687138
-3	31.3363	0.00104642	0.001349898
-2.8	32.18335	0.001868947	0.00255513
-2.6	33.0304	0.003207126	0.004661188
-2.4	33.87745	0.005287657	0.008197536
-2.2	34.7245	0.00837604	0.013903448
-2	35.57155	0.01274801	0.022750132
-1.8	36.4186	0.018641219	0.035930319
-1.6	37.26565	0.026189936	0.054799292
-1.4	38.11269	0.035352716	0.080756659
-1.2	38.95974	0.045850001	0.11506967
-1	39.80679	0.057132619	0.158655254
-0.8	40.65384	0.068400164	0.211855399
-0.6	41.50089	0.078678916	0.274253118
-0.4	42.34794	0.08695365	0.344578258
-0.2	43.19499	0.092330563	0.420740291
1.27676E-15	44.04204	0.094195764	0.5
0.2	44.88909	0.092330563	0.579259709
0.4	45.73614	0.08695365	0.655421742
0.6	46.58319	0.078678916	0.725746882
0.8	47.43024	0.068400164	0.788144601
1	48.27729	0.057132619	0.841344746
1.2	49.12434	0.045850001	0.88493033
1.4	49.97138	0.035352716	0.919243341
1.6	50.81843	0.026189936	0.945200708
1.8	51.66548	0.018641219	0.964069681
2	52.51253	0.01274801	0.977249868
2.2	53.35958	0.00837604	0.986096552
2.4	54.20663	0.005287657	0.991802464
2.6	55.05368	0.003207126	0.995338812
2.8	55.90073	0.001868947	0.99744487
3	56.74778	0.00104642	0.998650102
3.2	57.59483	0.000562916	0.999312862
3.4	58.44188	0.000290944	0.999663071
3.6	59.28893	0.000144478	0.999840891
3.8	60.13598	6.89327E-05	0.999927652
4	60.98303	3.15992E-05	0.999968329

Cumulative Probability Graph



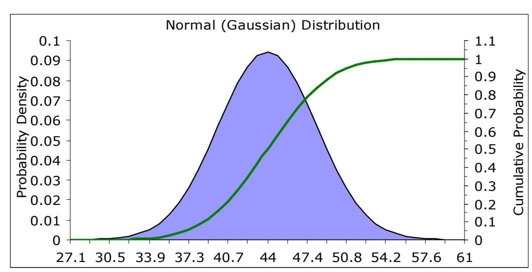


Figure A 6 1.80g/cc Float fraction Statistics

Descriptive Statistics	
ASH at 1.90g/cc	
Mean	50.22767
Standard Error	0.076601
Median	50.9
Mode	51.4
Standard Deviation	4.511677
Sample Variance	20.35522
Kurtosis	0.190818
Skewness	-0.53009
Range	30.4
Minimum	32.7
Maximum	63.1
Sum	174239.8
Count	3469
Largest(1)	63.1
Smallest(1)	32.7
Confidence Level(95.0%)	0.150188

NORMAL DISTRIBUTION

Mean, μ 50.22767355
Standard Deviation, σ 4.511676516

Graph Limits

z_{min} -4
z_{max} 4

$$z = \frac{x-\mu}{\sigma}$$

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

z	*x*	*f(x)*	*F(x)*
-4	32.18097	2.96631E-05	3.16712E-05
-3.8	33.0833	6.47092E-05	7.2348E-05
-3.6	33.98564	0.000135626	0.000159109
-3.4	34.88797	0.000273118	0.000336929
-3.2	35.79031	0.000528426	0.000687138
-3	36.69264	0.000982306	0.001349898
-2.8	37.59498	0.001754437	0.00255513
-2.6	38.49731	0.003010626	0.004661188
-2.4	39.39965	0.004963683	0.008197536
-2.2	40.30199	0.007862841	0.013903448
-2	41.20432	0.011966941	0.022750132
-1.8	42.10666	0.017499073	0.035930319
-1.6	43.00899	0.024585281	0.054799292
-1.4	43.91133	0.033186658	0.080756659
-1.2	44.81366	0.043040775	0.11506967
-1	45.716	0.053632109	0.158655254
-0.8	46.61833	0.064209292	0.211855399
-0.6	47.52067	0.073858266	0.274253118
-0.4	48.423	0.081626007	0.344578258
-0.2	49.32534	0.086673478	0.420740291
1.27676E-15	50.22767	0.088424398	0.5
0.2	51.13001	0.086673478	0.579259709
0.4	52.03234	0.081626007	0.655421742
0.6	52.93468	0.073858266	0.725746882
0.8	53.83701	0.064209292	0.788144601
1	54.73935	0.053632109	0.841344746
1.2	55.64169	0.043040775	0.88493033
1.4	56.54402	0.033186658	0.919243341
1.6	57.44636	0.024585281	0.945200708
1.8	58.34869	0.017499073	0.964069681
2	59.25103	0.011966941	0.977249868
2.2	60.15336	0.007862841	0.986096552
2.4	61.0557	0.004963683	0.991802464
2.6	61.95803	0.003010626	0.995338812
2.8	62.86037	0.001754437	0.99744487
3	63.7627	0.000982306	0.998650102
3.2	64.66504	0.000528426	0.999312862
3.4	65.56737	0.000273118	0.999663071
3.6	66.46971	0.000135626	0.999840891
3.8	67.37204	6.47092E-05	0.999927652
4	68.27438	2.96631E-05	0.999968329

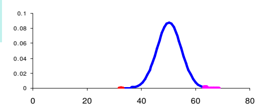
Generate Random Normal

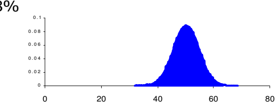
NORMINV(rand(),mean,standard_dev)
50.09281

Cumulative Probability

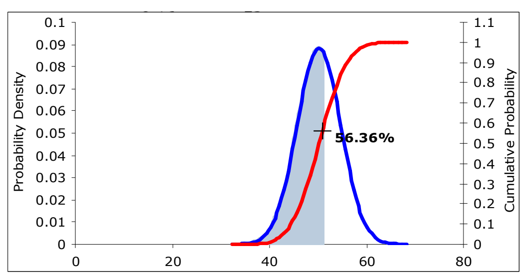
x_{min} 32.7
x_{max} 63.1

$Pr(x<x_{min})$ 0.01%
$Pr(x>x_{max})$ 0.22%
$Pr(x_{min}<x<x_{max})$ 99.78%





Cumulative Probability Graph



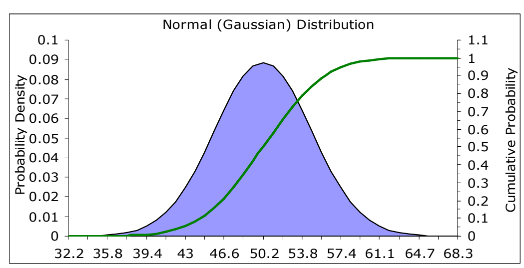


Figure A-7 1.90g/cc Float fraction Statistics

Descriptive Statistics	
ASH at 2.00g/cc	
Mean	56.06499
Standard Error	0.085097
Median	56.4
Mode	60
Standard Deviation	5.004132
Sample Variance	25.04134
Kurtosis	0.195535
Skewness	-0.51245
Range	34.00112
Minimum	36.29888
Maximum	70.3
Sum	193872.7
Count	3458
Largest(1)	70.3
Smallest(1)	36.29888
Confidence Level(95.0	0.166846

NORMAL DISTRIBUTION

Mean, μ	56.06498736
Standard Deviation, σ	5.004132319

Graph Limits

zmin	-4
zmax	4

$$z = \frac{x-\mu}{\sigma}$$

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

z	*x*	*f(x)*	*F(x)*
-4	36.04846	2.67439E-05	3.16712E-05
-3.8	37.04928	5.83412E-05	7.2348E-05
-3.6	38.05011	0.000122279	0.000159109
-3.4	39.05094	0.00024624	0.000336929
-3.2	40.05176	0.000476424	0.000687138
-3	41.05259	0.000885638	0.001349898
-2.8	42.05342	0.001581783	0.00255513
-2.6	43.05424	0.002714351	0.004661188
-2.4	44.05507	0.004475207	0.008197536
-2.2	45.0559	0.00708906	0.013903448
-2	46.05672	0.010789276	0.022750132
-1.8	47.05755	0.015776993	0.035930319
-1.6	48.05838	0.022165848	0.054799292
-1.4	49.0592	0.029920765	0.080756659
-1.2	50.06003	0.03880514	0.11506967
-1	51.06086	0.048354182	0.158655254
-0.8	52.06168	0.057890466	0.211855399
-0.6	53.06251	0.066589886	0.274253118
-0.4	54.06333	0.073593206	0.344578258
-0.2	55.06416	0.078143956	0.420740291
1.27676E-15	56.06499	0.079722568	0.5
0.2	57.06581	0.078143956	0.579259709
0.4	58.06664	0.073593206	0.655421742
0.6	59.06747	0.066589886	0.725746882
0.8	60.06829	0.057890466	0.788144601
1	61.06912	0.048354182	0.841344746
1.2	62.06995	0.03880514	0.88493033
1.4	63.07077	0.029920765	0.919243341
1.6	64.0716	0.022165848	0.945200708
1.8	65.07243	0.015776993	0.964069681
2	66.07325	0.010789276	0.977249868
2.2	67.07408	0.00708906	0.986096552
2.4	68.0749	0.004475207	0.991802464
2.6	69.07573	0.002714351	0.995338812
2.8	70.07656	0.001581783	0.99744487
3	71.07738	0.000885638	0.998650102
3.2	72.07821	0.000476424	0.999312862
3.4	73.07904	0.00024624	0.999663071
3.6	74.07986	0.000122279	0.999840891
3.8	75.08069	5.83412E-05	0.999927652
4	76.08152	2.67439E-05	0.999968329

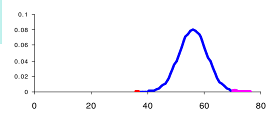
Generate Random Normal

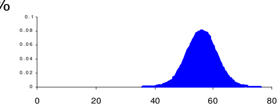
NORMINV(rand(),mean,standard_dev)

62.21774

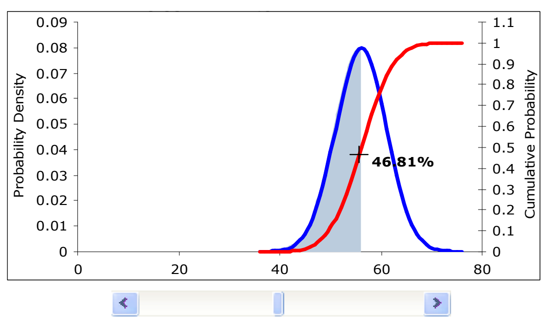
Cumulative Probability

x_{min}	36.29888
x_{max}	70.3
Pr($x<x_{min}$)	0.00%
Pr($x>x_{max}$)	0.22%
Pr($x_{min}<x<x_{max}$)	99.77%





Cumulative Probability Graph



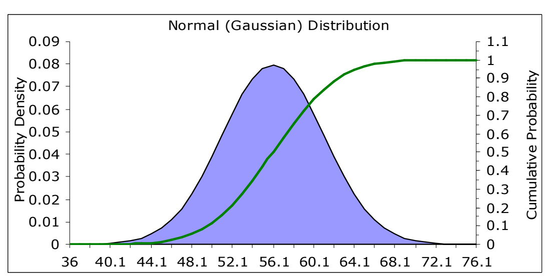


Figure A-8 2.00g/cc Float fraction Statistics

Descriptive Statistics	
ASH at 2.10g/cc	
Mean	60.8408
Standard Error	0.10176
Median	61.59076
Mode	66.3
Standard Deviation	5.984831
Sample Variance	35.8182
Kurtosis	0.01181
Skewness	-0.60114
Minimum	39.08679
Sum	210448.3
Largest(1)	75.1
Smallest(1)	39.08679
Count	3458
Largest(1)	70.3
Smallest(1)	36.29888
Confidence Level(95.(	0.166846

NORMAL DISTRIBUTION

Mean, μ	60.84079776
Standard Deviation, σ	5.984830818

Graph Limits

zmin	-4
zmax	4

$$z = \frac{x-\mu}{\sigma}$$

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

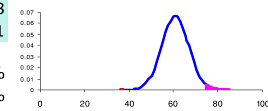
Generate Random Normal

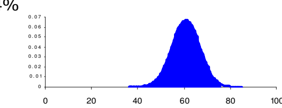
NORMINV(rand(),mean,standard_dev)

62.21299

Cumulative Probability

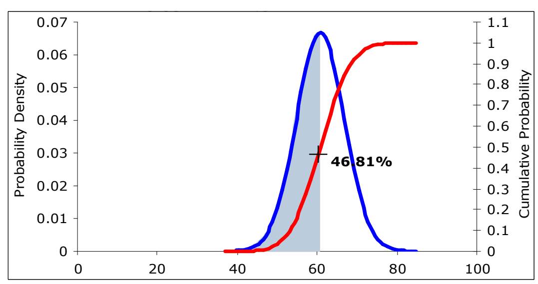
x_{min}	36.29888
x_{max}	75.1
$Pr(x<x_{min})$	0.00%
$Pr(x>x_{max})$	0.86%
$Pr(x_{min}<x<x_{max})$	99.14%





z	x	f(x)	F(x)
-4	36.90147	2.23616E-05	3.16712E-05
-3.8	38.09844	4.87811E-05	7.2348E-05
-3.6	39.29541	0.000102242	0.000159109
-3.4	40.49237	0.00020589	0.000336929
-3.2	41.68934	0.000398355	0.000687138
-3	42.88631	0.000740514	0.001349898
-2.8	44.08327	0.001322586	0.00255513
-2.6	45.28024	0.002269566	0.004661188
-2.4	46.4772	0.003741882	0.008197536
-2.2	47.67417	0.005927418	0.013903448
-2	48.87114	0.009021302	0.022750132
-1.8	50.0681	0.013191711	0.035930319
-1.6	51.26507	0.018533663	0.054799292
-1.4	52.46203	0.025017828	0.080756659
-1.2	53.659	0.032446373	0.11506967
-1	54.85597	0.040430671	0.158655254
-0.8	56.05293	0.048404301	0.211855399
-0.6	57.2499	0.055678199	0.274253118
-0.4	58.44687	0.061533927	0.344578258
-0.2	59.64383	0.065338972	0.420740291
1.27676E-15	60.8408	0.066658907	0.5
0.2	62.03776	0.065338972	0.579259709
0.4	63.23473	0.061533927	0.655421742
0.6	64.4317	0.055678199	0.725746882
0.8	65.62866	0.048404301	0.788144601
1	66.82563	0.040430671	0.841344746
1.2	68.02259	0.032446373	0.88493033
1.4	69.21956	0.025017828	0.919243341
1.6	70.41653	0.018533663	0.945200708
1.8	71.61349	0.013191711	0.964069681
2	72.81046	0.009021302	0.977249868
2.2	74.00743	0.005927418	0.986096552
2.4	75.20439	0.003741882	0.991802464
2.6	76.40136	0.002269566	0.995338812
2.8	77.59832	0.001322586	0.99744487
3	78.79529	0.000740514	0.998650102
3.2	79.99226	0.000398355	0.999312862
3.4	81.18922	0.00020589	0.999663071
3.6	82.38619	0.000102242	0.999840891
3.8	83.58315	4.87811E-05	0.999927652
4	84.78012	2.23616E-05	0.999968329

Cumulative Probability Graph



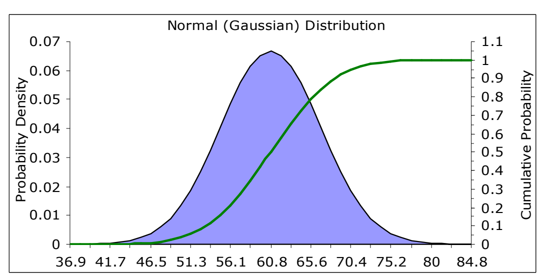


Figure A-8 2.00g/cc Float fraction Statistics

Descriptive Statistics	
ASH at 2.10g/cc	
Mean	60.8408
Standard Error	0.10176
Median	61.59076
Mode	66.3
Standard Deviation	5.984831
Sample Variance	35.8182
Kurtosis	0.01181
Skewness	-0.60114
Minimum	39.08679
Sum	210448.3
Largest(1)	75.1
Smallest(1)	39.08679
Count	3458
Largest(1)	70.3
Smallest(1)	36.29888
Confidence Level(95.(	0.166846

NORMAL DISTRIBUTION

Mean, μ 60.84079776

Standard Deviation, σ 5.984830818

Graph Limits

z_{min} -4

z_{max} 4

$$z = \frac{x-\mu}{\sigma}$$

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Generate Random Normal

NORMINV(rand(),mean,standard_dev)

62.21299

Cumulative Probability

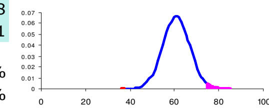
x_{min} 36.29888

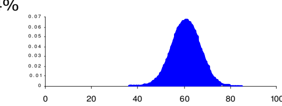
x_{max} 75.1

Pr(x<x_{min}) 0.00%

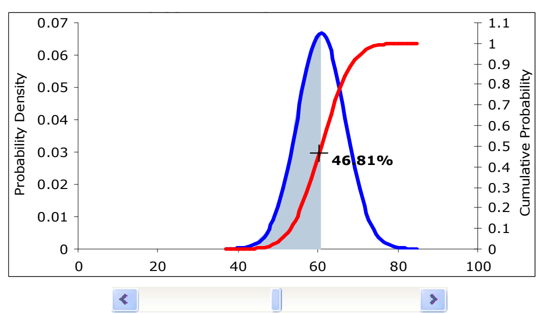
Pr(x>x_{max}) 0.86%

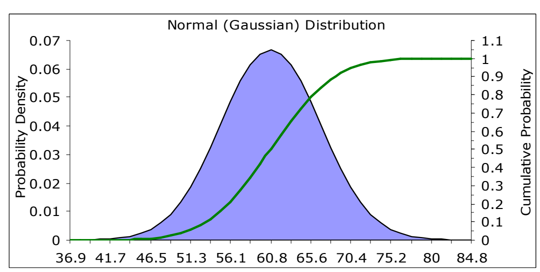
Pr(x_{min}<x<x_{max}) 99.14%





Cumulative Probability Graph





z	*x*	***f(x)***	***F(x)***
-4	36.90147	2.23616E-05	3.16712E-05
-3.8	38.09844	4.87811E-05	7.2348E-05
-3.6	39.29541	0.000102242	0.000159109
-3.4	40.49237	0.00020589	0.000336929
-3.2	41.68934	0.000398355	0.000687138
-3	42.88631	0.000740514	0.001349898
-2.8	44.08327	0.001322586	0.00255513
-2.6	45.28024	0.002269566	0.004661188
-2.4	46.4772	0.003741882	0.008197536
-2.2	47.67417	0.005927418	0.013903448
-2	48.87114	0.009021302	0.022750132
-1.8	50.0681	0.013191711	0.035930319
-1.6	51.26507	0.018533663	0.054799292
-1.4	52.46203	0.025017828	0.080756659
-1.2	53.659	0.032446373	0.11506967
-1	54.85597	0.040430671	0.158655254
-0.8	56.05293	0.048404301	0.211855399
-0.6	57.2499	0.055678199	0.274253118
-0.4	58.44687	0.061533927	0.344578258
-0.2	59.64383	0.065338972	0.420740291
1.27676E-15	60.8408	0.066658907	0.5
0.2	62.03776	0.065338972	0.579259709
0.4	63.23473	0.061533927	0.655421742
0.6	64.4317	0.055678199	0.725746882
0.8	65.62866	0.048404301	0.788144601
1	66.82563	0.040430671	0.841344746
1.2	68.02259	0.032446373	0.88493033
1.4	69.21956	0.025017828	0.919243341
1.6	70.41653	0.018533663	0.945200708
1.8	71.61349	0.013191711	0.964069681
2	72.81046	0.009021302	0.977249868
2.2	74.00743	0.005927418	0.986096552
2.4	75.20439	0.003741882	0.991802464
2.6	76.40136	0.002269566	0.995338812
2.8	77.59832	0.001322586	0.99744487
3	78.79529	0.000740514	0.998650102
3.2	79.99226	0.000398355	0.999312862
3.4	81.18922	0.00020589	0.999663071
3.6	82.38619	0.000102242	0.999840891
3.8	83.58315	4.87811E-05	0.999927652
4	84.78012	2.23616E-05	0.999968329

Figure A-9 2.10g/cc Float fraction Statistics

Descriptive Statistics	
ASH at 2.20g/cc	
Mean	65.71414
Standard Error	0.138604
Median	67.07761
Mode	74.4
Standard Deviation	8.155284
Sample Variance	66.50865
Kurtosis	-0.61334
Skewness	-0.45342
Range	50.4
Minimum	39.9
Maximum	90.3
Sum	227502.4
Count	3462
Largest(1)	90.3
Smallest(1)	39.9
Confidence Level(95.(	0.271754

NORMAL DISTRIBUTION

Mean, μ	65.71414385
Standard Deviation, σ	8.155283573

Graph Limits

zmin	-4
zmax	4

$$z = \frac{x-\mu}{\sigma}$$

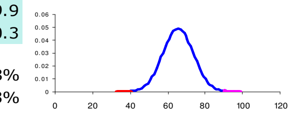
$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Generate Random Normal

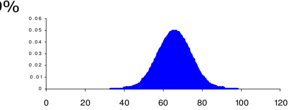
NORMINV(rand(),mean,standard_dev)
65.87996

Cumulative Probability

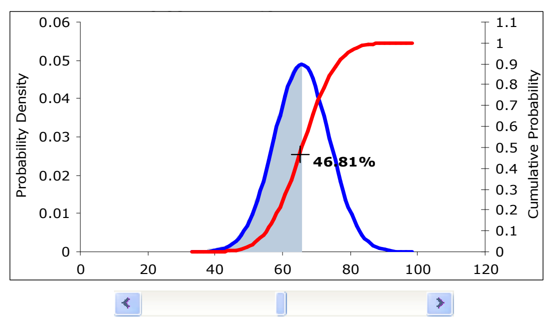
x_{min}	39.9
x_{max}	90.3

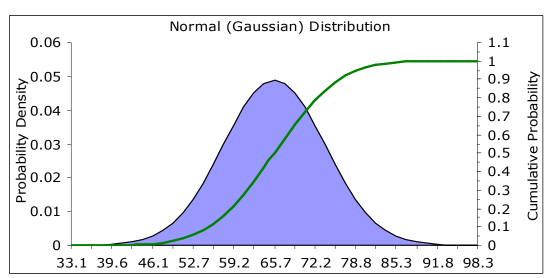


Pr(x<x_{min})	0.08%
Pr(x>x_{max})	0.13%
Pr(x_{min}<x<x_{max})	99.79%



Cumulative Probability Graph





z	*x*	*f(x)*	*F(x)*
-4	33.09301	1.64102E-05	3.16712E-05
-3.8	34.72407	3.57985E-05	7.2348E-05
-3.6	36.35512	7.50313E-05	0.000159109
-3.4	37.98618	0.000151095	0.000336929
-3.2	39.61724	0.000292337	0.000687138
-3	41.24829	0.000543433	0.001349898
-2.8	42.87935	0.000970592	0.00255513
-2.6	44.51041	0.001665542	0.004661188
-2.4	46.14146	0.002746015	0.008197536
-2.2	47.77252	0.004349891	0.013903448
-2	49.40358	0.006620367	0.022750132
-1.8	51.03463	0.00968086	0.035930319
-1.6	52.66569	0.013601101	0.054799292
-1.4	54.29675	0.018359566	0.080756659
-1.2	55.9278	0.023811073	0.11506967
-1	57.55886	0.029670424	0.158655254
-0.8	59.18992	0.035521947	0.211855399
-0.6	60.82097	0.040859965	0.274253118
-0.4	62.45203	0.045157245	0.344578258
-0.2	64.08309	0.047949613	0.420740291
1.27676E-15	65.71414	0.04891826	0.5
0.2	67.3452	0.047949613	0.579259709
0.4	68.97626	0.045157245	0.655421742
0.6	70.60731	0.040859965	0.725746882
0.8	72.23837	0.035521947	0.788144601
1	73.86943	0.029670424	0.841344746
1.2	75.50048	0.023811073	0.88493033
1.4	77.13154	0.018359566	0.919243341
1.6	78.7626	0.013601101	0.945200708
1.8	80.39365	0.00968086	0.964069681
2	82.02471	0.006620367	0.977249868
2.2	83.65577	0.004349891	0.986096552
2.4	85.28682	0.002746015	0.991802464
2.6	86.91788	0.001665542	0.995338812
2.8	88.54894	0.000970592	0.99744487
3	90.17999	0.000543433	0.998650102
3.2	91.81105	0.000292337	0.999312862
3.4	93.44211	0.000151095	0.999663071
3.6	95.07316	7.50313E-05	0.999840891
3.8	96.70422	3.57985E-05	0.999927652
4	98.33528	1.64102E-05	0.999968329

Figure A-10 2.20g/cc Float fraction Statistics

APPENDIX B

AN EXCEL SPREAD-SHEET BLOCK RATIO EVALUATION OF WEEKLY DATA.

BLOCKS PLANNED FOR WEEK AS WELL AS, AS- MINED BLOCKS.

The layout below illustrates the information required to evaluate wash data for the planned and the as mined blast blocks during a specific week. The initial data extracted is a pre-composited wash table derived for the specific blast block based on roof and floor information gleaned from geophysical logs of blast holes used for the blast block evaluation.

Available Blocks GG1

Planned Blocks	As Mined
b028406	b02vloer
b038202	b038202
b038408	b038308
b048307	b038201
	b048307
	b028406
	b038301
	b048308

Week Ending: 5/24/2008

	Blocks	Ratio
1	b028406	26
2	b038202	11
3	b038408	51
4	b048307	11
5	0	
6	0	
7	0	
8	0	

The following pages show the various stages followed in the evaluation of these blast blocks and their potential yields based on AAD and differing ratios of the blast blocks shown in different scenario's relating to Planning, Optimization and actual as mined values.

NORMAL WASH DATA FROM EMPIRICAL ANALYSIS FOR PLANNED BLOCKS

BLOCK #	Gradcon original fractional data										
b028406											
26	FRACT	RD_1	RD_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	SULPHUR	CV
			1.35	7.101830017	2.255013	6.32482	36.621179	5.15285	67	1.03373	30.3527
			1.4	6.193967705	2.017004	12.0055	35.803979	4.56569	62	1.09967	28.3567
			1.5	12.93283667	1.821005	20.436	33.07602	3.26612	43	1.27919	25.2064
			1.6	7.093117671	1.764101	30.511	29.38048	0.89217	1	1.41298	21.3519
			1.7	4.760330125	1.761392	38.7005	26.002983	0.42507	0	1.59532	18.0735
			1.8	3.886170379	1.786294	46.1973	22.691631	0.03772	0	1.64805	15.0048
			1.9	2.926191371	2.148451	54.5855	19.656303	0	0	1.78747	11.3761
			2	2.374124938	2.32034	60.7201	17.542515	0	0	1.93765	8.73375
			2.1	2.239568444	2.328198	66.3073	15.647703	0	0	1.98224	6.32176
			2.2	4.870659127	3.069697	74.9932	12.741802	0	0	1.16185	2.31721
			2.5	45.60502766	1.426173	85.3189	9.9015272	0	0	1.58786	1.00532

b038202	Gradcon original fractional data										
11	FRACT	RD_1	RD_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	SULPHUR	CV
			1.35	6.261195815	2.386667	5.82212	35.589755	4.77974	67	0.86149	30.5022
			1.4	6.299715874	2.225322	11.3607	35.184915	4.06045	63	0.89589	28.523
			1.5	11.67162038	1.86453	20.0813	32.474326	2.69357	42	1.11518	25.374
			1.55	0.616002038	1.841034	23.887	31.717014	2.1623	31	0	23.8162
			1.6	8.072835207	1.714833	29.3153	29.110764	1.55145	12	1.11619	21.8553
			1.7	6.042222906	1.62106	37.558	26.116378	0.78598	0	1.07732	18.597
			1.8	4.106891297	1.727428	44.3926	23.513921	0.53871	0	1.41477	15.8348
			1.9	2.98189274	1.867866	52.231	20.440664	0	0	1.51383	12.5488
			2	2.66450903	1.932877	58.8624	18.092105	0	0	1.49539	9.74563
			2.1	2.915044925	1.907929	65.1704	15.81285	0	0	1.33501	7.03378
			2.2	5.818927321	2.058045	72.4213	13.183628	0	0	0.79945	3.74781
			2.5	42.54499287	1.175923	83.2795	10.399982	0	0	0.97485	1.08615

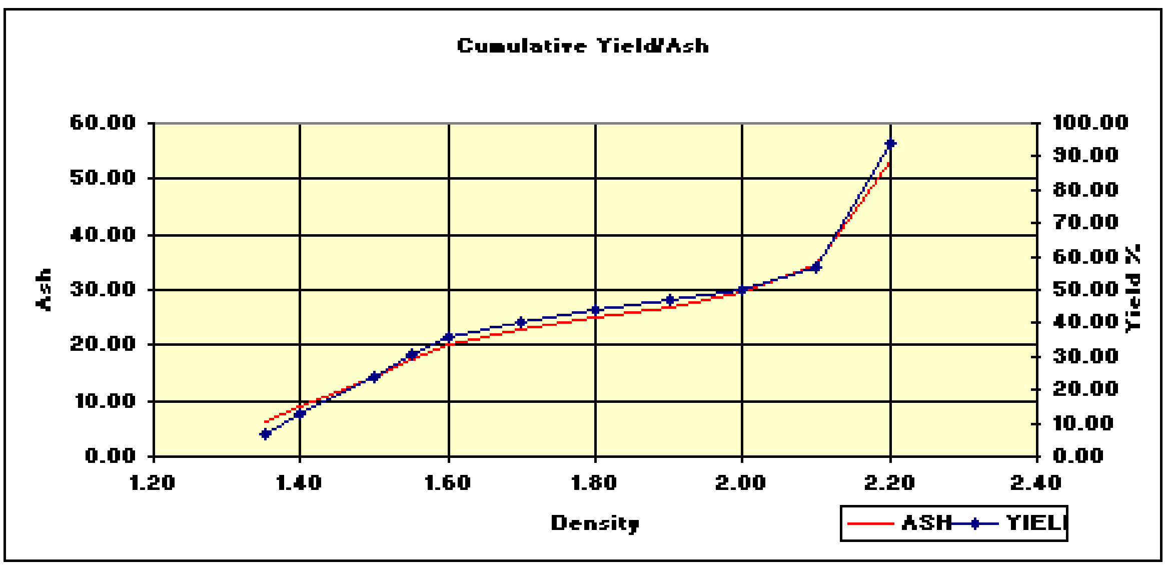
b038408	Gradcon original fractional data										
51	FRACT	RD_1	RD_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	SULPHUR	CV
			1.35	7.147115226	2.124964	6.52369	35.562583	5.11226	65	0.8753	30.2462
			1.4	5.889331681	1.909824	12.9184	34.430572	4.17704	57	0.9883	27.9487
			1.5	11.34601	1.784041	20.6795	31.75205	2.14896	26	1.08856	25.0492
			1.6	7.793340327	1.759799	29.8763	28.237839	1.27824	2	1.20814	21.4866
			1.7	5.683738356	1.840675	37.5602	25.055296	0.41058	0	1.31019	18.3896
			1.8	4.106845865	1.913182	44.9821	22.081094	0.01717	0	1.22764	15.3273
			1.9	3.088529326	2.026243	52.3833	20.26613	0	0	1.40338	12.1647
			2	2.851407811	2.107692	59.2445	17.858302	0	0	1.31881	9.17325
			2.1	3.197762408	2.148705	65.4422	15.597202	0	0	1.24554	6.43569
			2.2	7.396535278	2.413269	73.7516	12.555003	0	0	0.5964	2.60805
			2.5	41.49662098	1.667045	83.8684	10.051763	0	0	0.92513	0.62958

b048307	Gradcon original fractional data										
11	FRACT	RD_1	RD_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	SULPHUR	CV
			1.35	5.92948584	2.044351	6.24499	36.151766	4.99038	60	0.99728	30.3654
			1.4	4.255731386	1.682095	10.6749	35.431057	4.05883	54	1.03151	28.7968
			1.5	9.151104371	1.750771	18.6755	32.706237	2.19276	22	1.04499	25.8302
			1.6	6.206832616	1.611007	27.3449	30.003545	1.22295	4	0.93284	22.532
			1.7	4.357614304	1.533197	34.9976	27.229359	0.42636	0	1.06951	19.5503
			1.8	4.385243557	1.682083	43.0439	23.816269	0.01995	0	0.91877	16.2402
			1.9	4.336981591	1.840489	52.156	20.364235	0	0	0.80834	12.4385
			2	5.069107925	1.974186	58.7655	17.872445	0	0	0.66144	9.59091
			2.1	6.251498792	2.06618	64.7071	15.756678	0	0	0.56532	6.96328
			2.2	13.27710343	2.125861	72.9374	13.233052	0	0	0.38663	3.248
			2.5	36.17492712	1.279496	79.8961	12.118945	0.00034	0	0.8996	0.76179

THE COMPOSITE WASH TABLE FOR FOUR BLAST BLOCKS WITH THEIR CONTRIBUTORY RATIOS TAKEN INTO ACCOUNT

Planned Mix to SSCC Plant									
Composite Fractional Table									
RD_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	ULPHU	CV	PHOS
1.35	6.83	2.16	6.30	35.55	5.02	64.54	0.92	30.01	0.00
1.40	5.78	1.95	12.13	34.64	4.21	58.06	1.00	27.93	0.00
1.50	11.44	1.78	20.14	31.96	2.48	31.48	1.13	24.96	0.00
1.55	6.57	1.74	28.81	28.83	1.26	5.13	1.09	21.61	0.00
1.60	5.57	1.75	36.29	25.74	0.54	1.32	1.32	18.63	0.00
1.70	4.25	1.80	43.82	22.65	0.11	0.00	1.27	15.55	0.00
1.80	3.26	1.98	51.53	20.27	0.06	0.00	1.43	12.27	0.00
1.90	2.96	2.10	58.21	17.88	0.00	0.00	1.42	9.38	0.00
2.00	3.19	2.14	64.21	15.75	0.00	0.00	1.38	6.76	0.00
2.10	6.82	2.47	72.30	12.91	0.00	0.00	0.80	3.06	0.00
2.20	37.64	1.59	81.71	10.48	0.00	0.00	1.07	1.08	0.00
2.50	4.68	0.13	9.16	1.14	0.00	0.00	0.11	0.12	0.00

Composite Cumulative Table									
RD_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	ULPHU	CV	PHOS
1.35	6.83	2.16	6.30	35.55	5.02	64.54	0.92	30.01	0.00
1.40	12.61	2.06	8.97	35.13	4.65	61.57	0.96	29.06	0.00
1.50	24.05	1.93	14.28	33.62	3.62	47.26	1.04	27.11	0.00
1.55	30.62	1.89	17.40	32.60	3.11	38.22	1.05	25.93	0.00
1.60	36.19	1.87	20.31	31.54	2.72	32.54	1.09	24.81	0.00
1.70	40.44	1.86	22.78	30.61	2.44	29.12	1.11	23.83	0.00
1.80	43.70	1.87	24.93	29.83	2.26	26.94	1.13	22.97	0.00
1.90	46.66	1.88	27.04	29.08	2.12	25.23	1.15	22.11	0.00
2.00	49.85	1.90	29.42	28.22	1.98	23.62	1.17	21.13	0.00
2.10	56.67	1.97	34.58	26.38	1.75	20.78	1.12	18.95	0.00
2.20	94.31	1.82	53.39	20.04	1.05	12.48	1.10	11.82	0.00
2.50	98.99	1.74	51.30	19.14	1.00	11.89	1.05	11.27	0.00



THE SAME COMPOSITED BLOCK DATA AFTER AAD APPLIED

BLOCK #

b028406	djusted Ash-Density Fractional da										
26	FRACT	RD_1	RD_2	YIELD	MOIST	ASH	/OLATILES	SWELL	ROGA	SULPHUI	CV
			1.35	7.10	2.26	6.32	36.62	5.15	67.00	1.03	30.35
			1.40	6.19	2.02	12.01	35.81	4.57	62.00	1.10	28.36
			1.50	12.93	1.82	20.50	33.08	3.27	43.00	1.28	25.21
			1.60	7.09	1.76	30.51	29.38	0.89	1.00	1.41	21.35
			1.70	4.76	1.76	38.70	26.00	0.43	0.00	1.60	18.07
			1.80	3.89	1.79	46.20	22.69	0.04	0.00	1.65	15.00
			1.90	2.93	2.15	54.59	19.66	0.00	0.00	1.79	11.38
			2.00	2.37	2.32	60.72	17.54	0.00	0.00	1.94	8.73
			2.10	2.24	2.33	66.31	15.65	0.00	0.00	1.98	6.32
			2.20	4.87	3.07	74.99	12.74	0.00	0.00	1.16	2.32
			2.50	45.61	1.43	85.32	9.90	0.00	0.00	1.59	1.01
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

b038202	djusted Ash-Density Fractional da										
11	FRACT	RD_1	RD_2	YIELD	MOIST	ASH	/OLATILES	SWELL	ROGA	SULPHUI	CV
			1.35	6.26	2.39	5.82	35.59	4.78	67.00	0.86	30.50
			1.40	6.30	2.23	11.36	35.18	4.06	63.00	0.90	28.52
			1.50	11.67	1.86	20.08	32.47	2.69	42.00	1.12	25.37
			1.55	0.62	1.84	23.89	31.72	2.16	31.00	0.00	23.82
			1.60	8.07	1.71	29.32	29.11	1.55	12.00	1.12	21.86
			1.70	6.04	1.62	37.56	26.12	0.79	0.00	1.08	18.60
			1.80	4.11	1.73	44.39	23.51	0.54	0.00	1.41	15.83
			1.90	2.98	1.87	52.23	20.44	0.00	0.00	1.51	12.55
			2.00	2.66	1.93	58.86	18.09	0.00	0.00	1.50	9.75
			2.10	2.92	1.91	65.17	15.81	0.00	0.00	1.34	7.03
			2.20	5.82	2.06	72.42	13.18	0.00	0.00	0.80	3.75
			2.50	42.54	1.18	83.28	10.40	0.00	0.00	0.97	1.09

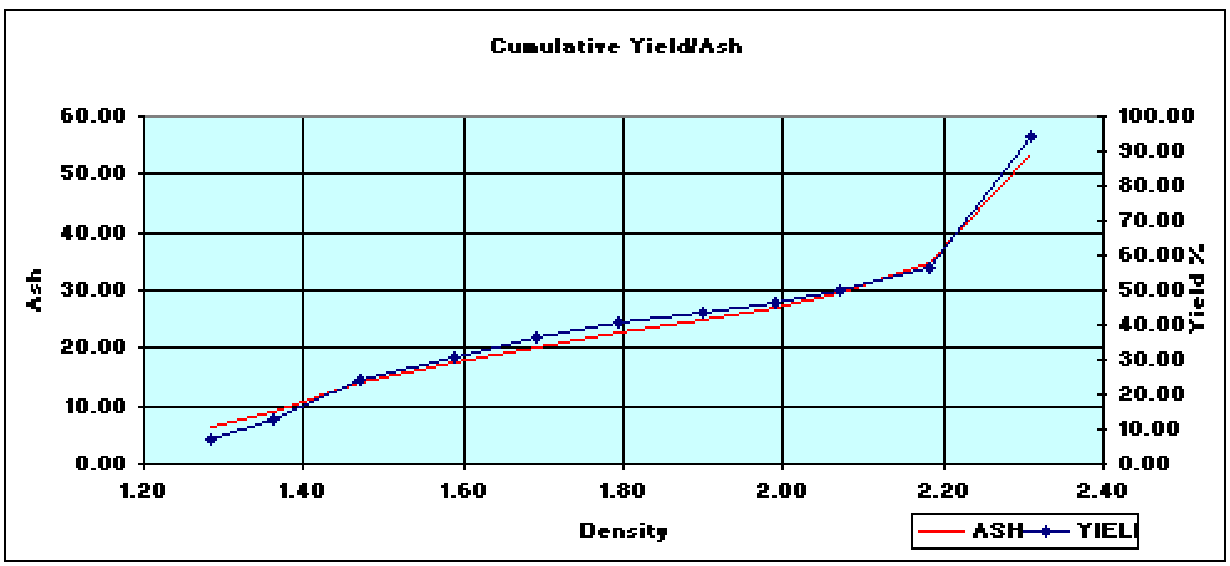
b038408	djusted Ash-Density Fractional da										
51	FRACT	RD_1	RD_2	YIELD	MOIST	ASH	/OLATILES	SWELL	ROGA	SULPHUI	CV
			1.35	7.15	2.12	6.52	35.56	5.11	65.00	0.88	30.25
			1.40	5.89	1.90	12.92	34.43	4.18	57.00	0.99	27.95
			1.50	11.35	1.78	20.68	31.75	2.15	26.00	1.09	25.05
			1.60	7.79	1.76	29.88	28.24	1.28	2.00	1.21	21.49
			1.70	5.68	1.84	37.56	25.06	0.41	0.00	1.31	18.39
			1.80	4.11	1.91	44.98	22.08	0.02	0.00	1.23	15.33
			1.90	3.09	2.03	52.38	20.27	0.00	0.00	1.40	12.16
			2.00	2.85	2.11	59.24	17.86	0.00	0.00	1.32	9.17
			2.10	3.20	2.15	65.44	15.60	0.00	0.00	1.25	6.44
			2.20	7.40	2.41	73.75	12.56	0.00	0.00	0.60	2.61
			2.50	41.50	1.67	83.87	10.05	0.00	0.00	0.93	0.63
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

b048307	djusted Ash-Density Fractional da										
11	FRACT	RD_1	RD_2	YIELD	MOIST	ASH	/OLATILES	SWELL	ROGA	SULPHUI	CV
			1.35	5.93	2.04	6.24	36.15	4.99	60.00	1.00	30.37
			1.40	4.26	1.88	10.67	35.43	4.06	54.00	1.03	28.80
			1.50	9.15	1.75	18.68	32.71	2.19	22.00	1.04	25.83
			1.60	6.21	1.61	27.34	30.00	1.22	4.00	0.93	22.53
			1.70	4.96	1.53	35.00	27.23	0.43	0.00	1.07	19.55
			1.80	4.39	1.68	43.04	23.82	0.02	0.00	0.92	16.24
			1.90	4.34	1.84	52.16	20.36	0.00	0.00	0.81	12.44
			2.00	5.07	1.97	58.77	17.87	0.00	0.00	0.66	9.59
			2.10	6.25	2.07	64.71	15.76	0.00	0.00	0.57	6.96
			2.20	13.28	2.13	72.94	13.23	0.00	0.00	0.39	3.25
			2.50	36.17	1.28	79.90	12.12	0.00	0.00	0.90	0.76
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

THE COMPOSITE WASH TABLE FOR FOUR BLAST BLOCKS WITH THEIR CONTRIBUTORY RATIOS TAKEN INTO ACCOUNT

Planned Mix to SSCC Plant									
Composite Fractional Table									
RD_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	ULPHUI	CV	PHOS
1.28	6.83	2.16	6.30	35.55	5.02	64.54	0.92	30.01	0.00
1.36	5.78	1.95	12.13	34.64	4.21	58.06	1.00	27.93	0.00
1.47	11.44	1.78	20.14	31.96	2.48	31.48	1.13	24.36	0.00
1.59	6.57	1.74	28.81	28.83	1.26	5.13	1.09	21.61	0.00
1.69	5.57	1.75	36.29	25.74	0.54	1.32	1.32	18.63	0.00
1.79	4.25	1.80	43.82	22.65	0.11	0.00	1.27	15.55	0.00
1.90	3.26	1.98	51.53	20.27	0.06	0.00	1.43	12.27	0.00
1.99	2.96	2.10	58.21	17.88	0.00	0.00	1.42	9.38	0.00
2.07	3.19	2.14	64.21	15.75	0.00	0.00	1.38	6.76	0.00
2.18	6.82	2.47	72.30	12.91	0.00	0.00	0.80	3.06	0.00
2.31	37.64	1.59	81.71	10.48	0.00	0.00	1.07	1.08	0.00

Cumulative Table									
RD_2	YIELD	MOIST	ASH	VOLATILES	SWELL	ROGA	ULPHUI	CV	PHOS
1.28	6.83	2.16	6.30	35.55	5.02	64.54	0.92	30.01	0.00
1.36	12.61	2.06	8.97	35.13	4.65	61.57	0.96	29.06	0.00
1.47	24.05	1.93	14.28	33.62	3.62	47.26	1.04	27.11	0.00
1.59	30.62	1.89	17.40	32.60	3.11	38.22	1.05	25.93	0.00
1.69	36.19	1.87	20.31	31.54	2.72	32.54	1.09	24.81	0.00
1.79	40.44	1.86	22.78	30.61	2.44	29.12	1.11	23.83	0.00
1.90	43.70	1.87	24.93	29.83	2.26	26.94	1.13	22.97	0.00
1.99	46.66	1.88	27.04	29.08	2.12	25.23	1.15	22.11	0.00
2.07	49.85	1.90	29.42	28.22	1.98	23.62	1.17	21.13	0.00
2.18	56.67	1.97	34.58	26.38	1.75	20.78	1.12	18.95	0.00
2.31	94.31	1.82	53.39	20.04	1.05	12.48	1.10	11.82	0.00



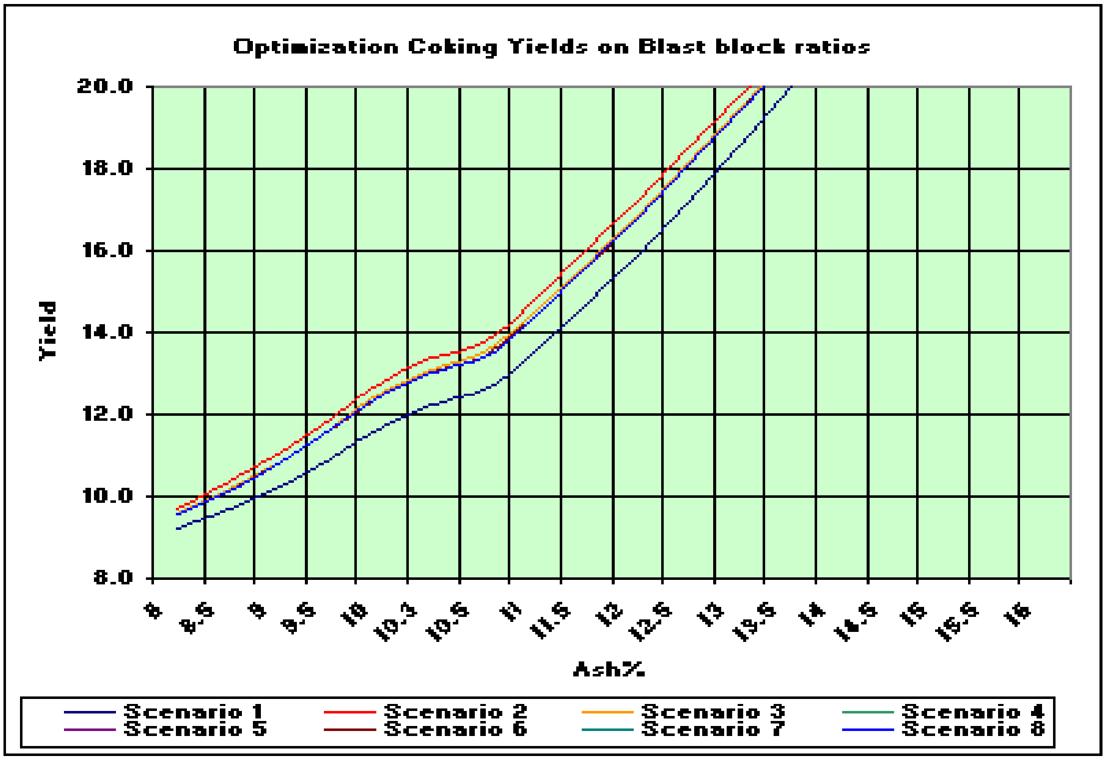
THE DATA USED FOR WEEKLY PLANNED RATIOS

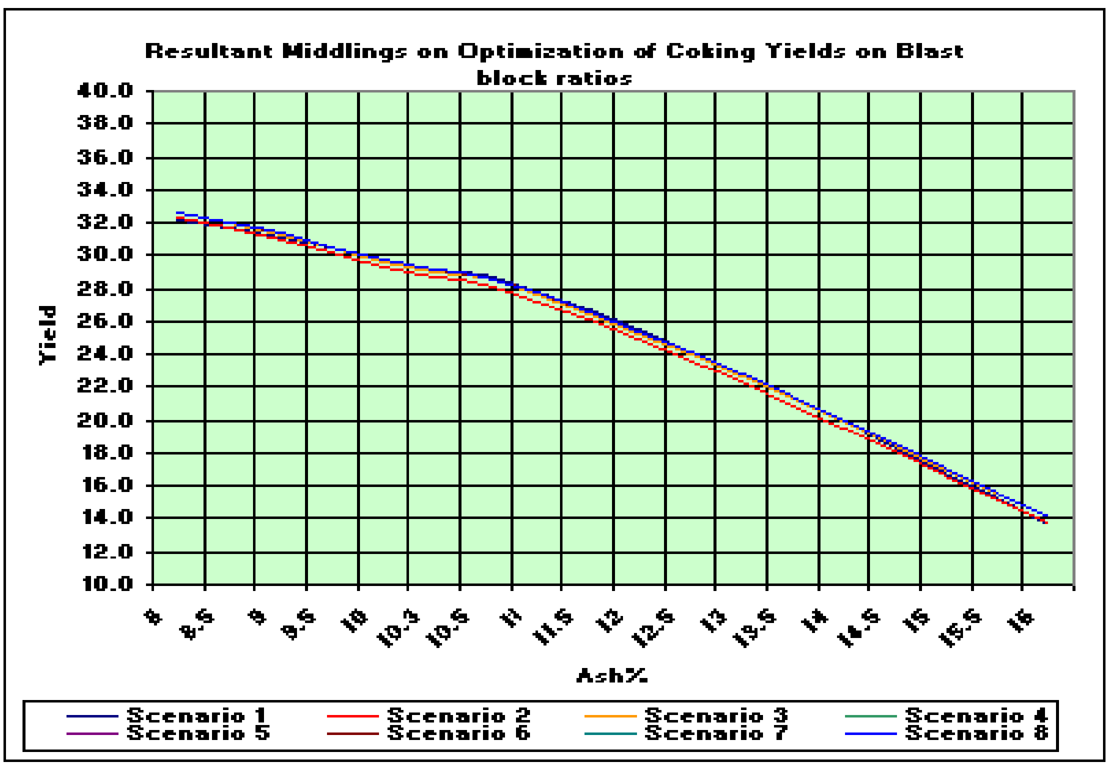
Week Ending:	10/7/2007									
	Blocks	Actual Ratio	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario 8
1	b028406		26.00	30.4	18.9	25	25	25	25	25
2	b038202		11	35.4	33	30	30	30	30	30
3	b038408		51	34.1	48	45	45	45	45	45
4	b048307		11							
5	0									
6	0									
7	0									
8	0									

Blast Block Blend in Use			Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario 8
Ash Product	Coking Yield	Cut Rd	Coking Yield	Coking Yield	Coking Yield	Coking Yield	Coking Yield	Coking Yield	Coking Yield	Coking Yield
8	9.212	1.317	9.212	9.696	9.558	9.552	9.552	9.552	9.552	9.552
8.5	9.680	1.324	9.680	10.352	10.177	10.151	10.151	10.151	10.151	10.151
9	10.246	1.333	10.246	11.087	10.879	10.835	10.835	10.835	10.835	10.835
9.5	10.917	1.342	10.917	11.905	11.665	11.606	11.606	11.606	11.606	11.606
10	11.694	1.353	11.694	12.804	12.537	12.466	12.466	12.466	12.466	12.466
10.3	12.212	1.360	12.212	13.383	13.101	13.025	13.025	13.025	13.025	13.025
10.5	12.580	1.364	12.580	13.785	13.494	13.414	13.414	13.414	13.414	13.414
11	13.573	1.377	13.573	14.844	14.534	14.449	14.449	14.449	14.449	14.449
11.5	14.672	1.390	14.672	15.980	15.654	15.568	15.568	15.568	15.568	15.568
12	15.870	1.404	15.870	17.185	16.849	16.765	16.765	16.765	16.765	16.765
12.5	17.160	1.418	17.160	18.455	18.112	18.034	18.034	18.034	18.034	18.034
13	18.531	1.434	18.531	19.781	19.436	19.367	19.367	19.367	19.367	19.367
13.5	19.972	1.450	19.972	21.155	20.812	20.754	20.754	20.754	20.754	20.754
14	21.468	1.467	21.468	22.567	22.229	22.186	22.186	22.186	22.186	22.186
14.5	23.004	1.484	23.004	24.006	23.677	23.649	23.649	23.649	23.649	23.649
15	24.563	1.502	24.563	25.461	25.143	25.133	25.133	25.133	25.133	25.133
15.5	26.128	1.520	26.128	26.919	26.614	26.623	26.623	26.623	26.623	26.623
16	27.682	1.538	27.682	28.368	28.079	28.107	28.107	28.107	28.107	28.107

Blast Block Blend in Use			Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario 8
Coke Ash	Middlings Yield	Middlings Rd	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield
8	32.155	1.938	32.155	32.379	32.586	32.618	32.618	32.618	32.618	32.618
8.5	31.687	1.945	31.687	31.723	31.967	32.019	32.019	32.019	32.019	32.019
9	31.121	1.954	31.121	30.987	31.266	31.335	31.335	31.335	31.335	31.335
9.5	30.450	1.964	30.450	30.170	30.479	30.564	30.564	30.564	30.564	30.564
10	29.673	1.976	29.673	29.271	29.607	29.704	29.704	29.704	29.704	29.704
10.3	29.155	1.985	29.155	28.692	29.043	29.145	29.145	29.145	29.145	29.145
10.5	28.787	1.990	28.787	28.290	28.650	28.756	28.756	28.756	28.756	28.756
11	27.794	2.007	27.794	27.230	27.610	27.721	27.721	27.721	27.721	27.721
11.5	26.695	2.025	26.695	26.095	26.490	26.602	26.602	26.602	26.602	26.602
12	25.497	2.047	25.497	24.890	25.295	25.405	25.405	25.405	25.405	25.405
12.5	24.207	2.070	24.207	23.620	24.032	24.136	24.136	24.136	24.136	24.136
13	22.836	2.097	22.836	22.293	22.708	22.803	22.803	22.803	22.803	22.803
13.5	21.395	2.127	21.395	20.919	21.332	21.416	21.416	21.416	21.416	21.416
14	19.899	2.160	19.899	19.507	19.915	19.984	19.984	19.984	19.984	19.984
14.5	18.363	2.196	18.363	18.068	18.467	18.521	18.521	18.521	18.521	18.521
15	16.804	2.236	16.804	16.614	17.002	17.037	17.037	17.037	17.037	17.037
15.5	15.239	2.281	15.239	15.156	15.530	15.547	15.547	15.547	15.547	15.547
16	13.684	2.330	13.684	13.707	14.065	14.063	14.063	14.063	14.063	14.063

WEEK PLANNING PLOTS OF YIELDS FOR SSCC AND MIDDLING AT VARIOUS ASH CONTROLS





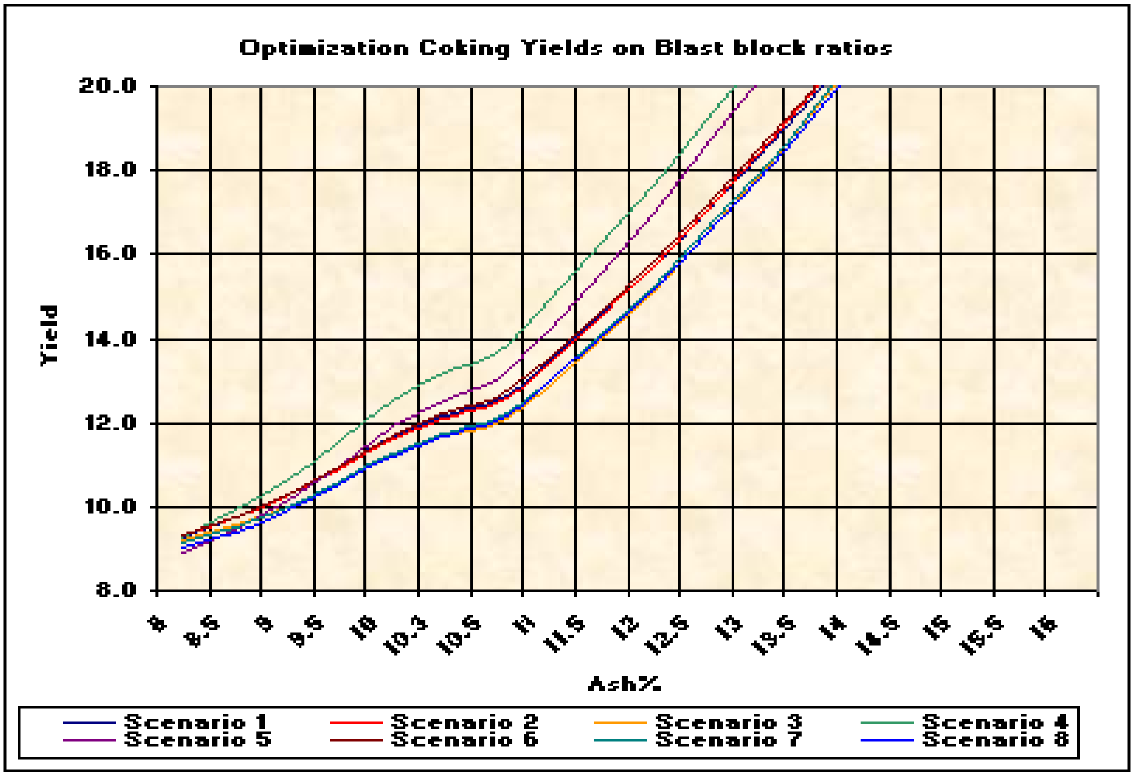
THE SAME DATA USED IN AN OPTIMIZATION ROLE

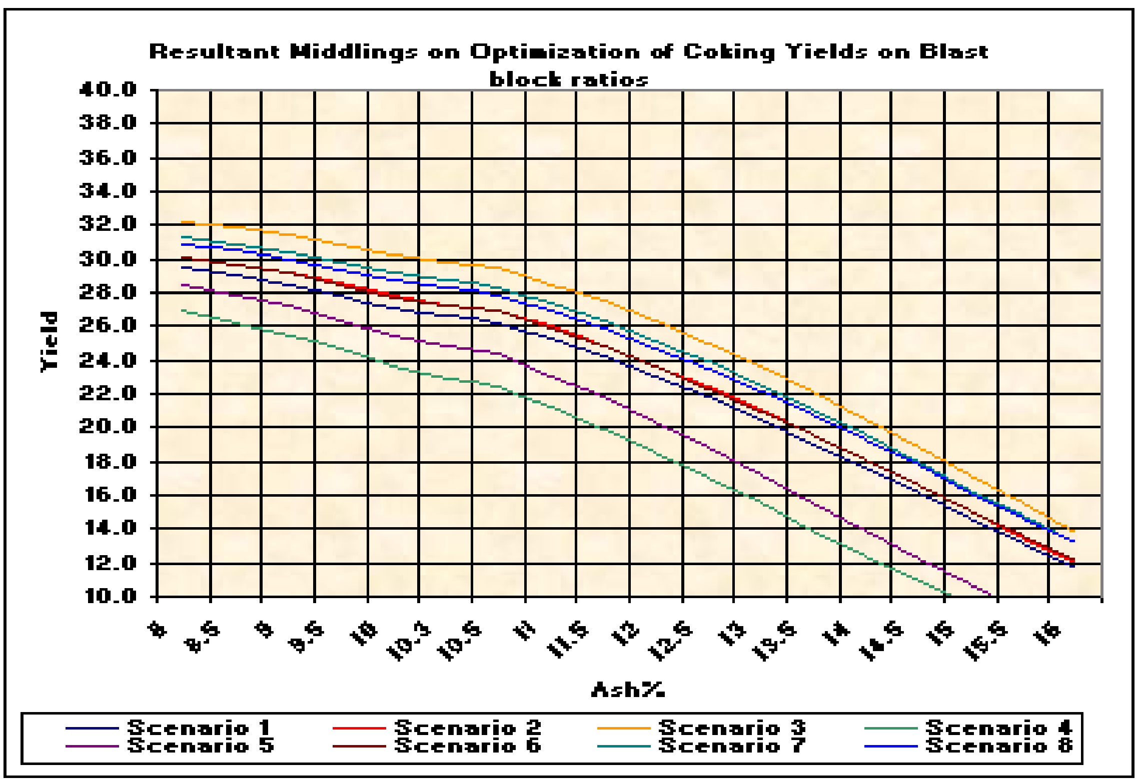
Week Ending:										
	Blocks	Actual Rati	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario 8
1	b028406		30	40	50	40	40	40	40	30
2	b038202		30	30	50	20	40	20	40	40
3	b038408		40	30		30	10			
4	b048307							40	20	30
5	0									
6	0									
7	0									
8	0									

Blast Block Blend in Use			Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario 8
Ash Product	Coking Yield	Cut Rd	Coking Yield	Coking Yield	Coking Yield	Coking Yield	Coking Yield	Coking Yield	Coking Yield	Coking Yield
8	9.212	1.317	9.293	9.351	9.215	9.278	8.914	9.298	9.133	9.007
8.5	9.680	1.324	9.729	9.758	9.546	9.901	9.462	9.745	9.508	9.406
9	10.246	1.333	10.265	10.270	9.983	10.651	10.141	10.292	9.986	9.903
9.5	10.917	1.342	10.906	10.892	10.532	11.530	10.955	10.944	10.572	10.504
10	11.694	1.353	11.656	11.627	11.200	12.536	11.908	11.706	11.274	11.216
10.3	12.212	1.360	12.159	12.125	11.660	13.199	12.546	12.217	11.751	11.697
10.5	12.580	1.364	12.516	12.479	11.992	13.665	12.998	12.579	12.093	12.040
11	13.573	1.377	13.484	13.448	12.910	14.906	14.219	13.561	13.033	12.978
11.5	14.672	1.390	14.558	14.529	13.957	16.246	15.560	14.649	14.091	14.028
12	15.870	1.404	15.729	15.718	15.128	17.668	17.007	15.836	15.263	15.184
12.5	17.160	1.418	16.990	17.004	16.418	19.152	18.541	17.112	16.541	16.439
13	18.531	1.434	18.327	18.376	17.818	20.674	20.140	18.467	17.915	17.782
13.5	19.972	1.450	19.727	19.819	19.315	22.212	21.778	19.886	19.372	19.200
14	21.468	1.467	21.173	21.317	20.893	23.740	23.429	21.353	20.895	20.678
14.5	23.004	1.484	22.648	22.850	22.533	25.235	25.067	22.851	22.466	22.200
15	24.563	1.502	24.135	24.400	24.216	26.675	26.664	24.362	24.067	23.746
15.5	26.128	1.520	25.614	25.947	25.919	28.039	28.196	25.869	25.676	25.298
16	27.682	1.538	27.069	27.470	27.619	29.310	29.640	27.352	27.274	26.838

Blast Block Blend in Use			Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario	Scenario 8
Coke Ash	Middlings Yield	Middlings R	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield
8	32.155	1.938	29.477	30.091	32.218	26.890	28.428	30.163	31.295	30.919
8.5	31.687	1.945	29.041	29.684	31.887	26.267	27.879	29.717	30.919	30.521
9	31.121	1.954	28.504	29.172	31.450	25.517	27.201	29.170	30.442	30.024
9.5	30.450	1.964	27.863	28.550	30.901	24.638	26.387	28.517	29.855	29.422
10	29.673	1.976	27.114	27.815	30.233	23.632	25.434	27.755	29.154	28.710
10.3	29.155	1.985	26.611	27.317	29.773	22.969	24.796	27.245	28.676	28.229
10.5	28.787	1.990	26.254	26.962	29.441	22.503	24.344	26.882	28.334	27.886
11	27.794	2.007	25.286	25.994	28.522	21.262	23.123	25.900	27.395	26.948
11.5	26.695	2.025	24.212	24.913	27.476	19.922	21.782	24.813	26.337	25.898
12	25.497	2.047	23.041	23.724	26.305	18.500	20.335	23.626	25.165	24.742
12.5	24.207	2.070	21.780	22.438	25.014	17.016	18.801	22.349	23.887	23.487
13	22.836	2.097	20.443	21.066	23.614	15.494	17.202	20.994	22.512	22.144
13.5	21.395	2.127	19.043	19.623	22.118	13.956	15.564	19.576	21.056	20.726
14	19.899	2.160	17.597	18.125	20.540	12.428	13.913	18.109	19.533	19.248
14.5	18.363	2.196	16.122	16.592	18.900	10.933	12.275	16.611	17.961	17.727
15	16.804	2.236	14.635	15.042	17.217	9.494	10.678	15.099	16.361	16.180
15.5	15.239	2.281	13.156	13.495	15.514	8.129	9.146	13.593	14.752	14.628
16	13.684	2.330	11.701	11.972	13.813	6.858	7.702	12.109	13.154	13.088

PLOTS DEPICTING OPTIMIZATION RATIOS





THE AS MINED RATIOS DELIVERED TO THE PLANT

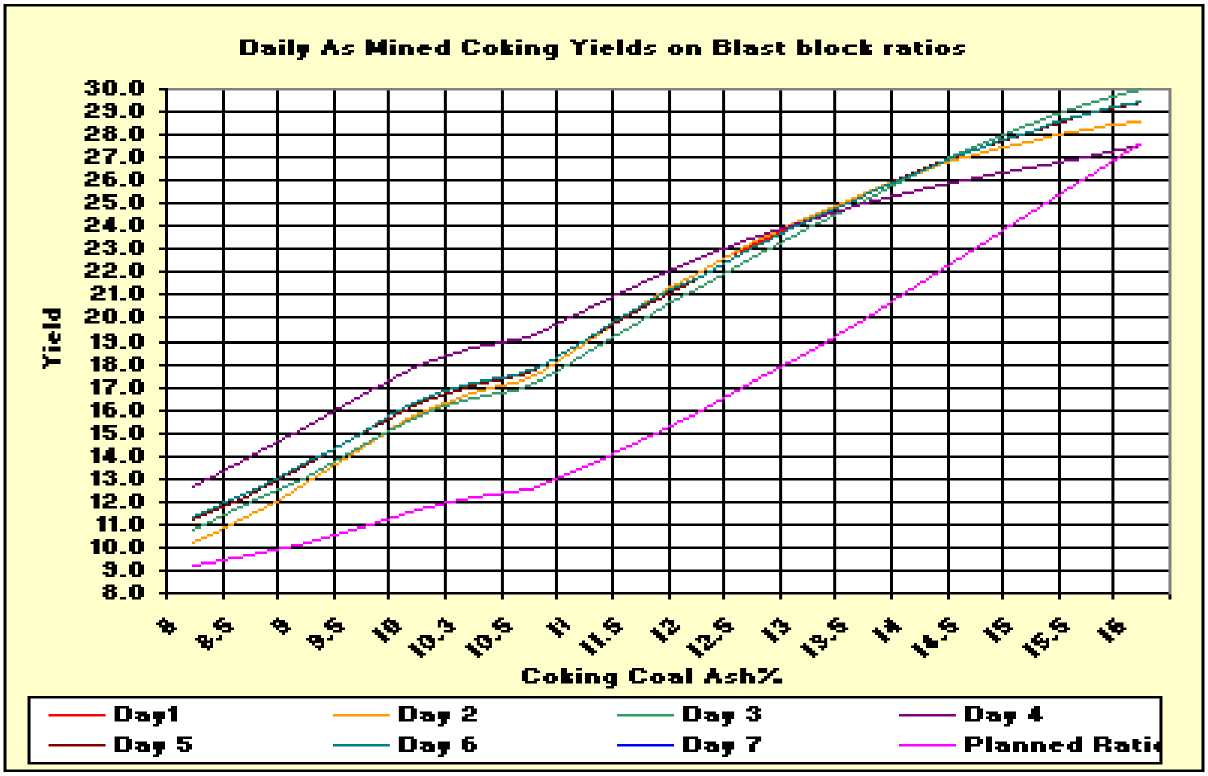
Week Ending: 20080524

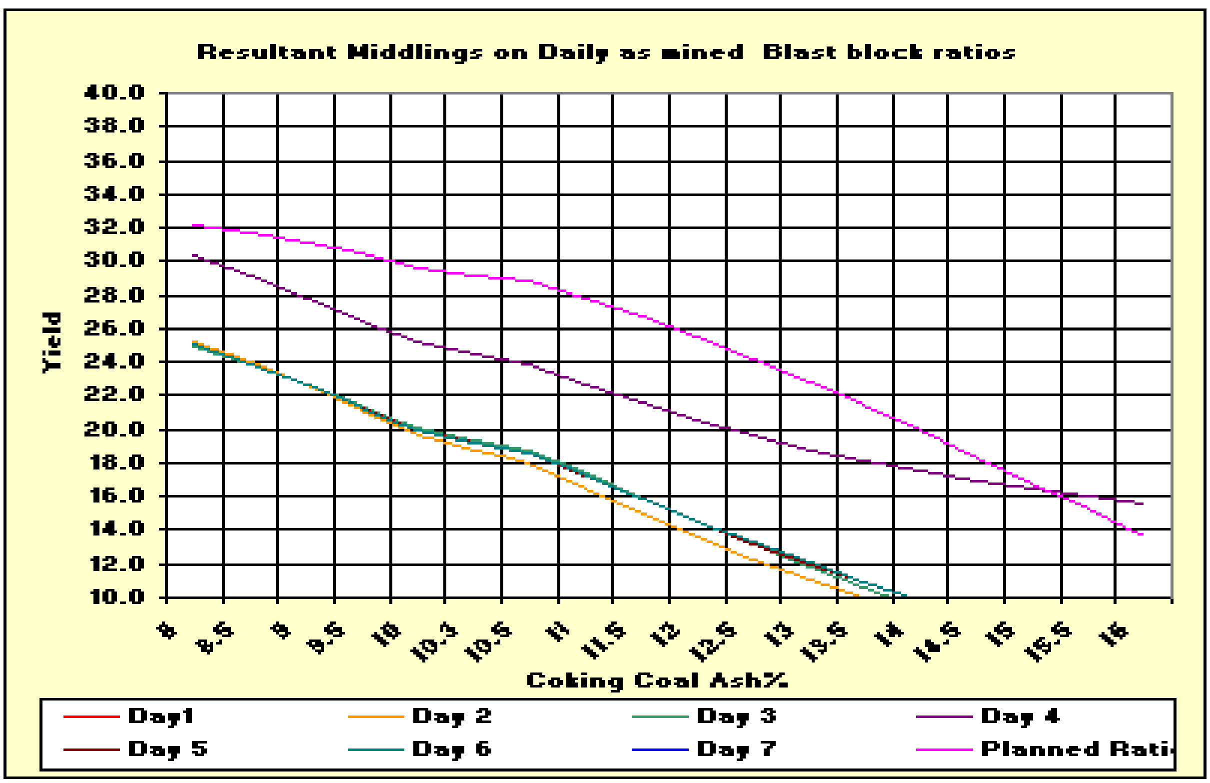
	Blocks	Planned Ratio's		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
1	b02vloer	7.20		7.20	7.20	7.00			
2	b038202	6.20		6.30	6.20	33.00	34.00	33.00	35.00
3	b038308	46.04		46.05	46.04	34.00	26.00	37.00	35.00
4	b038201	7.77		7.70	7.77				
5	b048307	13.27		13.27	13.27				
6	b028406	10.04		10.05	10.04	18.00	36.00	25.00	27.00
7	b038301	9.01		9.43	9.01				
8	b048308	0.00			0.00	8.00	4.00	5.00	3.00

Blast Block Blend in Use				Day1	Day 2	Day 3	Day 4	Day 5	Day 6
Ash Produc	Coking Yield	Cut Rd	Coking Yield	Coking Yield	Coking Yield	Coking Yield	Coking Yield	Coking Yield	Coking Yield
8	9.212	1.32		10.229	10.230	10.818	12.685	11.184	11.301
8.5	9.680	1.32		11.477	11.479	11.929	13.976	12.363	12.476
9	10.246	1.33		12.847	12.850	13.122	15.293	13.614	13.719
9.5	10.917	1.34		14.312	14.316	14.385	16.617	14.924	15.017
10	11.694	1.35		15.841	15.846	15.707	17.926	16.278	16.355
10.3	12.212	1.36		16.774	16.779	16.521	18.694	17.104	17.170
10.5	12.580	1.36		17.398	17.403	17.072	19.196	17.658	17.717
11	13.573	1.38		18.947	18.952	18.464	20.406	19.044	19.085
11.5	14.672	1.39		20.451	20.456	19.865	21.536	20.416	20.440
12	15.870	1.40		21.878	21.882	21.257	22.567	21.756	21.764
12.5	17.160	1.42		23.199	23.201	22.620	23.489	23.042	23.037
13	18.531	1.43		24.393	24.392	23.936	24.295	24.258	24.243
13.5	19.972	1.45		25.443	25.440	25.188	24.989	25.388	25.366
14	21.468	1.47		26.344	26.339	26.360	25.583	26.420	26.394
14.5	23.004	1.48		27.096	27.089	27.440	26.098	27.346	27.321
15	24.563	1.50		27.711	27.700	28.418	26.568	28.163	28.141
15.5	26.128	1.52		28.203	28.191	29.290	27.033	28.873	28.857
16	27.682	1.54		28.598	28.584	30.055	27.544	29.485	29.476

Blast Block Blend in Use				Day1	Day 2	Day 3	Day 4	Day 5	Day 6
Cake Ash	Middlings Yield	Middlings I	Middlings	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield	Middlings Yield
8	32.155	1.94		25.216	25.225	24.999	30.407	25.041	25.006
8.5	31.687	1.95		23.968	23.976	23.887	29.116	23.862	23.831
9	31.121	1.95		22.598	22.605	22.695	27.799	22.611	22.588
9.5	30.450	1.96		21.133	21.139	21.432	26.475	21.300	21.290
10	29.673	1.98		19.604	19.610	20.110	25.167	19.947	19.952
10.3	29.155	1.98		18.671	18.676	19.295	24.398	19.121	19.137
10.5	28.787	1.99		18.047	18.052	18.745	23.896	18.567	18.590
11	27.794	2.01		16.498	16.504	17.353	22.686	17.181	17.222
11.5	26.695	2.03		14.994	15.000	15.951	21.557	15.809	15.867
12	25.497	2.05		13.567	13.574	14.560	20.525	14.469	14.543
12.5	24.207	2.07		12.246	12.254	13.197	19.604	13.183	13.270
13	22.836	2.10		11.052	11.063	11.881	18.798	11.967	12.064
13.5	21.395	2.13		10.002	10.015	10.629	18.104	10.837	10.941
14	19.899	2.16		9.101	9.117	9.457	17.510	9.805	9.912
14.5	18.363	2.20		8.349	8.367	8.377	16.994	8.879	8.986
15	16.804	2.24		7.734	7.755	7.398	16.524	8.062	8.166
15.5	15.239	2.28		7.242	7.264	6.526	16.059	7.352	7.450
16	13.684	2.33		6.847	6.871	5.762	15.549	6.740	6.830

PLOTS DEPICTING AS MINED RATIOS


Daily As Mined Coking Yields on Blast block ratios
Yield
30.0
29.0
28.0
27.0
26.0
25.0
24.0
23.0
22.0
21.0
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
8
8.5
9
9.5
10
10.3
10.6
11
11.5
12
12.5
13
13.5
14
14.5
15
15.5
16
Coking Coal Ash%
Day1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Planned Rati


Resultant Middlings on Daily as mined Blast block ratios
Yield
40.0
38.0
36.0
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8
8.5
9
9.5
10
10.3
10.6
11
11.5
12
12.5
13
13.5
14
14.5
15
15.5
16
Coking Coal Ash%
Day1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Planned Rati

APPENDIX C

DAILY RATIO CHANGES AND LABORATORY REPORTED PERIOD ASH CONTROL VALUES.

Utilizing the spreadsheet evaluation technique as set out in Appendix A and applying it to as mined ratios over a week coupled with periodical laboratory ash values illustrates the differences one can expect regarding the behaviour of the raw feedstock within the overall process.

The first screenshot displayed portrays the format of the laboratory information available for use in hourly analysis of samples taken from the production stream, in this case samples from area 04 in the GG1 plant.

The spot ash values obtained are on a dry basis and the shift mean is merely an arithmetical average of the samples taken, not a weighted average based on masses over that particular period, thus a small discrepancy may already have been introduced.

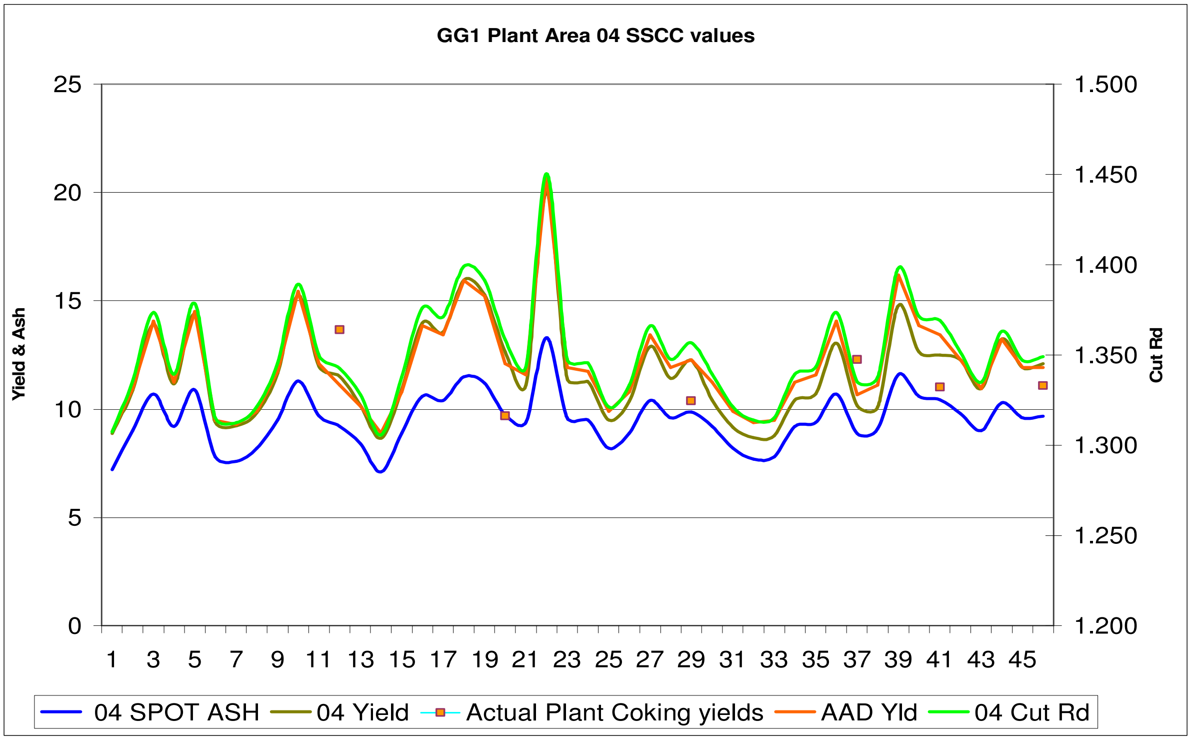
Secondly, hourly analysis are supposed to be the norm, this however is not the case in this particular week, making the comparison or verification of yields obtained at specific ash values more difficult to determine.

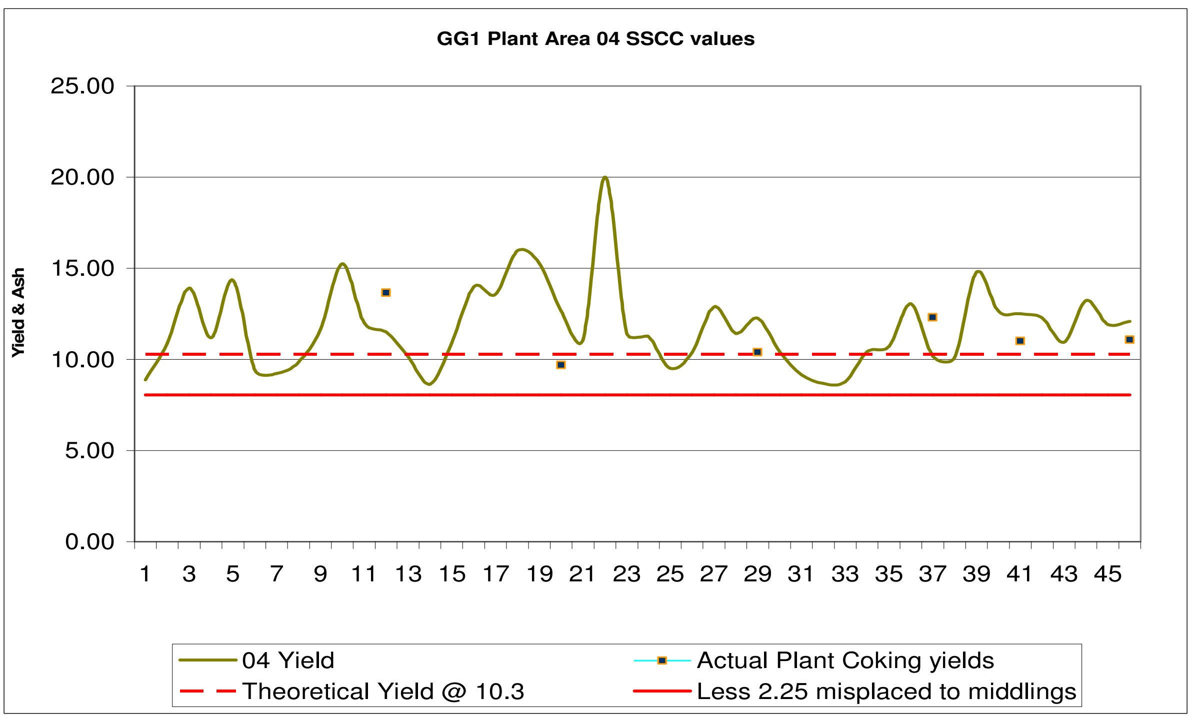
The second set of values taken from analysis of Area 07 in the same plant and representative of the final product stream appear more satisfactory although there are also analysis missing.

Department: Production
Sample Type: A04_435_A (A04 CC module 435 A)
Method: SPOT ASH
Report: Horizontal
Period: 6/29/2008 7/6/2008

A04_435_A (A04 CC module 435 A)

Sample Id	Shift	Date Time	SPOT ASH %ASH(DB)	Reference No	Comments
A04_435_A_080630_0100		6/30/2008 1:00	7.2		
A04_435_A_080630_0300		6/30/2008 3:00	9		
A04_435_A_080630_0700	M	6/30/2008 7:00	10.7		
A04_435_A_080630_0900	M	6/30/2008 9:00	9.2		
A04_435_A_080630_1100	M	6/30/2008 11:00	10.9		
A04_435_A_080630_1300	M	6/30/2008 13:00	7.8		
A04_435_A_080630_1500		6/30/2008 15:00	7.6		
A04_435_A_080630_1800	A	6/30/2008 18:00	8.2		
A04_435_A_080630_1900		6/30/2008 19:00	9.5		
A04_435_A_080630_2000	N	6/30/2008 20:00	11.3		
A04_435_A_080630_2300	N	6/30/2008 23:00	9.7		
		Daily Shift Mean	**9.19**		
A04_435_A_080701_0100	N	7/1/2008 1:00	8.4		
A04_435_A_080701_0300	N	7/1/2008 3:00	7.1		
A04_435_A_080701_1500	A	7/1/2008 15:00	8.9		
A04_435_A_080701_1700		7/1/2008 17:00	10.6		
A04_435_A_080701_1900		7/1/2008 19:00	10.4		
A04_435_A_080701_2100		7/1/2008 21:00	11.5		
A04_435_A_080701_2300	N	7/1/2008 23:00	11.2		
		Daily Shift Mean	**9.73**		
A04_435_A_080702_0100	N	7/2/2008 1:00	9.4		
A04_435_A_080702_0300	N	7/2/2008 3:00	13.3		
A04_435_A_080702_0700	M	7/2/2008 7:00	9.6		
A04_435_A_080702_0900	M	7/2/2008 9:00	9.5		
A04_435_A_080702_1100	M	7/2/2008 11:00	8.2		
A04_435_A_080702_1500		7/2/2008 15:00	8.9		
A04_435_A_080702_1700		7/2/2008 17:00	10.4		
A04_435_A_080702_2100		7/2/2008 21:00	9.6		
		Daily Shift Mean	**9.86**		
A04_435_A_080703_0100	N	7/3/2008 1:00	9.2		
A04_435_A_080703_0700	M	7/3/2008 7:00	8.2		
A04_435_A_080703_0900	M	7/3/2008 9:00	7.7		
A04_435_A_080703_1100	M	7/3/2008 11:00	7.8		
A04_435_A_080703_1500		7/3/2008 15:00	9.2		
A04_435_A_080703_1700		7/3/2008 17:00	9.4		
A04_435_A_080703_1900		7/3/2008 19:00	10.7		
		Daily Shift Mean	**8.89**		
A04_435_A_080704_1500		7/4/2008 15:00	9.1		
A04_435_A_080704_1700		7/4/2008 17:00	11.6		
A04_435_A_080704_1900		7/4/2008 19:00	10.6		
		Daily Shift Mean	**10.43**		
A04_435_A_080705_1100		7/5/2008 11:00	9.8		
A04_435_A_080705_1300		7/5/2008 13:00	9		
A04_435_A_080705_1700		7/5/2008 17:00	10.3		
A04_435_A_080705_1900		7/5/2008 19:00	9.6		
		Daily Shift Mean	**9.68**		


GG1 Plant Area 04 SSCC values
Yield & Ash
Cut Rd
25
20
15
10
5
0
1.500
1.450
1.400
1.350
1.300
1.250
1.200
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45
04 SPOT ASH
04 Yield
Actual Plant Coking yields
AAD Yld
04 Cut Rd


GG1 Plant Area 04 SSCC values
Yield & Ash
25.00
20.00
15.00
10.00
5.00
0.00
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45
04 Yield
Actual Plant Coking yields
Theoretical Yield @ 10.3
Less 2.25 misplaced to middlings

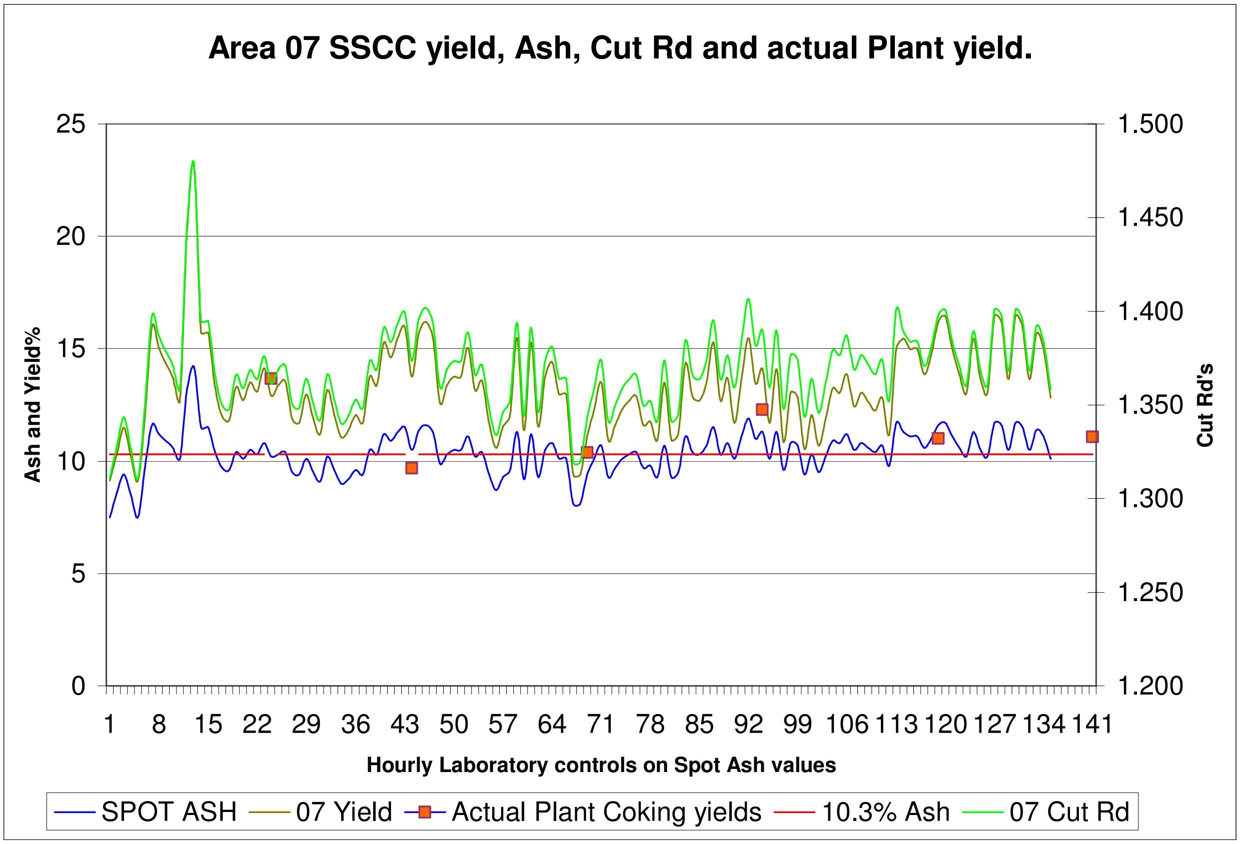
Area 07 Date and Time	SPOT ASH	Cut Rd	Yield
6/30/2008 0:00	7.5	1.311	9.135
6/30/2008 1:00	8.6	1.328	10.329
6/30/2008 2:00	9.4	1.344	11.491
6/30/2008 3:00	8.5	1.326	10.201
6/30/2008 4:00	7.5	1.311	9.135
6/30/2008 5:00	9.7	1.350	11.992
6/30/2008 6:00	11.6	1.398	15.974
6/30/2008 7:00	11.2	1.387	15.025
6/30/2008 8:00	10.9	1.379	14.351
6/30/2008 9:00	10.6	1.371	13.709
6/30/2008 10:00	10.1	1.359	12.716
6/30/2008 11:00	13.2	1.446	20.249
6/30/2008 12:00	14.2	1.479	23.192
6/30/2008 13:00	11.5	1.395	15.732
6/30/2008 14:00	11.5	1.395	15.732
6/30/2008 15:00	10.4	1.366	13.300
6/30/2008 16:00	9.7	1.350	11.992
6/30/2008 18:00	9.6	1.348	11.821
6/30/2008 19:00	10.4	1.366	13.300
6/30/2008 20:00	10.1	1.359	12.716
6/30/2008 21:00	10.5	1.369	13.503
6/30/2008 22:00	10.3	1.364	13.102
6/30/2008 23:00	10.8	1.376	14.133
	10.34	1.368	13.570
7/1/2008 0:00	10.2	1.361	12.907
7/1/2008 1:00	10.3	1.369	13.366

7/1/2008 2:00		**10.4**	**1.371**	**13.566**
7/1/2008 3:00		**9.5**	**1.351**	**11.882**
7/1/2008 4:00		**9.4**	**1.348**	**11.711**
7/1/2008 5:00		**10.1**	**1.364**	**12.976**
7/1/2008 6:00		**9.5**	**1.351**	**11.882**
7/1/2008 12:00		**9.1**	**1.342**	**11.217**
7/1/2008 13:00		**10.2**	**1.366**	**13.169**
7/1/2008 14:00		**9.6**	**1.353**	**12.056**
7/1/2008 15:00		**9**	**1.340**	**11.059**
7/1/2008 16:00		**9.2**	**1.344**	**11.379**
7/1/2008 17:00		**9.6**	**1.353**	**12.056**
7/1/2008 18:00		**9.4**	**1.348**	**11.711**
7/1/2008 19:00		**10.5**	**1.374**	**13.769**
7/1/2008 20:00		**10.3**	**1.369**	**13.366**
7/1/2008 21:00		**11.2**	**1.391**	**15.275**
7/1/2008 22:00		**10.9**	**1.384**	**14.611**
7/1/2008 23:00		**11.3**	**1.394**	**15.502**
		9.98	**1.362**	**12.814**
7/2/2008 0:00		**11.5**	**1.399**	**15.965**
7/2/2008 1:00		10.5	**1.374**	**13.769**
7/2/2008 2:00		11.4	**1.397**	**15.732**
7/2/2008 3:00		11.6	**1.402**	**16.200**
7/2/2008 4:00		11.3	**1.394**	**15.502**
7/2/2008 5:00		9.9	**1.359**	**12.598**
7/2/2008 6:00		10.3	**1.369**	**13.366**
7/2/2008 7:00		10.5	**1.374**	**13.769**
7/2/2008 8:00		10.5	**1.374**	**13.769**
7/2/2008 9:00		11.1	**1.389**	**15.051**
7/2/2008 10:00		10.2	**1.366**	**13.169**

7/2/2008 11:00		10.4	**1.371**	**13.566**
7/2/2008 12:00		9.4	**1.348**	**11.711**
7/2/2008 13:00		8.7	**1.334**	**10.604**
7/2/2008 15:00		9.3	**1.346**	**11.543**
7/2/2008 16:00		9.6	**1.353**	**12.056**
7/2/2008 17:00		11.3	**1.394**	**15.502**
7/2/2008 18:00		9.2	**1.344**	**11.379**
7/2/2008 19:00		11.2	**1.391**	**15.275**
7/2/2008 20:00		9.3	**1.346**	**11.543**
7/2/2008 21:00		10.5	**1.374**	**13.769**
7/2/2008 22:00		10.8	**1.381**	**14.396**
7/2/2008 23:00		10.1	**1.364**	**12.976**
7/3/2008 0:00		10.1	**1.364**	**12.976**
			1.371	**13.591**
7/3/2008 1:00		8.1	**1.320**	**9.398**
7/3/2008 2:00		8.1	**1.320**	**9.398**
7/3/2008 3:00		9.4	**1.343**	**11.106**
7/3/2008 4:00		10.1	**1.359**	**12.307**
7/3/2008 5:00		10.7	**1.374**	**13.490**
7/3/2008 6:00		9.3	**1.341**	**10.951**
7/3/2008 7:00		9.7	**1.350**	**11.596**
7/3/2008 8:00		10.1	**1.359**	**12.307**
7/3/2008 9:00		10.3	**1.364**	**12.685**
7/3/2008 10:00		10.4	**1.366**	**12.881**
7/3/2008 11:00		9.7	**1.350**	**11.596**
7/3/2008 12:00		9.8	**1.352**	**11.768**
7/3/2008 13:00		9.3	**1.341**	**10.951**
7/3/2008 14:00		10.7	**1.374**	**13.490**
7/3/2008 15:00		9.3	**1.341**	**10.951**

7/3/2008 16:00		9.5	**1.345**	**11.265**
7/3/2008 17:00		11.1	**1.384**	**14.354**
7/3/2008 18:00		10.4	**1.366**	**12.881**
7/3/2008 19:00		10.3	**1.364**	**12.685**
7/3/2008 20:00		10.7	**1.374**	**13.490**
7/3/2008 21:00		11.5	**1.395**	**15.274**
7/3/2008 22:00		10.3	**1.364**	**12.685**
7/3/2008 23:00		10.8	**1.376**	**13.700**
7/4/2008 0:00		10.1	**1.359**	**11.698**
		9.988	**1.358**	**12.204**
7/4/2008 1:00	3.4	11.1	**1.384**	**13.665**
7/4/2008 2:00	3.6	11.9	**1.407**	**15.483**
7/4/2008 3:00	3.7	11	**1.382**	**13.453**
7/4/2008 4:00	3.5	11.3	**1.390**	**14.101**
7/4/2008 5:00	2.7	10.1	**1.359**	**11.698**
7/4/2008 6:00	3.3	11.3	**1.390**	**14.101**
7/4/2008 7:00	3.6	9.6	**1.348**	**10.854**
7/4/2008 8:00	2.4	10.8	**1.376**	**13.038**
7/4/2008 9:00	3.2	10.7	**1.374**	**12.835**
7/4/2008 10:00	2.9	9.4	**1.344**	**10.543**
7/4/2008 11:00	3.1	10.3	**1.364**	**12.063**
7/4/2008 12:00	3.4	9.5	**1.346**	**10.696**
7/4/2008 13:00	2.4	10.2	**1.362**	**11.879**
7/4/2008 14:00	2.8	10.9	**1.379**	**13.243**
7/4/2008 15:00	2.7	10.8	**1.376**	**13.038**
7/4/2008 16:00	3.3	11.2	**1.387**	**13.881**
7/4/2008 17:00	2.9	10.5	**1.369**	**12.442**
7/4/2008 18:00	2.6	10.8	**1.376**	**13.038**
7/4/2008 19:00	2.9	10.6	**1.371**	**12.637**

7/4/2008 20:00	3.5	10.4	**1.366**	**12.250**
7/4/2008 21:00	3.3	10.7	**1.374**	**12.835**
7/4/2008 22:00	3	9.8	**1.352**	**11.180**
7/4/2008 23:00	3.2	11.7	**1.401**	**15.010**
7/5/2008 0:00	3	11.3	**1.389**	**15.455**
		10.6625	**1.3736332**	**12.892413**
7/5/2008 1:00	3.5	11.1	**1.384**	**14.981**
7/5/2008 2:00	3.4	11.1	**1.384**	**14.981**
7/5/2008 3:00	3.6	10.6	**1.371**	**13.860**
7/5/2008 4:00	4	11	**1.381**	**14.749**
7/5/2008 5:00	3.2	11.6	**1.398**	**16.192**
7/5/2008 6:00	3.8	11.7	**1.401**	**16.444**
7/5/2008 7:00	3.7	11.1	**1.384**	**14.981**
7/5/2008 8:00	3.5	10.6	**1.371**	**13.860**
7/5/2008 9:00	3	10.2	**1.361**	**13.032**
7/5/2008 10:00	3.5	11.3	**1.389**	**15.455**
7/5/2008 11:00	3.8	10.5	**1.368**	**13.647**
7/5/2008 12:00	3.2	10.2	**1.361**	**13.032**
7/5/2008 13:00	3.1	11.7	**1.401**	**16.444**
7/5/2008 14:00	3.3	11.6	**1.398**	**16.192**
7/5/2008 15:00	2.7	10.5	**1.368**	**13.647**
7/5/2008 16:00	3.2	11.7	**1.401**	**16.444**
7/5/2008 17:00	3.5	11.5	**1.395**	**15.943**
7/5/2008 18:00	3.5	10.5	**1.368**	**13.647**
7/5/2008 19:00	3.5	11.4	**1.392**	**15.697**
7/5/2008 20:00	2.9	11.1	**1.384**	**14.981**
7/5/2008 21:00	2.8	10.1	**1.358**	**12.835**
		11.0047619	**1.3817362**	**14.811424**


Area 07 SSCC yield, Ash, Cut Rd and actual Plant yield.
25
20
15
10
5
0
Ash and Yield%
1.500
1.450
1.400
1.350
1.300
1.250
1.200
Cut Rd's
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99 106 113 120 127 134 141
Hourly Laboratory controls on Spot Ash values
SPOT ASH
07 Yield
Actual Plant Coking yields
10.3% Ash
07 Cut Rd

APPENDIX D

Detailed evaluation of a week's information with regard to GG1 Coking coal yields taking planning and wash data into account for the week ending the 28th June 2008 to determine suitable correlation factors

D1. INTRODUCTION

As part of the ongoing investigation with regard to the implementation of AAD determined yields for predictive purposes, a recent week's information has been analyzed in detail using LIMS data relevant to hourly analysis values received in order to ascertain what is happening to the run of mine material in the beneficiation plant regarding coking coal production. Note that this analysis has been done on GG1 data although it is equally applicable to GG6.

D2. OBJECTIVES

- The major objective being to illustrate differences influencing the predicted values and the plant's production of coking coal from ROM material and to determine correlation between the predicted values and the actual production.

- Initially yields and their associated properties are derived from the geological model which takes the idealized situation with regard to block dimensions and bench definitions into account. Polygons representative of the blast block scheduled per strip are generated and populated with the respective analytical data associated with said polygons in respect to their relative positions within the exploration grid.

- At this stage SABLE are finalizing the CAB package to accommodate AAD methodology, thus model values, not used in this paper, are still based on the old system.

- Short term mine planning however needs to assess the practical effects of mining in altering the dimensions of the fore mentioned blocks, such as new roof and floor parameters which would be comprised of different sample assemblages thus altering the washability data for these polygons. This is all accounted for in the grade control exercise, which has already been dealt with in great detail in previous papers.

D3. METHODOLOGY

Theoretical yields for the blast blocks planned for this week were derived using the AAD cumulative wash tables for the individual blocks. Plots of these tables are shown in Figure D-1. Differences in the wash curves pertinent to yield are very obvious on assessing the plotted data. Block numbers, the respective cut Rd's for a 10.3% ash product as well as the expected theoretical yields for this product are shown in this figure.

Note the significant range of yields possible from these individual blocks, ranging from 11.52% for the bench 4, block to 19.01% for Bench 3 block b038301.

Planned Blocks and their ratios in the different scenarios, depicting days of the week.

Week Ending:										
	Blocks	Actual Ratio	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
1	b028405		28.00	38	28	37	28	28	50	60
2	b038301		36	26	36	0				
3	b048407		36	36	36	27	36	36	40	20
4	b038302					36	36	36	20	20
5	0									
6	0									
7	0									
8	0									

Blocks	Cut Rd's	10.3% Yld
b028405	1.351	12.516
b038301	1.397	19.01
b048407	1.371	11.52
b038302	1.404	16.96

Short term mine planning generally derive their yields from a simple arithmetical compilation.
Using the block yields multiplied by the representative ratio of the block in the mix and summing the components.
The result of this is shown below in the green shaded area.

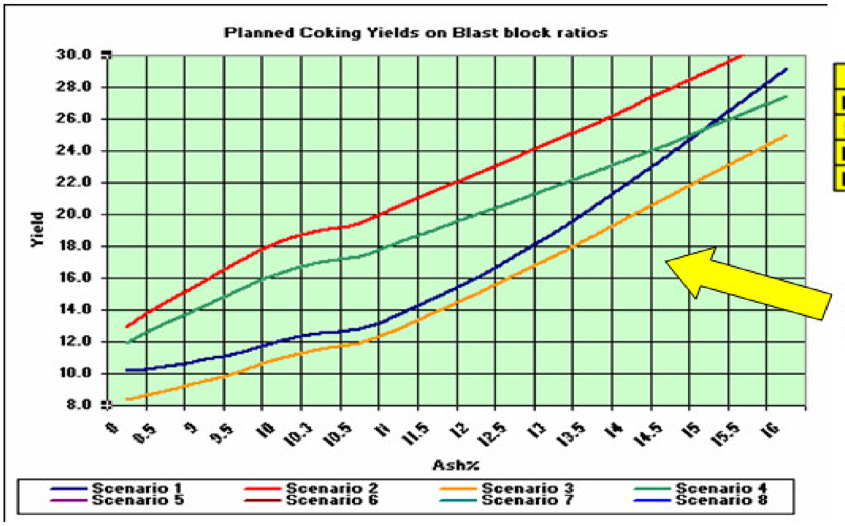
Expected yields based on planned ratios

Mine Planning Arith	14.50	13.85	14.50	13.85	13.76	13.76	14.26	13.21

Figure D-1 Individual block wash tables for planned blocks.

Coking coal wash curves, yield and cut Rd values for individual blocks planned

Week Ending:	20080628									
	Blocks	Actual Ratio	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
1	b028405		100.00							
2	b038301			100						
3	b048407				100					
4	b038302					100				
5	0									
6	0									
7	0									
8	0									



Individual block values from wash tables for each block

Blocks	Cut Rd's	10.3% Yld
b028405	1.351	12.516
b038301	1.397	19.01
b048407	1.371	11.52
b038302	1.404	16.96

Figure D-2 Blocks planned, their daily ratios and the derived expected theoretical yields per day.

As has been previously stated in an earlier report, the mine planner unfortunately does not have the luxury of being able to compile wash tables for the planned ratios of blended material, thus is reliant on simple arithmetic, whereby a yield for a specific blend is calculated using the ratios of the blocks in the blend and their yields (the information he requires is available from the geological evaluation completed in the grade control process and invariably has a correlation factor attached to the expected yields) Note though that in this evaluation theoretical values were initially used.

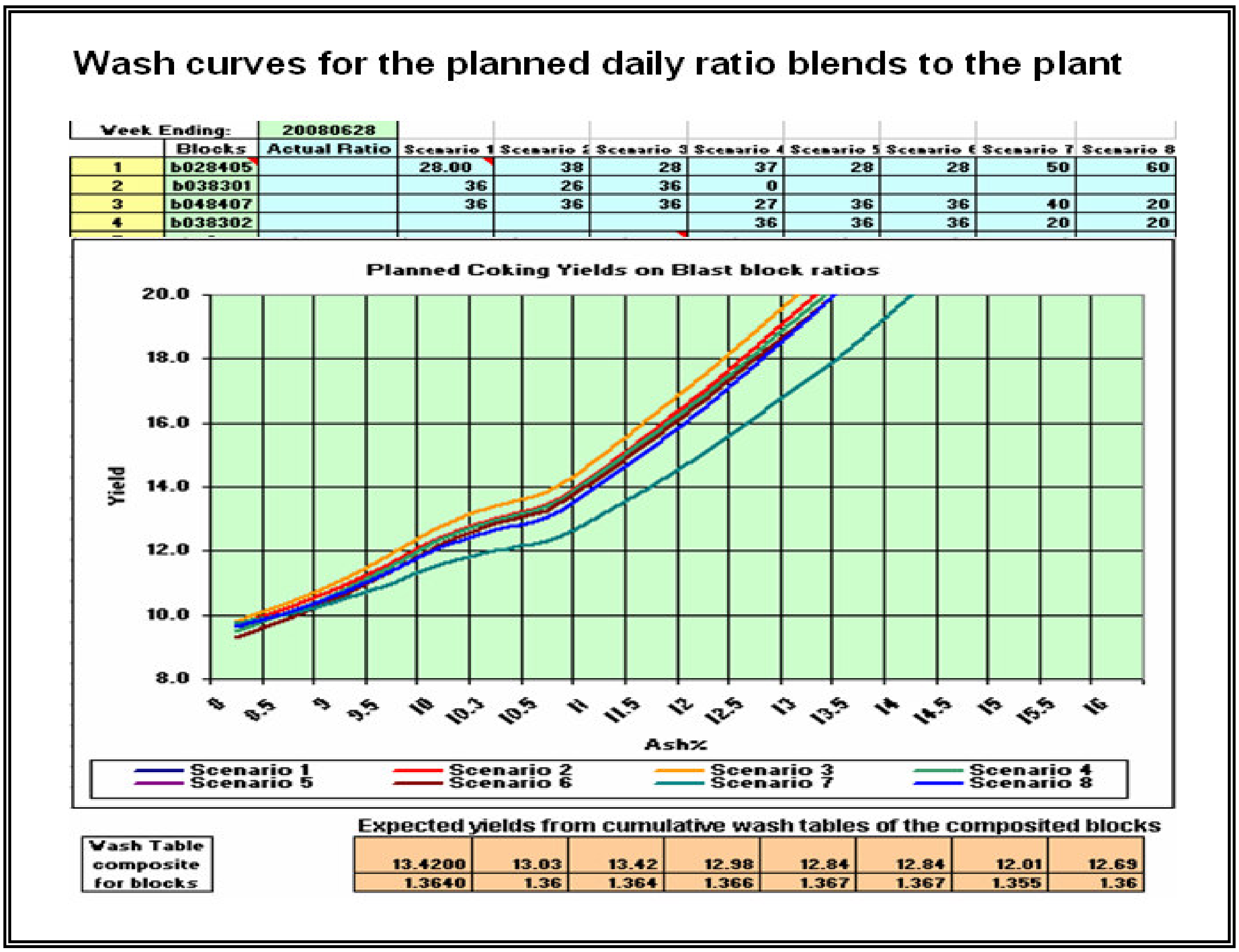
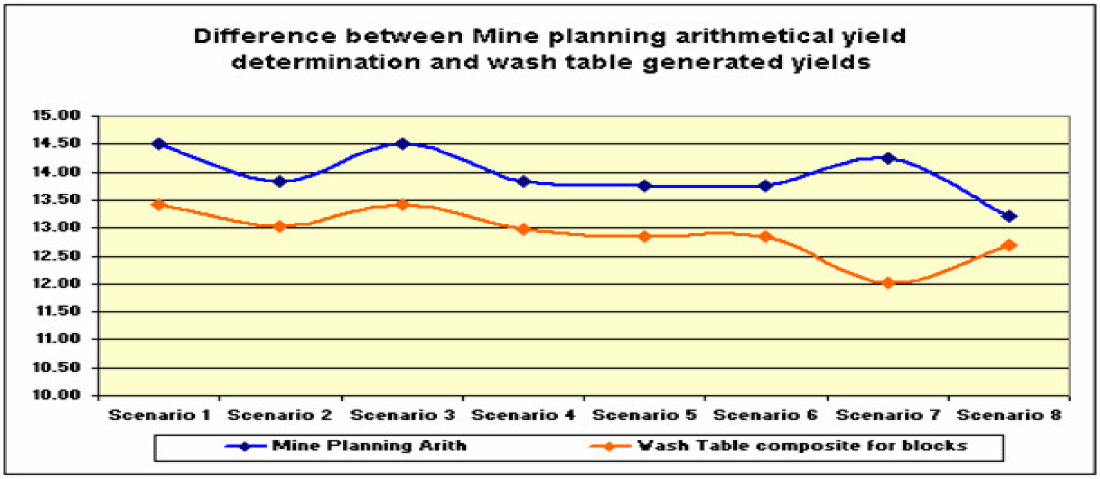


Figure D-3 Wash curves for planned block blend ratios.

The values shown in Figure D-3 are theoretical yields based on the ratios portrayed as different scenarios. The first 6 scenarios are relevant to the planning done for this particular week while the remaining 2 are admixtures including large proportions of bench 2 material. The daily wash tables for the blended material are shown in Figure D-3 with the yields and cut

Rd's tabulated below the plotted wash curves. The overall range is smaller than the calculated yields, ranging from 12.84% to 13.48% for the respective blends.



Expected yields based on planned ratios

Mine Planning Arith	14.50	13.85	14.50	13.85	13.76	13.76	14.26	13.21

Expected yields from cumulative wash tables of the composited blocks

Wash Table composite for blocks	13.42	13.03	13.42	12.98	12.84	12.84	12.01	12.69
	1.364	1.362	1.364	1.366	1.367	1.367	1.355	1.360
Average cut Rd			1.363					
DIFFERENCE	1.08	0.82	1.08	0.87	0.92	0.92	2.25	0.52
Percentage Difference	7.42	5.89	7.42	6.26	6.67	6.67	15.77	3.90

Figure D-4 Difference between Arithmetical and wash table derived daily yields on planned data.

A comparison between the two methods, the calculated arithmetical ratio adjusted yields and the actual blend wash tables was then done to establish the differences between the two methods and the consistency of the differences between the two, and whether the difference could be accommodated by a constant or correlation factor. Ignoring the last 2 scenario computations which are not relevant to this week's information, the difference between the two methods represents 7%. The wash table generated values are 7% lower than the arithmetically derived yields. This is shown in Figure D-4. The same approach has been used in evaluating the as mined data for this week and the results portrayed in the following series of figures from Figure D-5 thru D-9.

Actual Blocks Mined during same week

Blocks	Actual Ratio	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
b028405		18.93	23.79	20.59	24.16	30.7	22.3		
b038301		36.9	27.02	32.46	43.01	31.44	25.67		
b038302									
b038407		2.79	2.43		1.14	5.27	1.51		
b028410			0.65						
GG1Stockpile		1.93	2.06	2.38		1.2	18.3		
b048407		39.45	44.05	44.57	31.68	31.38	32.19		
0									

Blocks	Cut Rd's	10.3% Yld	Theor. 10.3% Yld	Theor. 90% Cf
b028405	1.351	12.52	12.52	11.26
b038301	1.397	19.01	19.01	17.11
b038302	1.404	16.96	16.96	15.26
b038407	1.345	9.46	9.46	8.51
b028410	1.362	22.58	22.58	20.32
GG1Stockpile	1.35	11.88	11.88	10.69
b048407	1.371	11.52	11.52	10.37

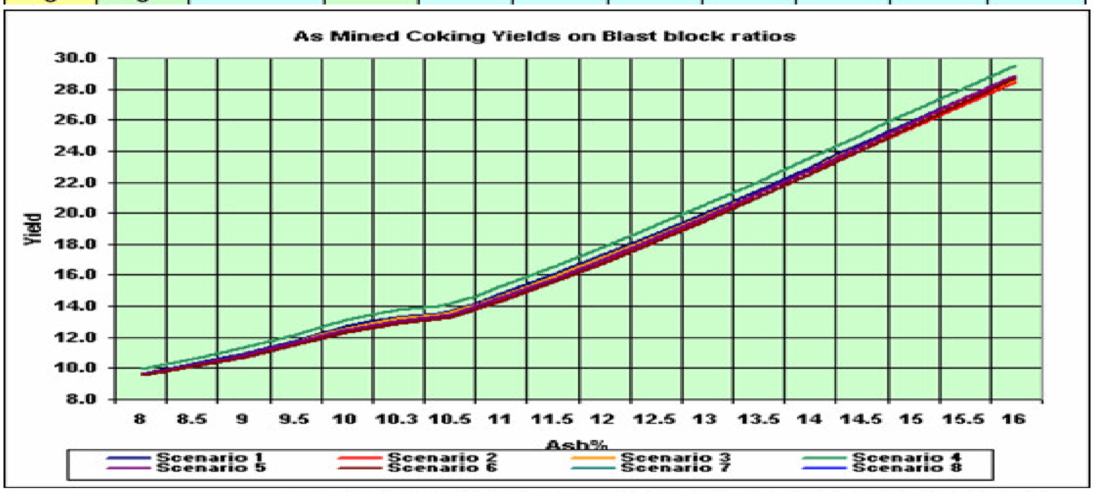
The as mined ratios yields are generally derived from a simple arithmetical compilation.
Using the block yields multiplied by the representative ratio of the block in the mix and summing the components.
The result of this is shown below in the green shaded area.

Expected yields based on Mined ratios

		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
As Mined Ratios Arith		14.42	13.81	14.16	14.96	14.08	13.70		

Figure D-5 Table of theoretical as mined block data for the same week as planned.

Week Ending:	28/06/2008									
	Blocks	Actual Ratio	ario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
1	b028405		.93	23.79	20.59	24.16	30.7	22.3		
2	b038301		36.9	27.02	32.46	43.01	31.44	25.67		
3	b038302									
4	b038407		2.79	2.43		1.14	5.27	1.51		
5	b028410			0.65						
6	G1Stockpile		1.93	2.06	2.38		1.2	18.3		
7	b048407		39.45	44.05	44.57	31.68	31.38	32.19		
8	0									



Expected yields from cumulative wash tables of the composited blocks

Wash Table composite								
	13.29	12.95	13.17	13.72	13.07	12.87		
	1.364	1.363	1.364	1.365	1.361	1.361		

Average cut Rd 1.363

Figure D-6 Wash curves for the ratio blends of as mined material per day. Days shown as scenario's 1-6

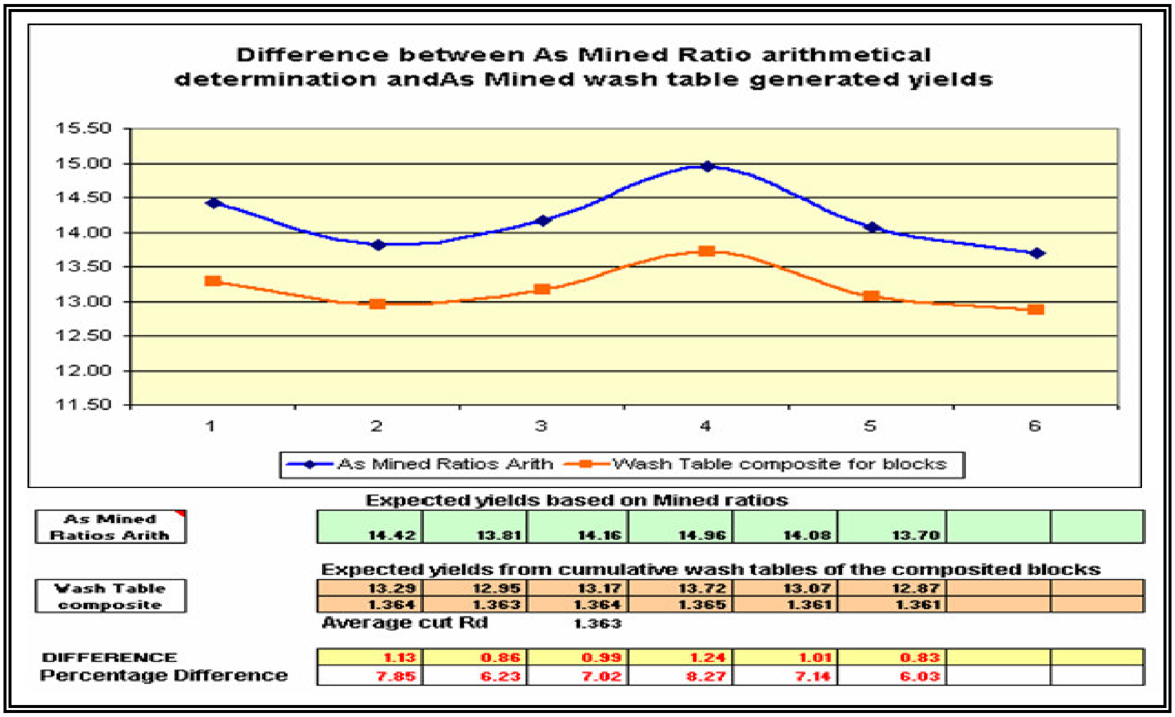


Figure D-7 Difference between Arithmetical and wash table derived daily yields on as mined data.

An interesting point to note, although the as mined blocks and ratios differ substantially from the planned blocks and ratios, the differences between the calculated yield based on the ratios and the wash table derived yields for this period are also approximately 7%, the wash table generated values being 7% lower than the arithmetically determined values. It would thus be relatively safe to assume that this value could be used as a constant in order to negate the difference between the two methods, although it should be proved by back testing over a reasonable period.

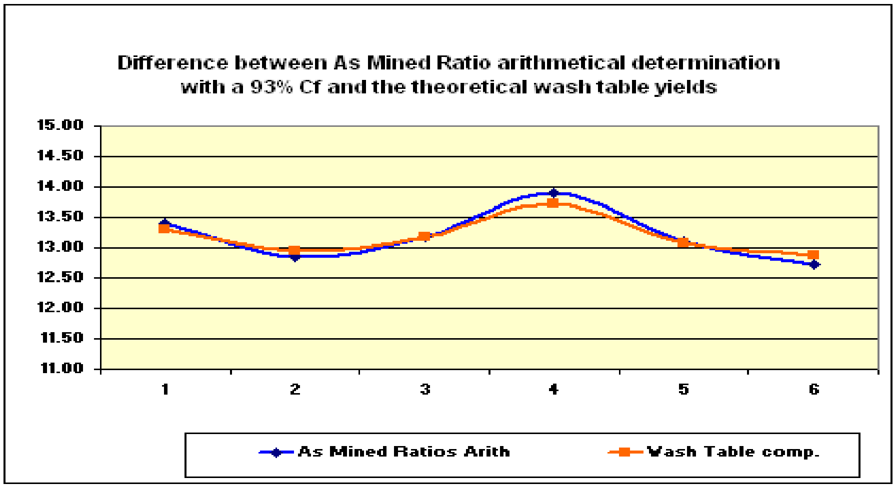


Figure D-8 Plotted theoretical wash table yields against arithmetical yield ratio blend adjusted with a 93% correlation factor.

Taking the above one step further and making allowances for coking coal misplaced to middling as a result of size fraction and liberation properties, the value previously obtained was between 10% and 15%, the lower value of 10% was used and implemented for yield derivation purposes, thus the wash table yields reported in the yield files from which mine planning obtain their data, were adjusted by a correlation factor of 90%. This still presents a reasonable target for the plant to obtain.

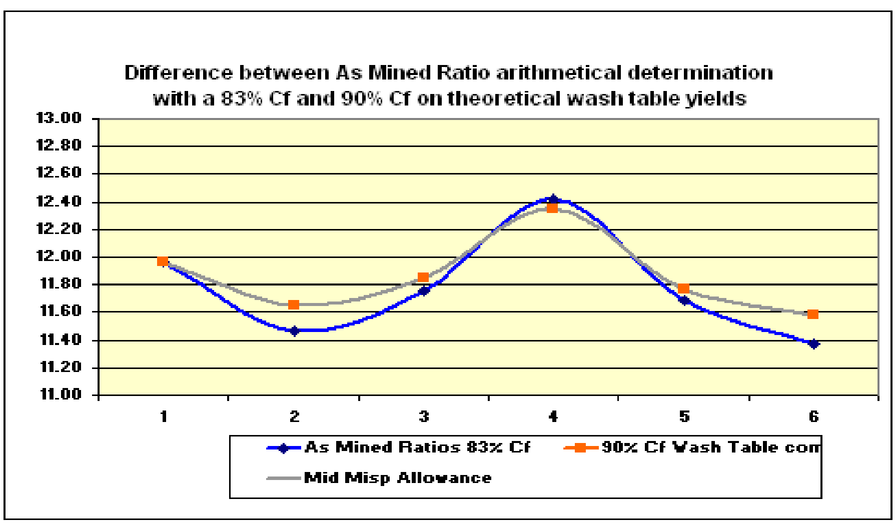


Figure D-9 Wash table correlation factor 90% and arithmetical derivation at 83%.

The difference between the two methods however, had not been taken into account; the correlation factor thus required for an arithmetical derivation of probable yields would then become 83%. Figure D-9 now shows an excellent correlation between the two methods of determining yields as well as the probable misplacement of coking coal to middling. This however only serves to remove the focus from what is happening in the plant because the values thus obtained and compared with actual yields will present a far more acceptable picture than the values that should be obtained theoretically. Including the actual plant yields on this background shows an apparently reasonable performance where the yields obtained are higher than the as mined values for the first two days, almost the same on day four with days 3 & 6 being substantially lower.

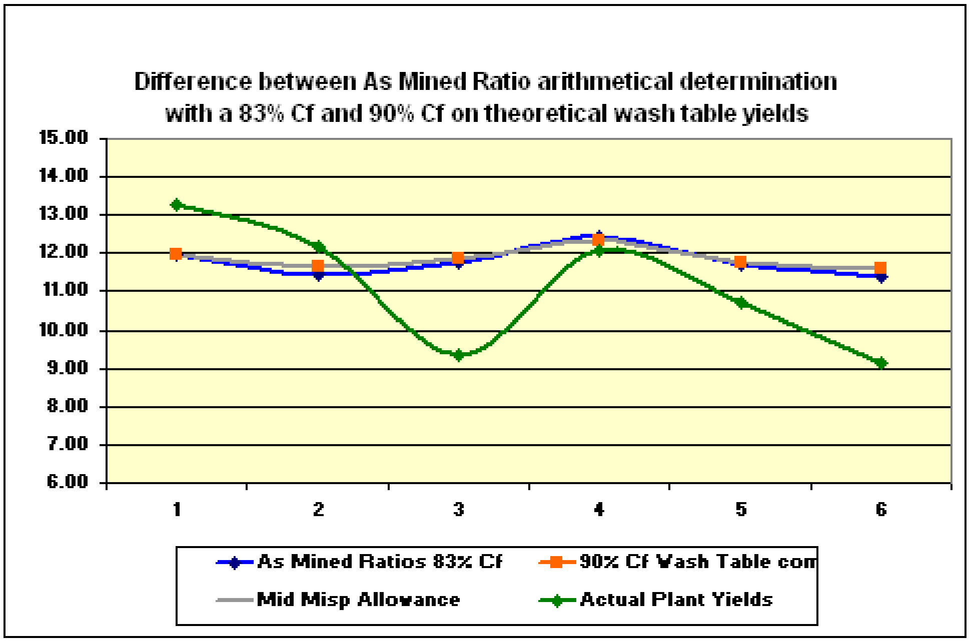


Figure D-10 Adjusted prediction yields with actual plant yields superimposed.

Assessing the same data against theoretical values presents a different perspective evident in Figure D-11, here the difference between the calculated and wash table generated data is evident, this adjustment can safely be made to accommodate both sets of data and be reasonably close to the theoretical wash table derived values. Actual production results have shown that the theoretical yield from the wash table data can be attained, and that far greater care needs to be exercised with regard to cut Rd's and ash controls, the ranges currently employed need to be dramatically reduced. Allowances can still be made for the misplacement of coking coal to middling's since this is directly related to the particulate size and may increase or decrease as a result of the amount of vitrinite material in the run of mine feedstock, increases in vitrinite content will result in higher misplacements to both middling's and slimes, while decreases should behave more homogeneously.

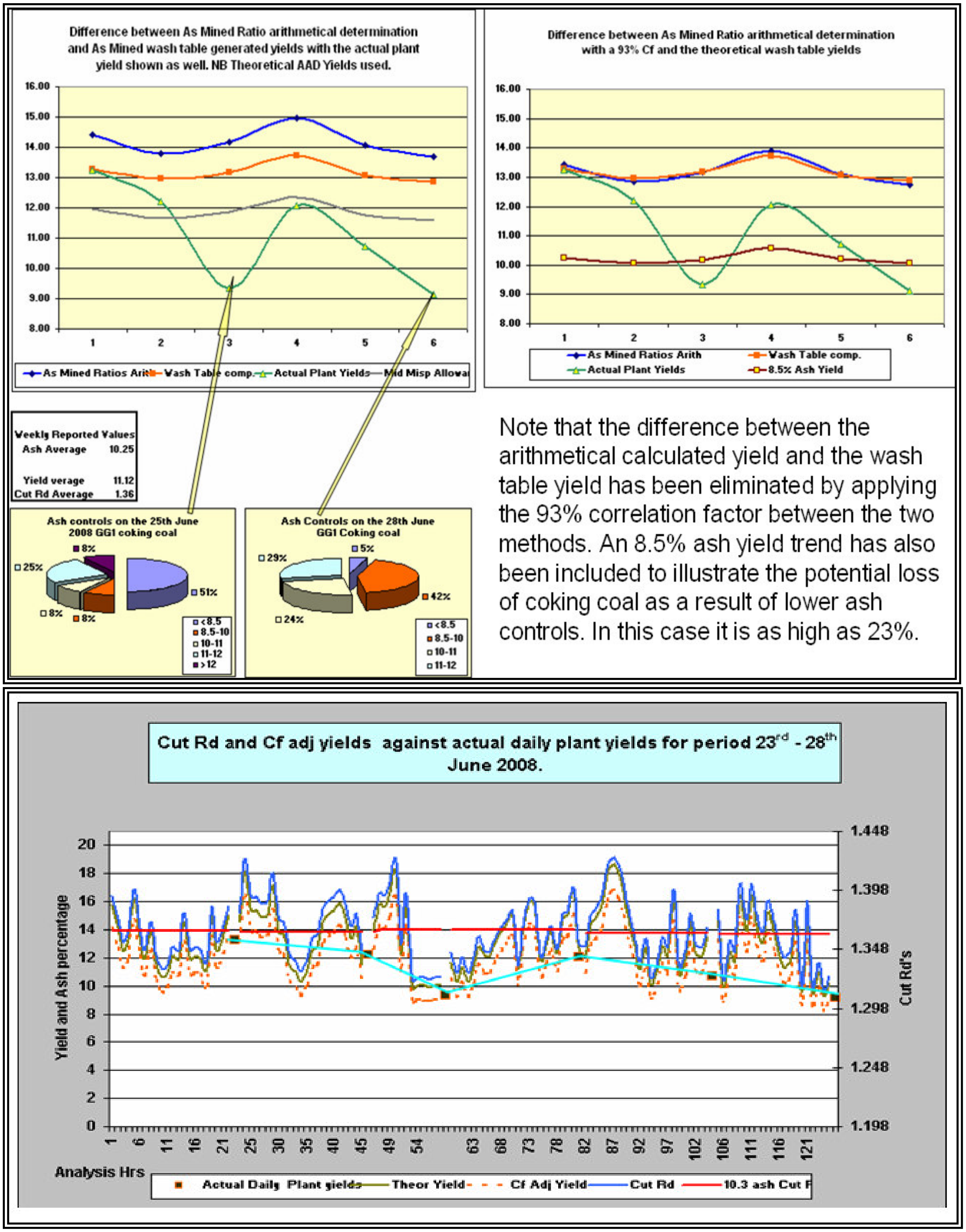


Figure D-11 Generalized evaluation of plant data against actual as mined data.

Although the week's average ash is 10.25 the fluctuations on a daily basis destroy value with regard to the coking coal product, the two worst case scenarios during this week were extracted, values obtained from the LIMS system and evaluated in the pie charts shown. The first shows that ash controls less than 8.5% ash made up almost 60% of the production on this day while the second shows a slight improvement to 47% less than a 10%Ash.

The cut Rd for the week also averages at 1.36g/cc but is not reflective of what is actually happening in the plant on an hourly basis. The lower portion of Figure D-11 is a plot of cut densities calculated from the ash values reported on the LIMS system, here calculated cut densities fluctuate between 1.312g/cc and 1.426g/cc. The same data was used to generate the distribution plot in Figure D-12 below. The density ranges were further reduced to represent percentages below or equal to 1.36g/cc, between 1.36g/cc and 1.39g/cc and greater than 1.39g/cc.

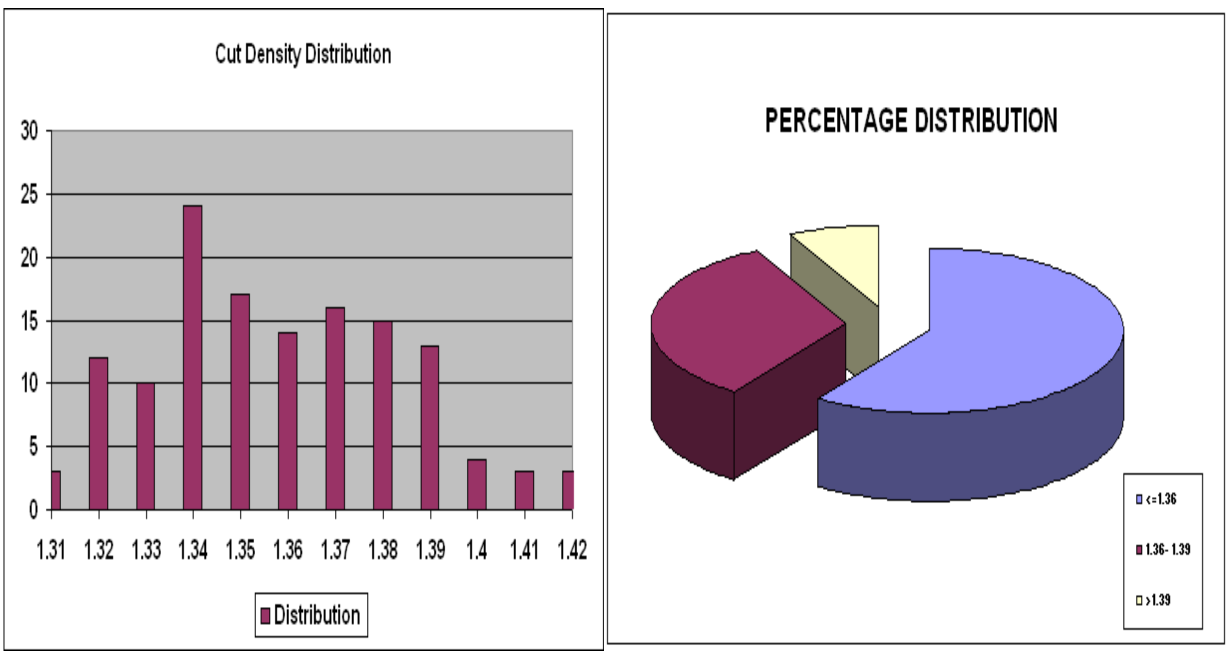


Figure D-12 Cut density distribution for week 23rd June 2008 – 28th June 2008.

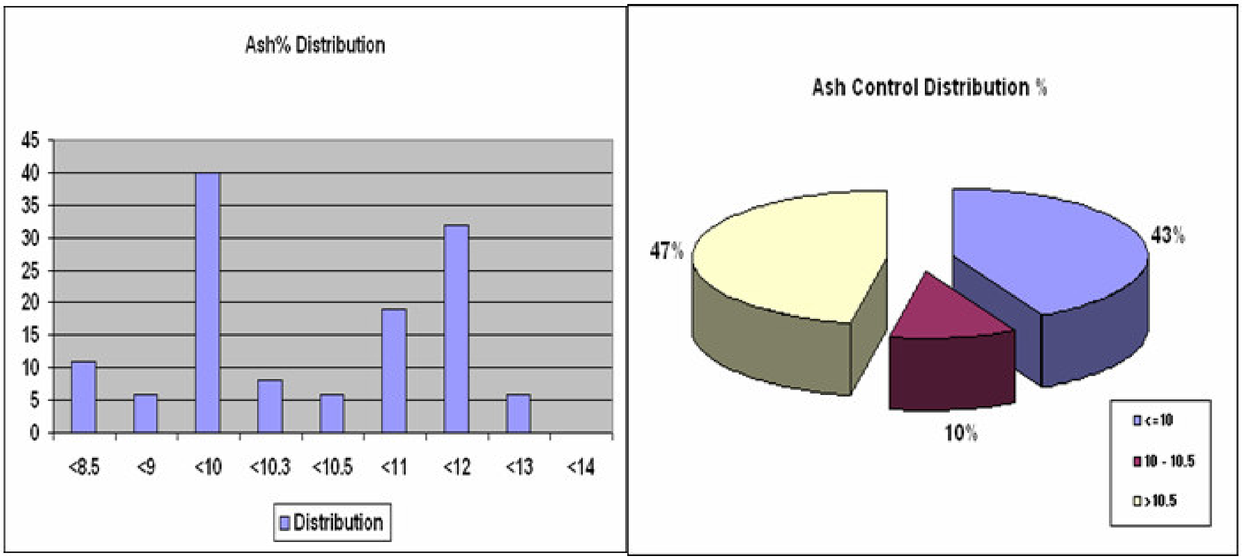


Figure D-13 Ash control distribution from LIMS hourly analysis for the same week.

The assessment of reported ash control values indicates that 53% of the time controls were below or equal to a 10% ash product therefore the actual yield would be lower than that predicted at a 10.3% ash value.

D4. CONCLUSIONS.

The disparity between the methods of determining daily planned and as mined coking coal yields and wash table derived yields for the various blends has been resolved.

- A 93% correlation factor applied to the individual yields obtained from the wash data for individual blocks composited according to the ratios that they have been blended in, correlates perfectly with the yields derived from a precompiled wash table using a composite of the data in its various ratios from the blocks to obtain a single wash table of the blend, from which products can be extracted at the prescribed controls.
- Allowing for misplacement of coking coal to middling as a result of particulate size distribution, the correlation factor for the arithmetical determination of expected yield is decreased to 83% while the correlation factor for AAD blended wash tables becomes 90%.
- The cut density range for coking coal production at 10.3% Ash, ie the operating ranges for bed building control need to be refined to reduce the span currently experienced so that

the maximum product can be extracted. Theoretically this would be at approximately 1.338g/cc although information evaluated over time has shown that it should be relatively safe to go to 1.36g/cc.

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L. Roux. 15th July 2008.

Senior Project Geologist.

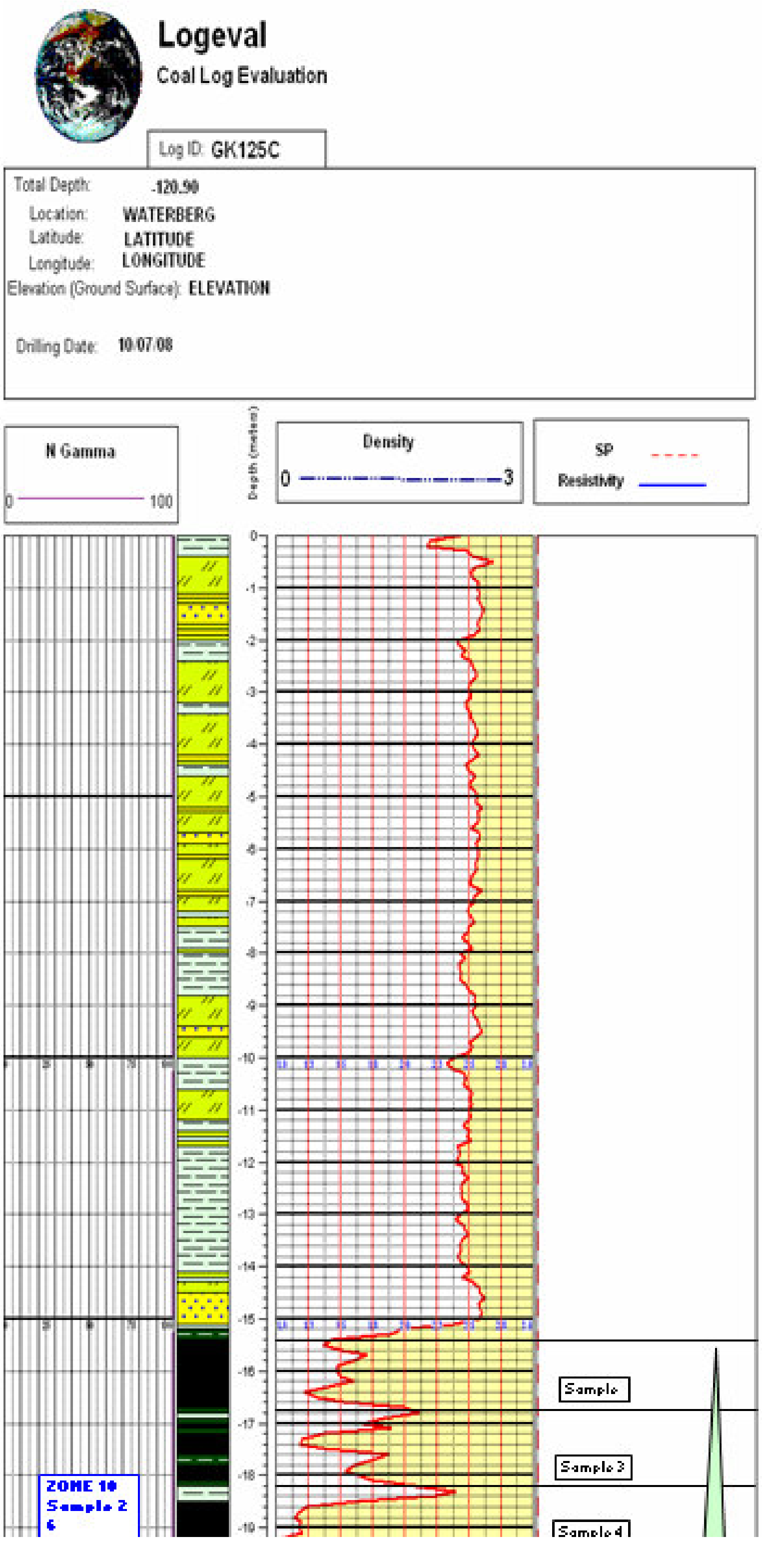
Grootegeluk Mine

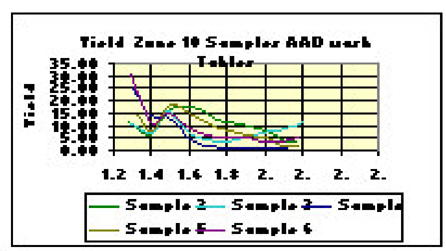
APPENDIX E

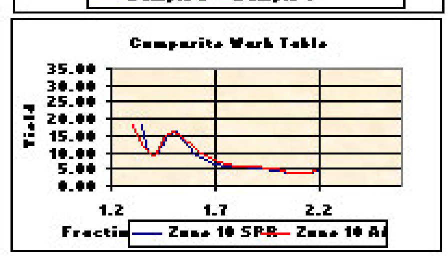
BOREHOLE GK125.

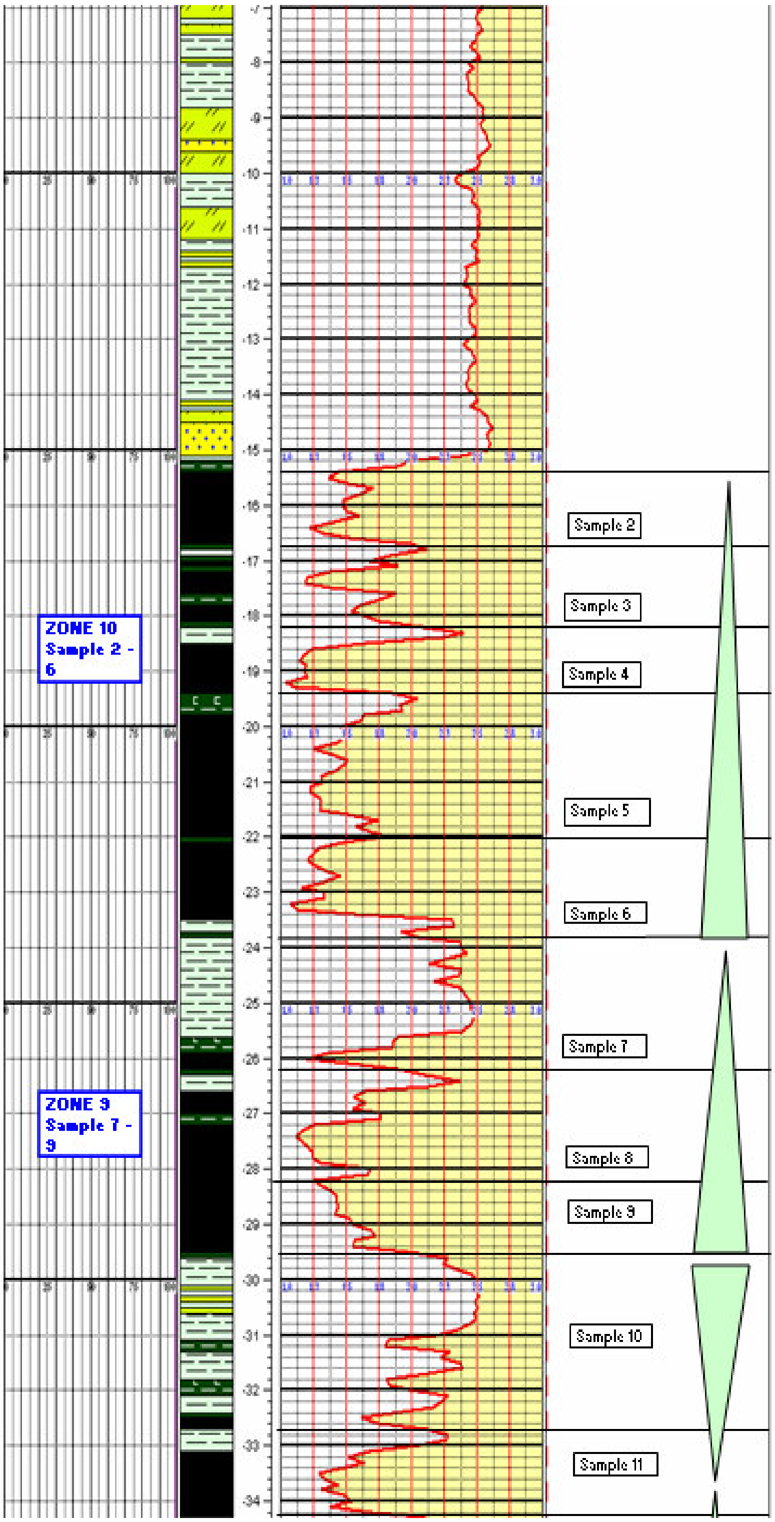
FRACTIONAL DENSITY DISTRIBUTIONS PER DEFINED CYCLIC SEDIMENTARY SAMPLE, THROUGHOUT THE VERTICAL SUCCESSION.

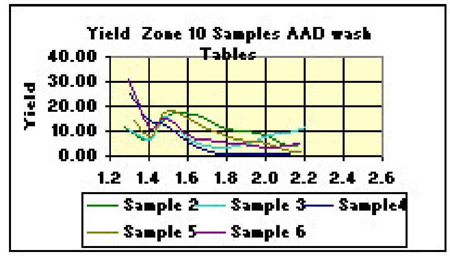
The following pages depict the analysis done on this borehole, on a sample basis, each composite sample's, i.e. coal and shale combined, wash table derived empirically and AAD adjusted was plotted next to the defined sample interval on the geophysical log to illustrate the distribution of fractional densities within the sample and also to give an indication of whether the sedimentary cycle could be defined in the context of upward fining or coarsening cycles.

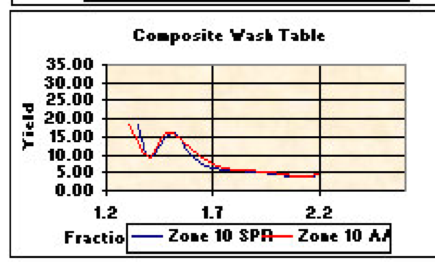

Logeval
Coal Log Evaluation
Log ID: GK125C
Total Depth: -120.90
Location: WATERBERG
Latitude: LATITUDE
Longitude: LONGITUDE
Elevation (Ground Surface): ELEVATION
Drilling Date: 10/07/08
N Gamma
0
100
Depth (meters)
Density
0
3
SP
Resistivity
ZONE 10
Sample 2
6
Sample
Sample 3
Sample 4

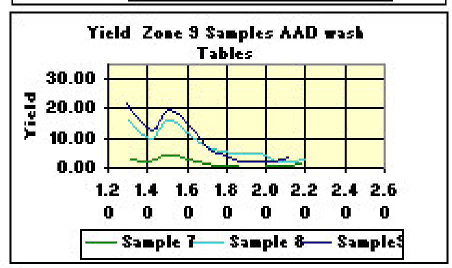

Yield
35.00
0.00
1.2
1.4
1.6
1.8
Sample 2
Sample 3
Sample 5
Sample 6

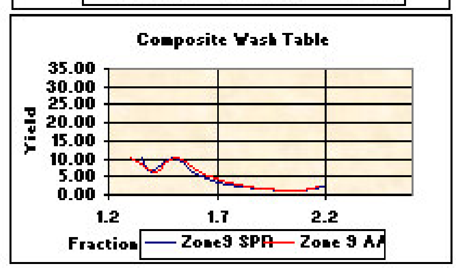

Composite Work Table
Yield
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1.2
1.7
2.2
Zone 10 SRB
Zone 10 A

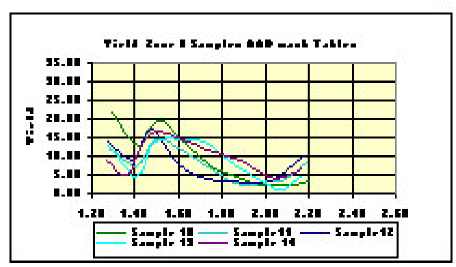

ZONE 10
Sample 2 - 6
ZONE 9
Sample 7 - 9
Sample 2
Sample 3
Sample 4
Sample 5
Sample 6
Sample 7
Sample 8
Sample 9
Sample 10
Sample 11

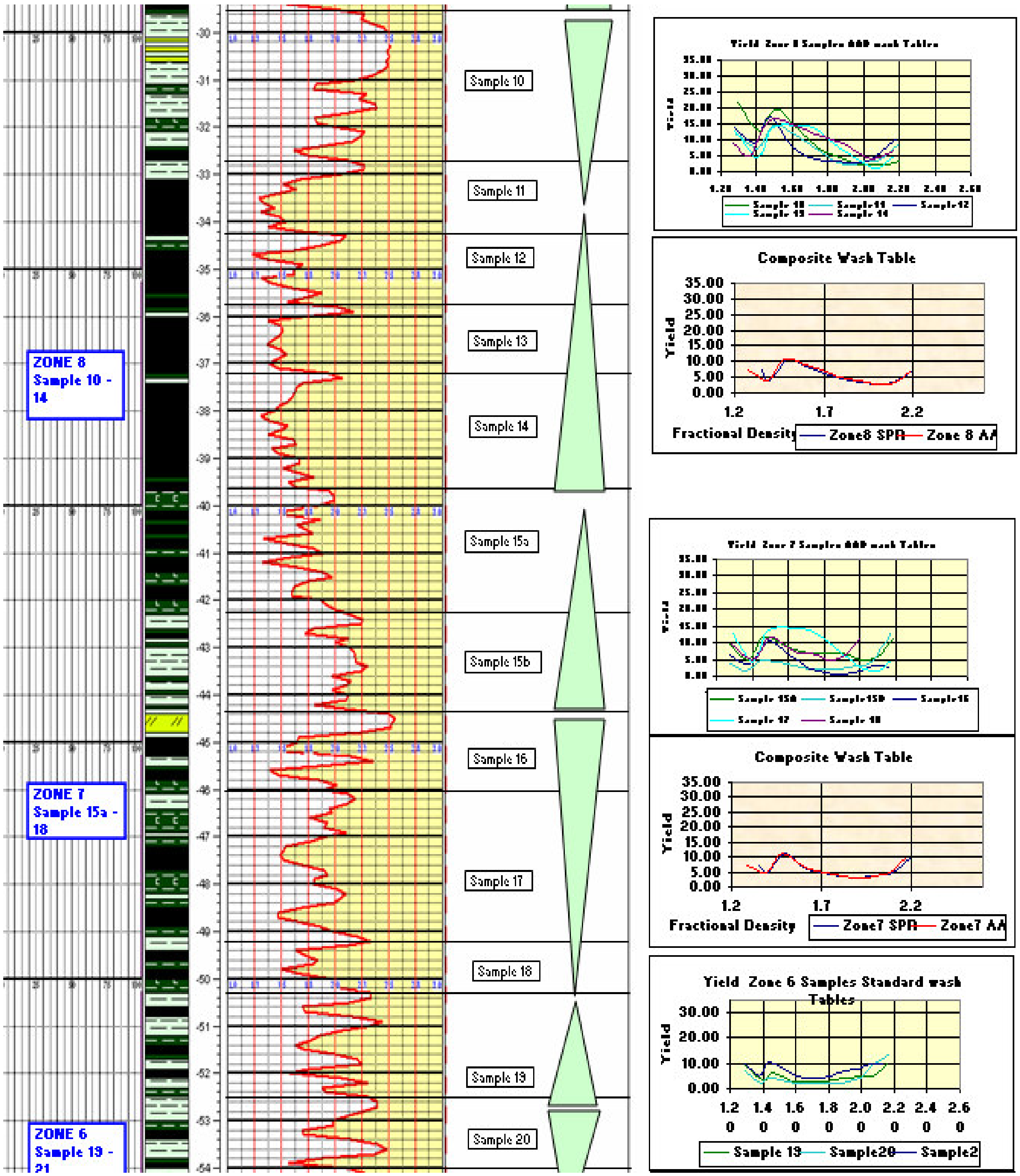

Yield Zone 10 Samples AAD wash Tables
Yield
40.00
30.00
20.00
10.00
0.00
1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6
Sample 2
Sample 3
Sample4
Sample 5
Sample 6

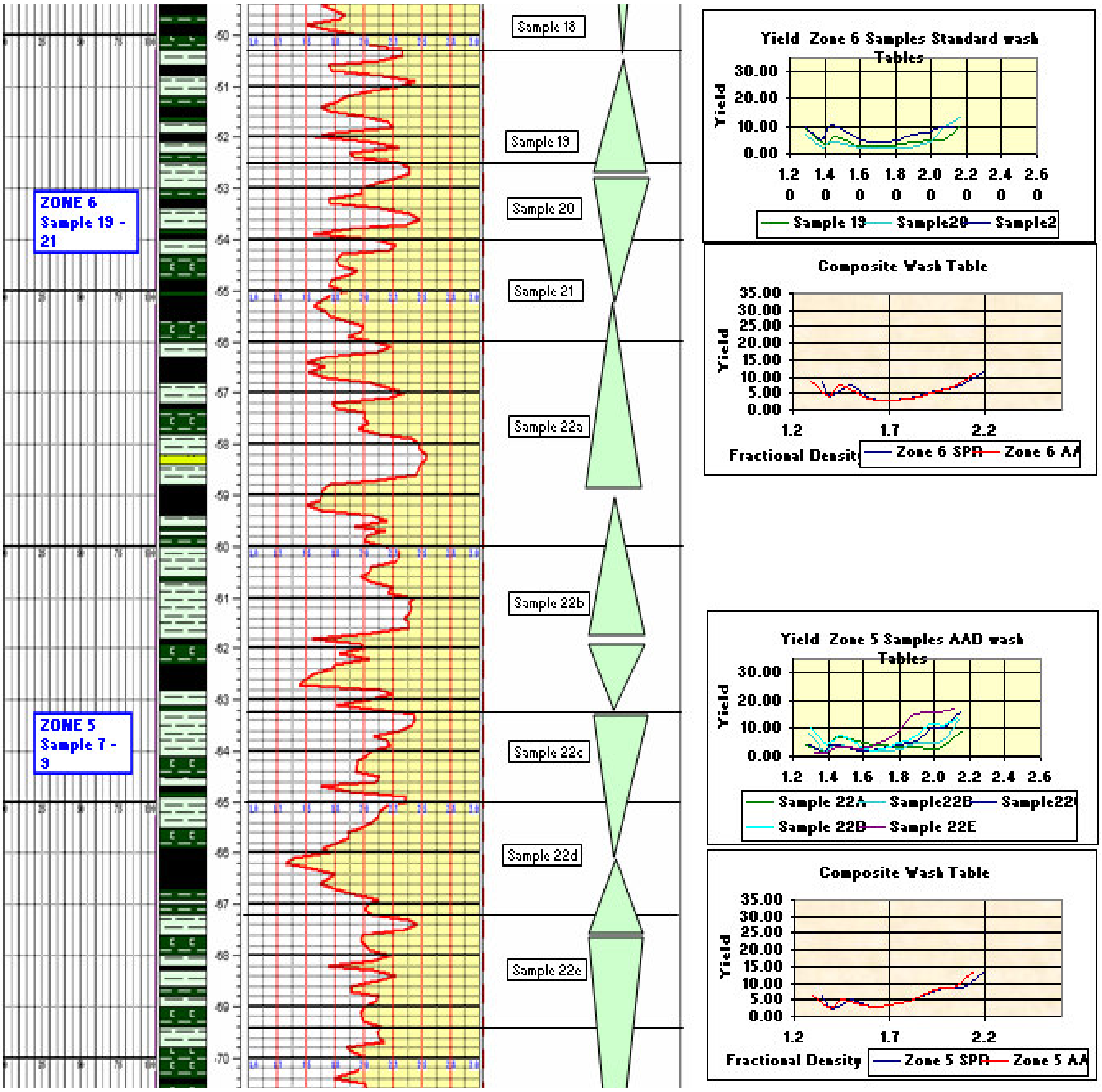

Composite Wash Table
Yield
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1.2 1.7 2.2
Fractio
Zone 10 SPR
Zone 10 AA

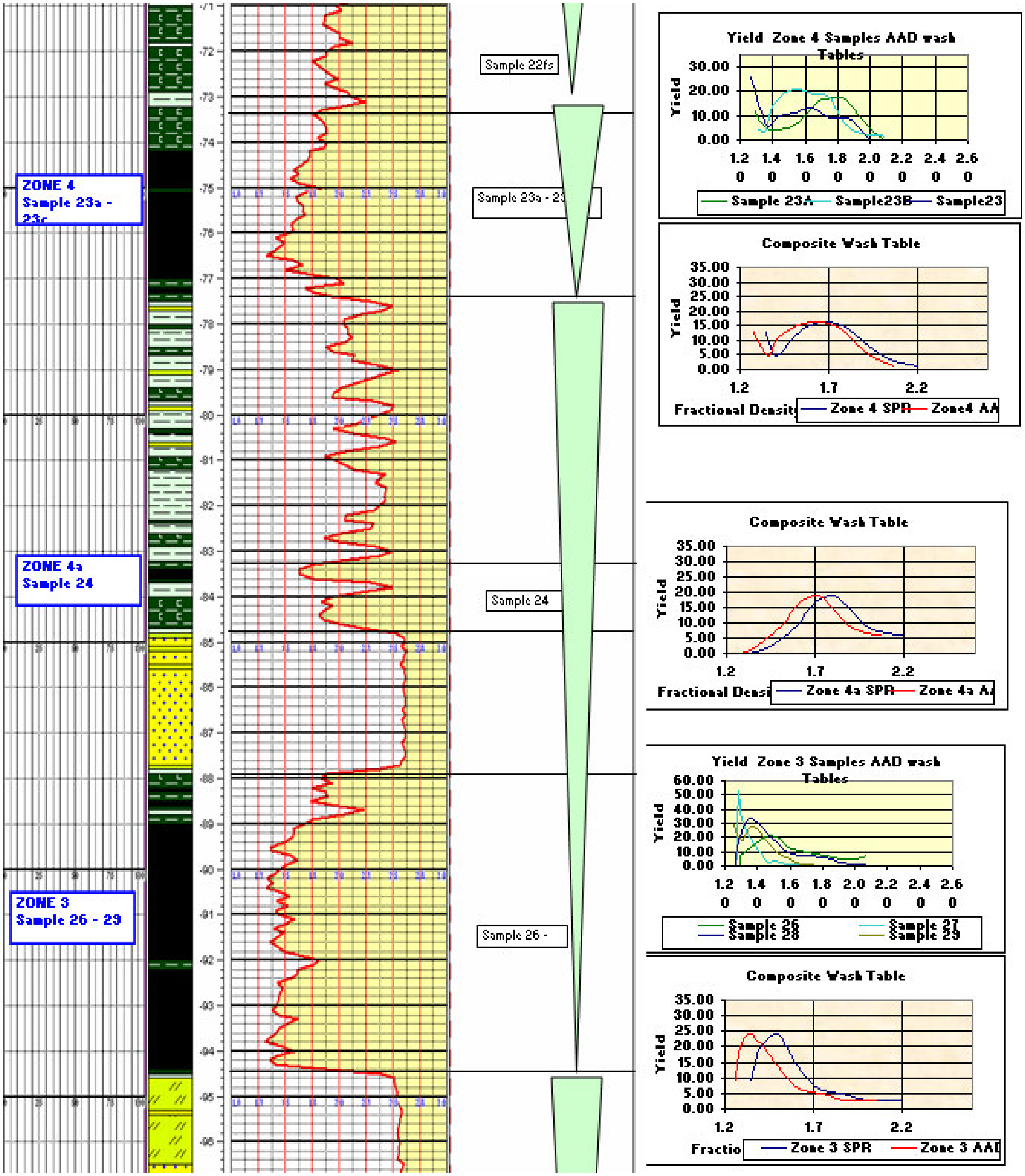

Yield Zone 9 Samples AAD wash Tables
Yield
30.00
20.00
10.00
0.00
1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6
0 0 0 0 0 0 0 0
Sample 7
Sample 8
Sample9

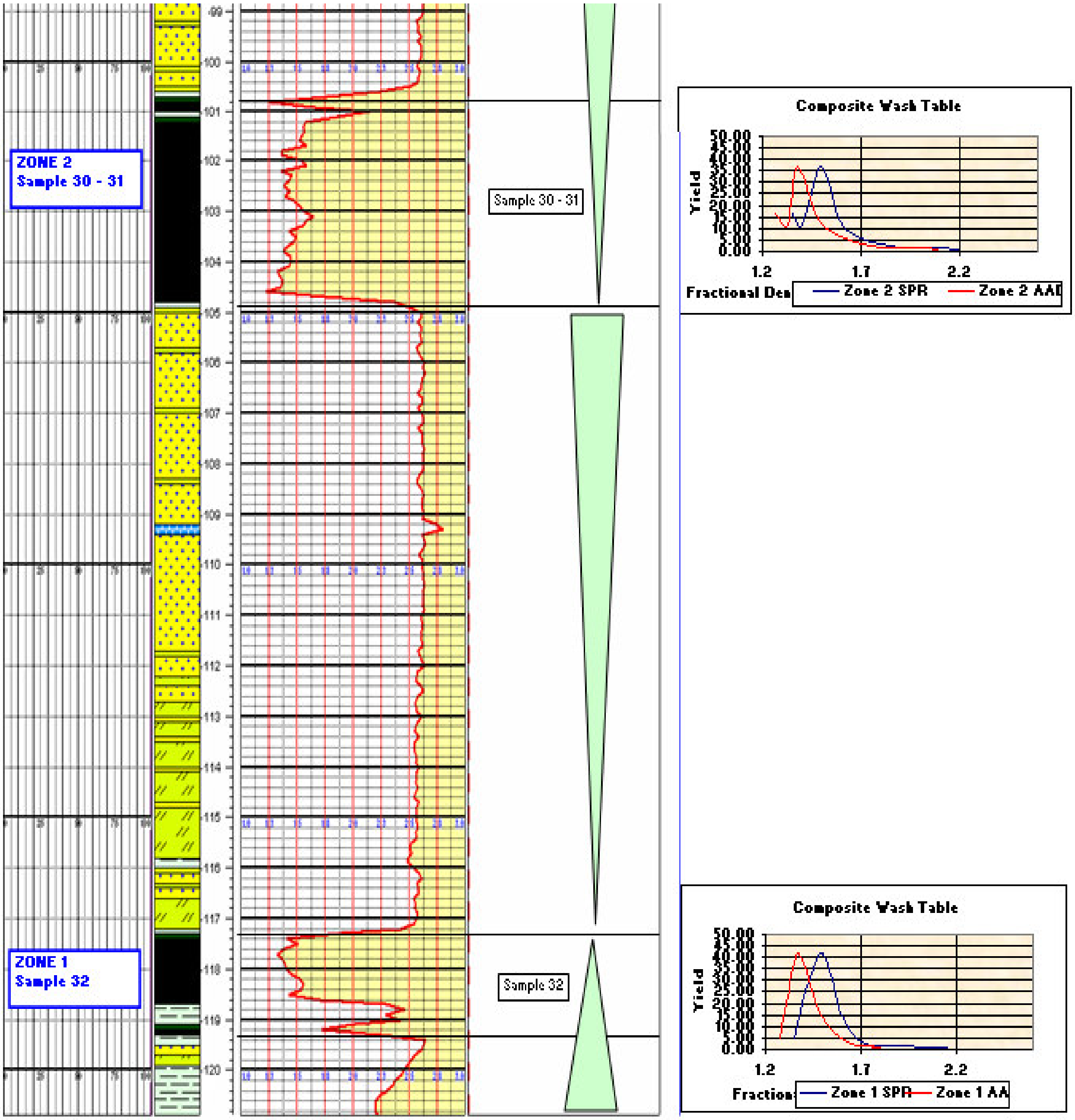

Composite Wash Table
Yield
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1.2 1.7 2.2
Fraction
Zone9 SPR
Zone 9 AA

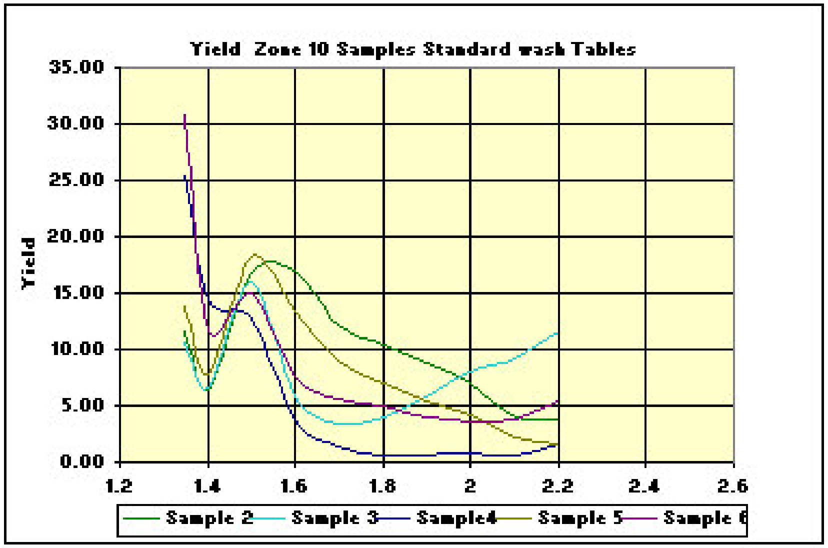



Sample 10
Sample 11
Sample 12
Sample 13
Sample 14
Sample 15a
Sample 15b
Sample 16
Sample 17
Sample 18
Sample 19
Sample 20
ZONE 8
Sample 10 - 14
ZONE 7
Sample 15a - 18
ZONE 6
Sample 19 - 21
Composite Wash Table
Yield
Fractional Density
Zone8 SPR
Zone 8 AA
Composite Wash Table
Yield
Fractional Density
Zone7 SPR
Zone7 AA
Yield Zone 6 Samples Standard wash Tables
Yield
Sample 19
Sample20
Sample2

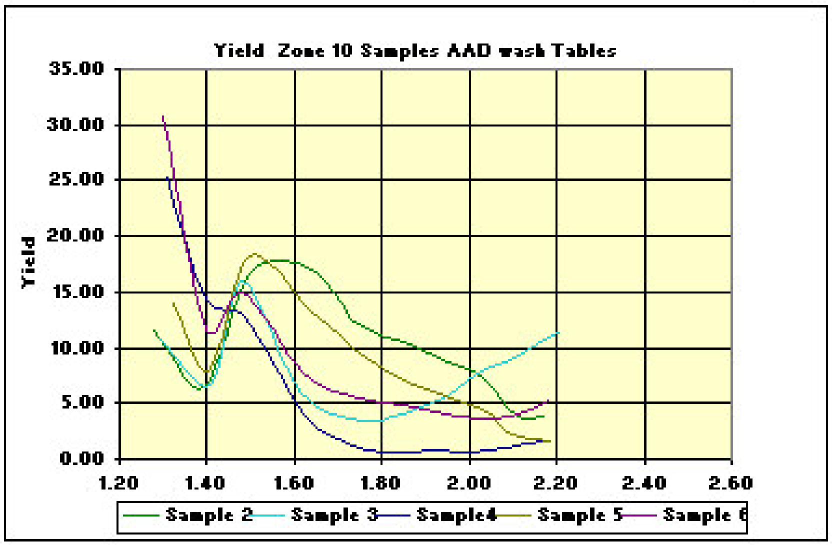

ZONE 6
Sample 19 - 21
ZONE 5
Sample 7 - 9
Sample 18
Sample 19
Sample 20
Sample 21
Sample 22a
Sample 22b
Sample 22c
Sample 22d
Sample 22e
Yield Zone 6 Samples Standard wash Tables
Yield
Sample 19
Sample20
Composite Wash Table
Fractional Density
Zone 6 SPR
Yield Zone 5 Samples AAD wash Tables
Sample 22A
Sample22B
Sample 22D
Sample 22E
Composite Wash Table
Fractional Density
Zone 5 SPR

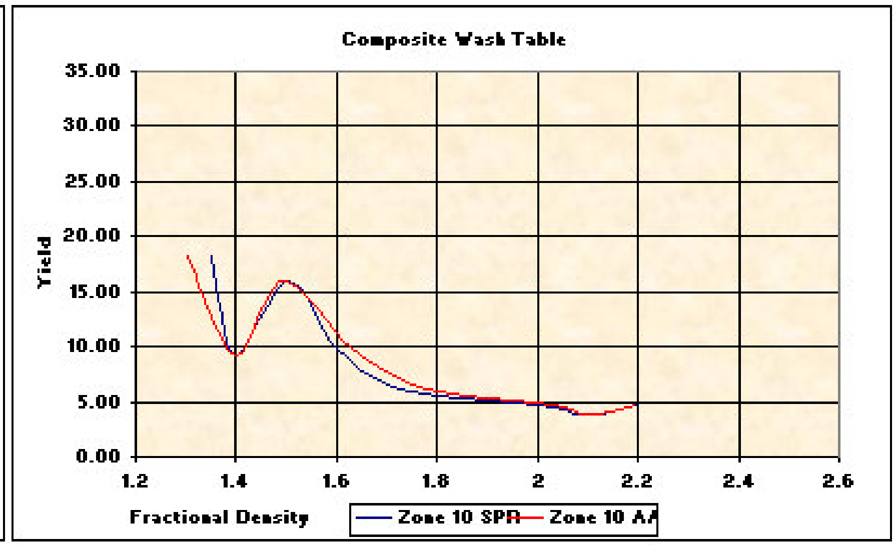

ZONE 4
Sample 23a - 23c
ZONE 4a
Sample 24
ZONE 3
Sample 26 - 29
Sample 22fs
Sample 23a - 23
Sample 24
Sample 26 -
Yield Zone 4 Samples AAD wash Tables
Yield
Sample 23A
Sample23B
Sample23
Composite Wash Table
Fractional Density
Zone 4 SPR
Zone4 AA
Composite Wash Table
Fractional Densi
Zone 4a SPR
Zone 4a A
Yield Zone 3 Samples AAD wash Tables
Sample 26
Sample 27
Sample 28
Sample 29
Composite Wash Table
Fractio
Zone 3 SPR
Zone 3 AAD

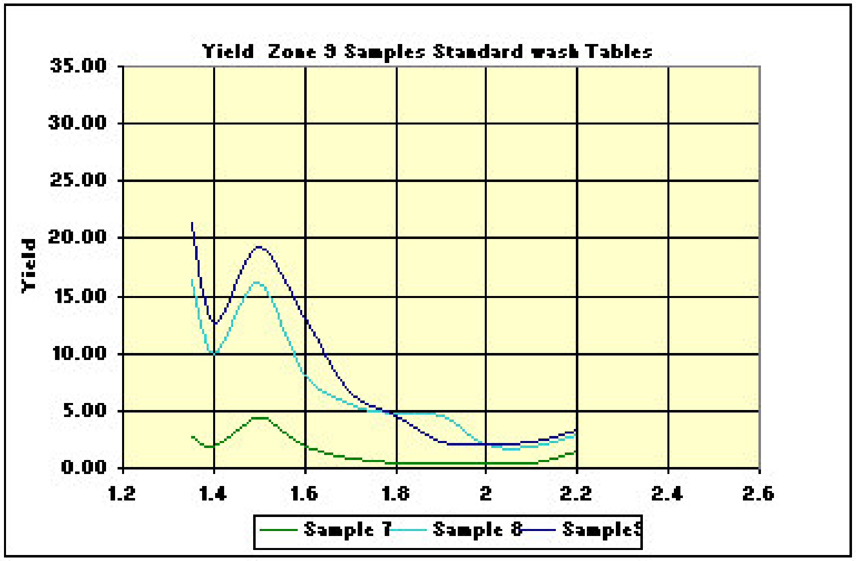

ZONE 2
Sample 30 - 31
ZONE 1
Sample 32
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
Sample 30 - 31
Sample 32
Composite Wash Table
Yield
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1.2
1.7
2.2
Fractional Den
Zone 2 SPR
Zone 2 AAD
Composite Wash Table
Yield
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1.2
1.7
2.2
Fraction
Zone 1 SPR
Zone 1 AA



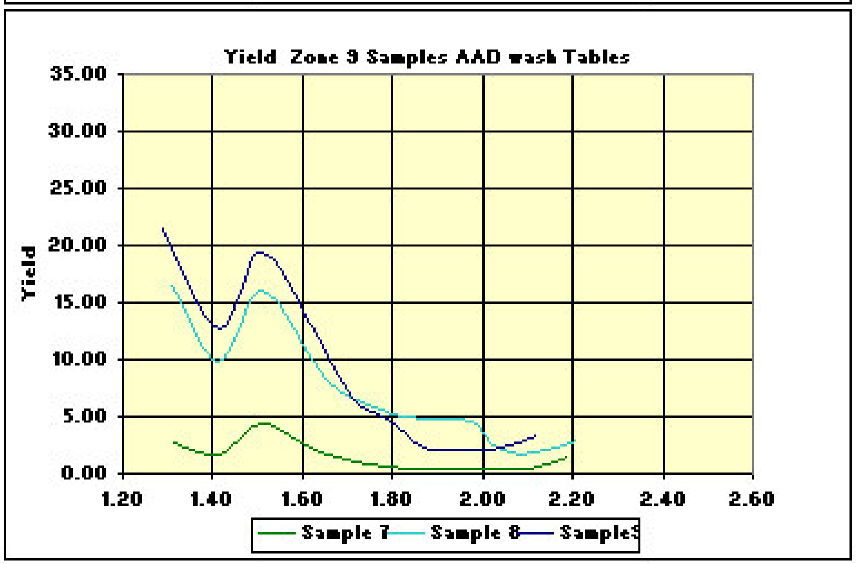
	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone10	1.35	1.30	18.15	2.31	7.75	38.03	5.68	79.00	1.23	30.37
zone10	1.4	1.40	9.19	2.03	14.82	36.69	4.83	71.00	1.30	27.78
zone10	1.5	1.49	16.06	2.00	21.55	33.24	3.13	41.00	1.39	25.48
zone10	1.6	1.63	9.81	1.92	31.95	28.91	0.92	15.00	1.40	21.58
zone10	1.7	1.75	6.55	1.87	40.70	25.13	0.66	0.00	1.27	18.25
zone10	1.8	1.85	5.56	1.91	48.14	21.96	0.00	0.00	1.16	15.41
zone10	1.9	1.95	5.04	2.48	55.36	18.97	0.00	0.00	1.06	12.28
zone10	2	2.03	4.78	2.60	61.21	16.87	0.00	0.00	1.06	9.86
zone10	2.1	2.10	3.93	2.76	66.46	14.59	0.00	0.00	1.05	7.81
zone10	2.2	2.20	4.70	2.58	73.36	12.08	0.00	0.00	0.90	5.34
zone10	9.99	2.28	16.23	1.90	79.88	10.85	0.00	0.00	5.88	2.92

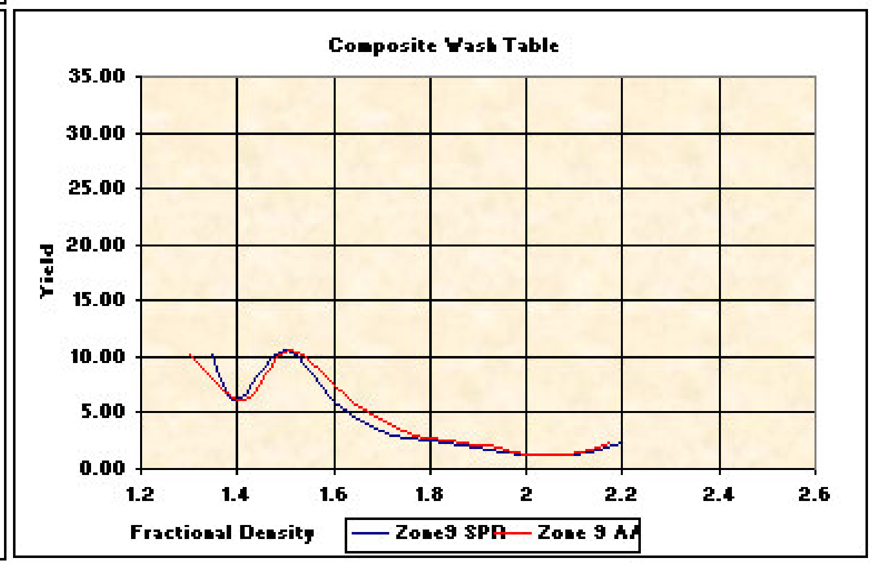


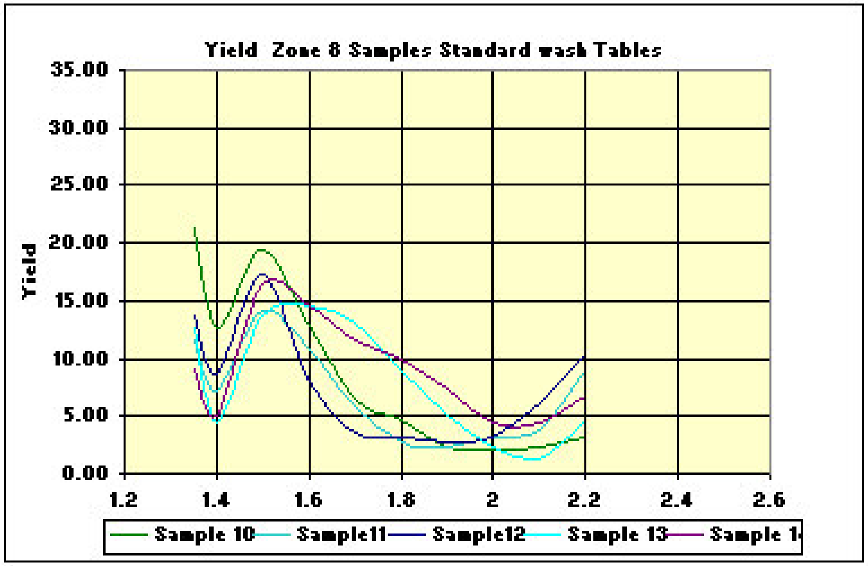




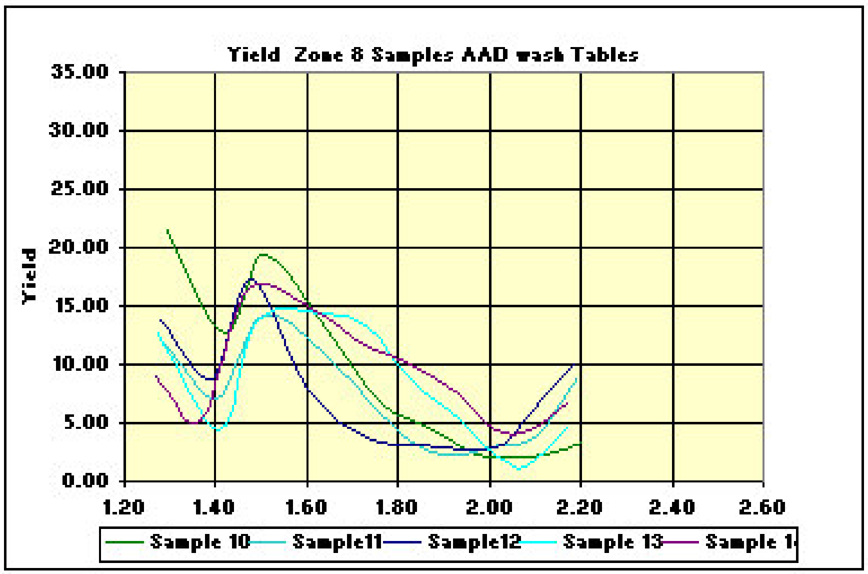
	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone9	1.35	1.30	10.22	2.17	7.59	36.95	5.64	78.00	0.96	30.25
zone9	1.4	1.41	6.18	2.10	15.85	35.21	4.98	73.00	1.09	27.41
zone9	1.5	1.51	10.57	1.82	22.87	32.26	3.11	40.00	1.17	25.06
zone9	1.6	1.64	5.85	1.80	32.29	28.63	0.83	13.00	1.66	21.47
zone9	1.7	1.74	3.30	1.73	40.17	25.69	0.33	0.00	2.04	18.57
zone9	1.8	1.84	2.47	1.71	47.20	22.95	0.00	0.00	2.20	15.71
zone9	1.9	1.94	1.90	1.57	54.68	20.81	0.00	0.00	2.00	12.78
zone9	2	2.00	1.17	1.85	58.75	18.06	0.00	0.00	2.70	11.04
zone9	2.1	2.09	1.21	2.02	65.32	14.98	0.00	0.00	2.23	8.42
zone9	2.2	2.18	2.27	2.11	71.88	12.11	0.00	0.00	1.75	5.90
zone9	9.99	2.35	54.86	1.71	84.99	9.35	0.00	0.00	1.92	0.71

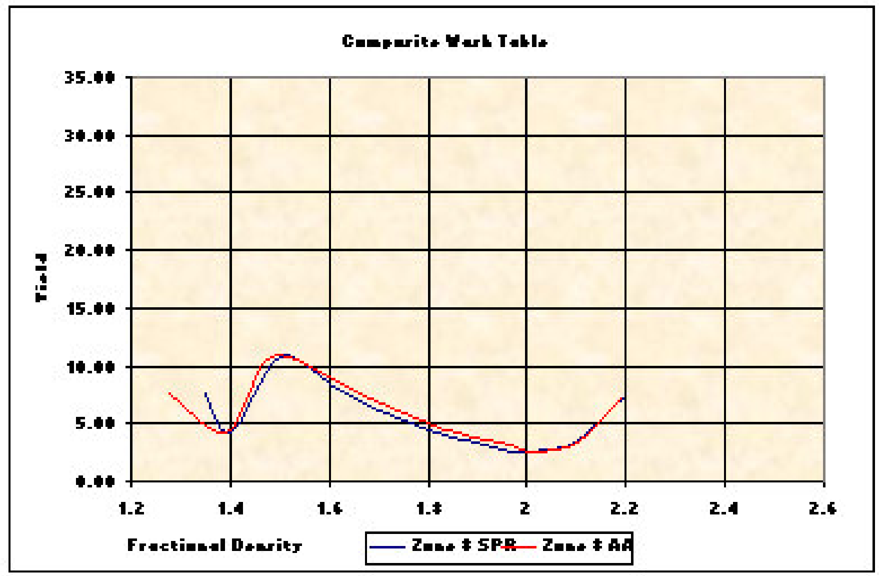


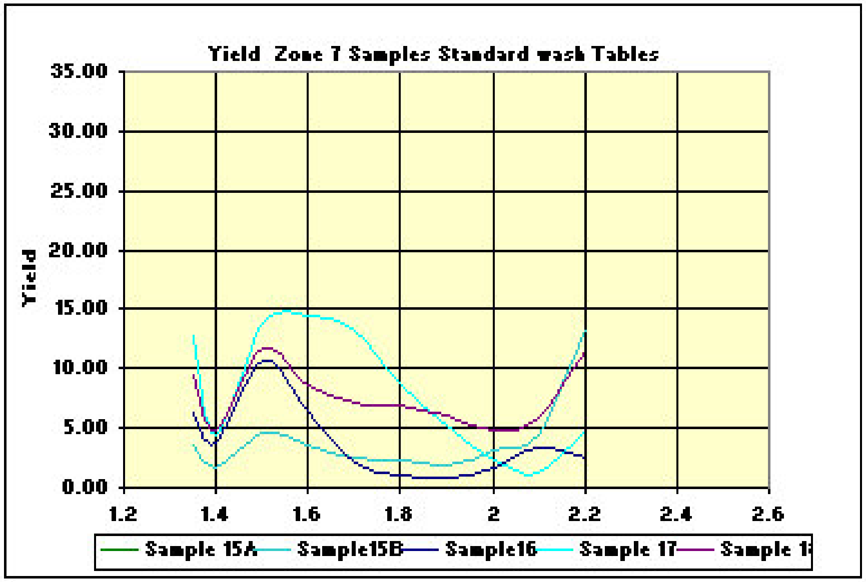




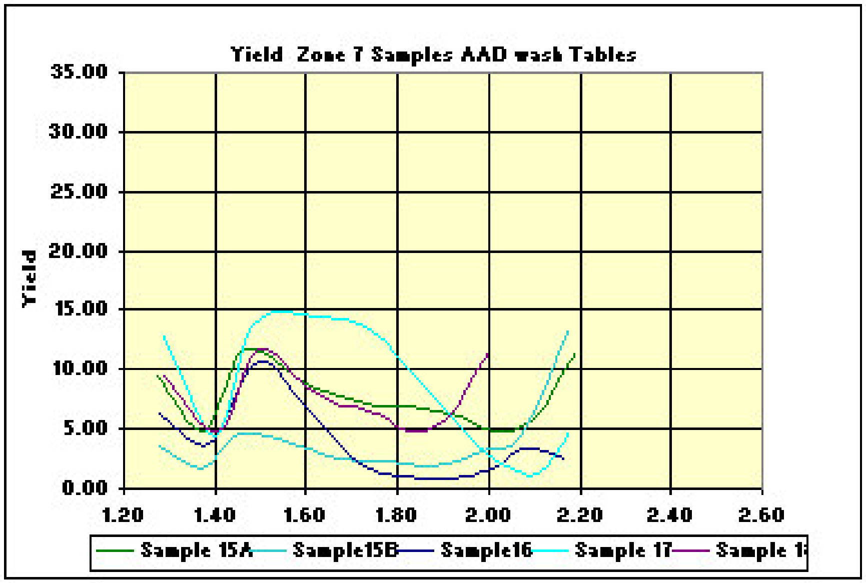
	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone8	1.35	1.28	7.55	2.31	5.88	37.19	5.37	77.00	0.96	30.60
zone8	1.4	1.39	4.20	1.88	14.25	35.02	4.58	62.00	1.12	27.85
zone8	1.5	1.48	10.85	1.93	21.09	31.73	1.87	23.00	1.08	25.38
zone8	1.6	1.62	8.46	1.83	31.37	27.66	0.85	12.00	1.12	21.54
zone8	1.7	1.74	6.06	1.76	39.61	24.17	0.11	0.00	0.97	18.48
zone8	1.8	1.84	4.47	1.83	46.85	21.74	0.00	0.00	0.92	15.67
zone8	1.9	1.94	3.29	1.70	54.65	18.87	0.00	0.00	0.95	12.57
zone8	2	2.02	2.58	1.71	60.64	16.54	0.00	0.00	0.96	9.90
zone8	2.1	2.10	3.29	1.67	66.50	14.18	0.00	0.00	0.68	7.35
zone8	2.2	2.19	7.40	1.73	73.17	12.06	0.00	0.00	0.49	5.12
zone8	9.99	2.34	41.85	1.02	83.64	9.84	0.00	0.00	2.30	1.28

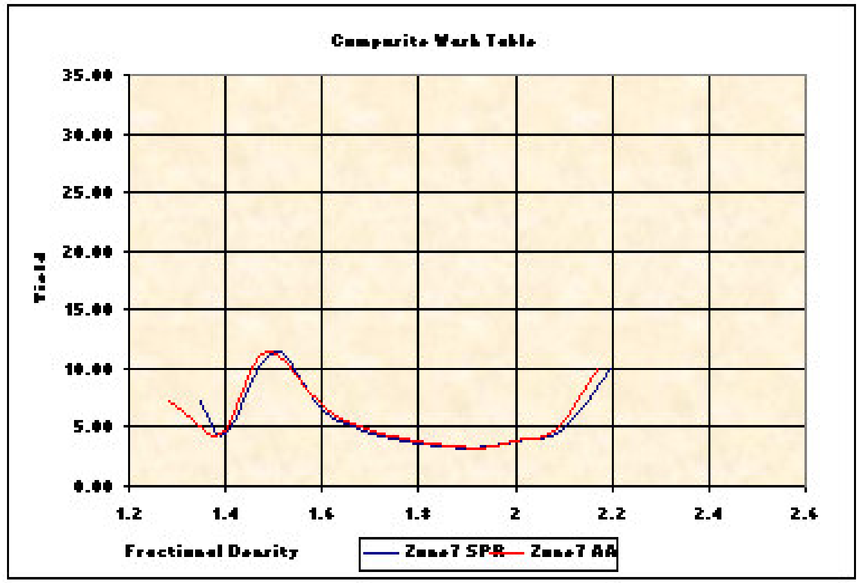


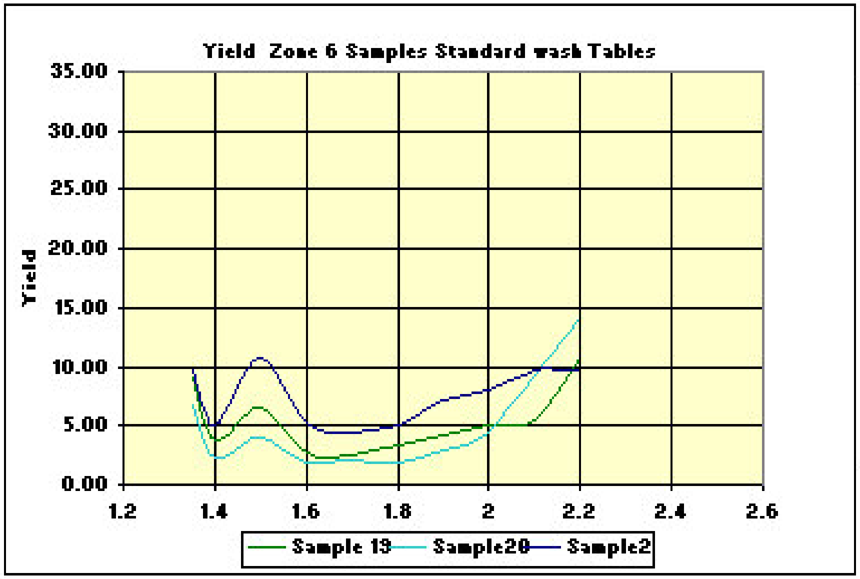




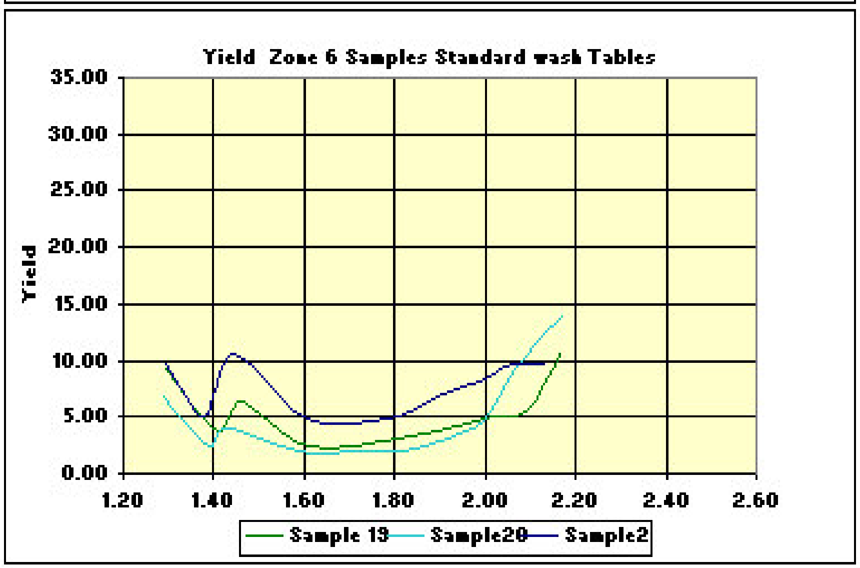
	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone7	1.35	1.28	7.19	2.26	6.17	37.28	5.30	76.00	0.94	30.79
zone7	1.4	1.39	4.50	1.95	14.27	35.58	4.59	67.00	1.12	28.02
zone7	1.5	1.48	11.39	1.81	20.79	32.66	1.87	25.00	1.11	25.60
zone7	1.6	1.61	6.63	1.69	30.15	29.21	0.86	14.00	1.26	22.09
zone7	1.7	1.72	4.47	1.54	38.35	26.03	0.22	0.00	1.31	18.94
zone7	1.8	1.82	3.63	1.63	45.68	23.15	0.00	0.00	1.17	16.00
zone7	1.9	1.92	3.22	1.63	52.90	20.18	0.00	0.00	1.06	13.03
zone7	2	2.00	3.71	1.54	58.78	18.14	0.00	0.00	0.93	10.44
zone7	2.1	2.09	4.79	1.42	65.24	15.81	0.00	0.00	0.70	7.98
zone7	2.2	2.18	10.17	1.39	71.85	13.21	0.00	0.00	0.47	5.24
zone7	9.99	2.29	40.30	1.15	79.94	11.81	0.00	0.00	2.63	2.69

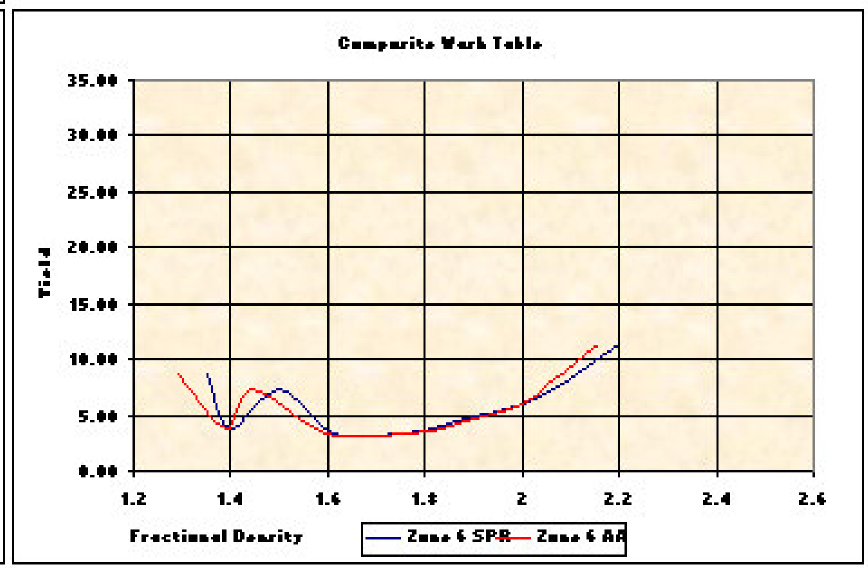


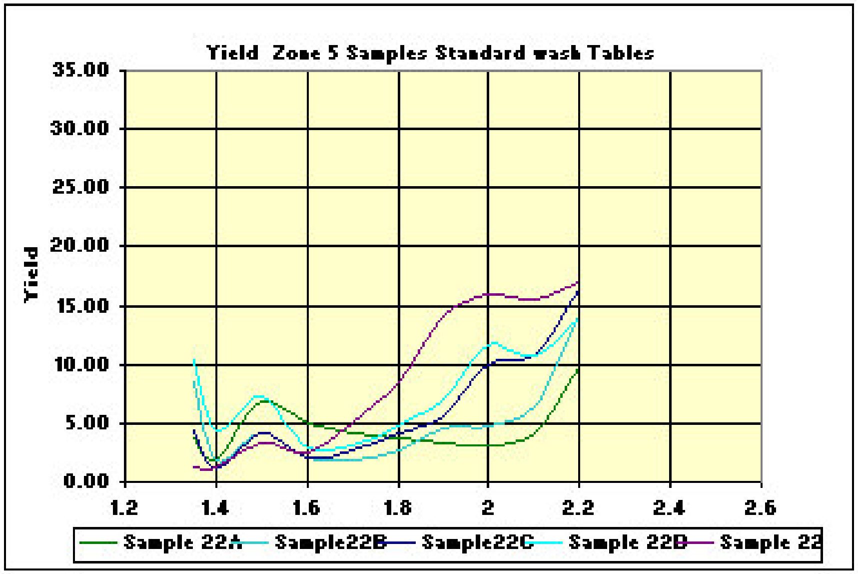




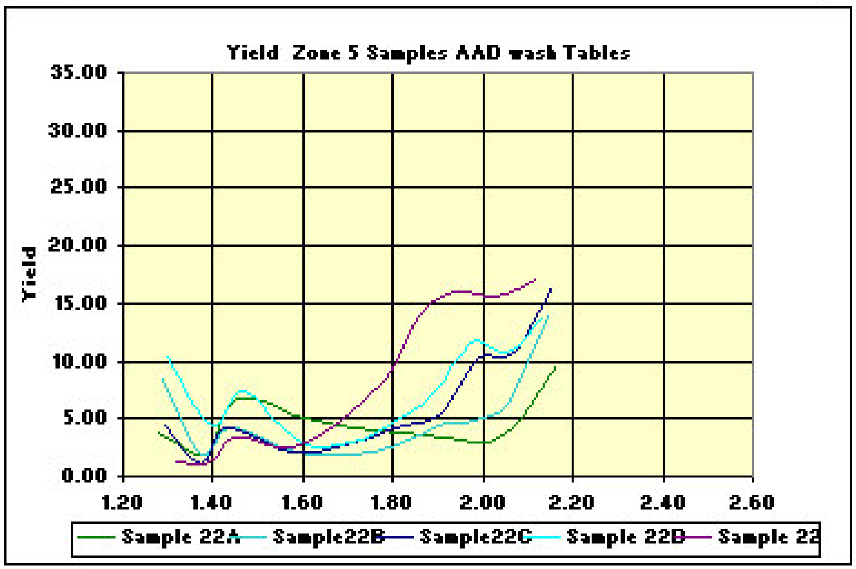
	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone6	1.35	1.29	8.61	2.14	6.98	37.75	5.38	74.00	1.17	30.61
zone6	1.4	1.39	3.87	1.77	14.00	36.07	4.41	56.00	1.22	28.09
zone6	1.5	1.45	7.36	1.94	18.24	32.45	1.55	21.00	1.15	26.39
zone6	1.6	1.58	3.46	1.74	28.39	29.53	0.73	12.00	1.13	22.41
zone6	1.7	1.70	3.08	1.55	37.18	26.37	0.37	0.00	0.94	18.99
zone6	1.8	1.82	3.61	1.58	45.58	23.10	0.07	0.00	0.73	15.95
zone6	1.9	1.92	5.01	1.72	52.93	20.07	0.00	0.00	0.55	12.96
zone6	2	2.00	6.08	1.72	58.95	17.91	0.00	0.00	0.51	10.21
zone6	2.1	2.07	8.28	2.00	63.94	15.56	0.00	0.00	0.42	7.99
zone6	2.2	2.16	11.35	1.77	70.68	13.54	0.00	0.00	0.34	5.42
zone6	9.99	2.26	39.30	1.26	78.21	12.35	0.00	0.00	2.80	2.53

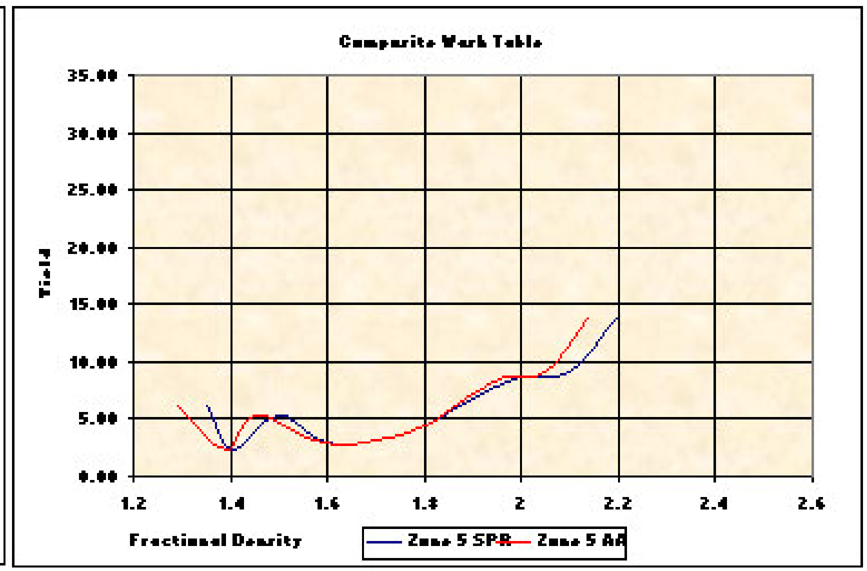


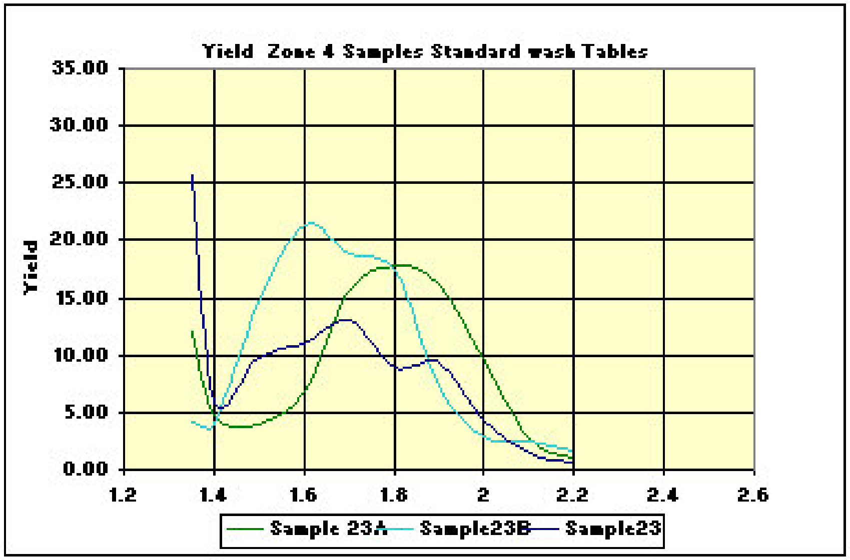




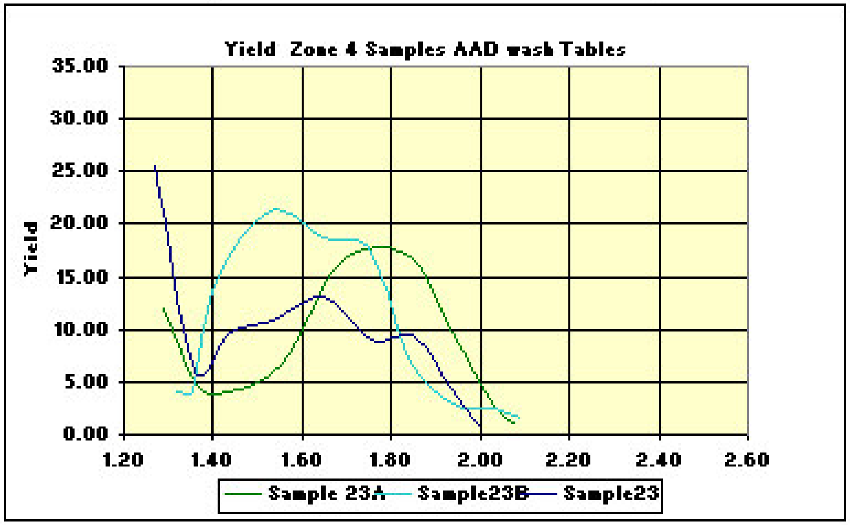
	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone5	1.35	1.29	6.24	2.20	7.04	37.12	4.79	70.00	0.84	30.84
zone5	1.4	1.39	2.24	1.93	13.91	34.84	3.05	40.00	0.91	28.21
zone5	1.5	1.45	5.27	1.99	18.59	32.49	1.05	15.00	0.97	26.14
zone5	1.6	1.59	2.93	1.85	28.96	28.83	0.49	8.00	0.92	22.06
zone5	1.7	1.70	3.21	1.99	36.79	25.10	0.17	0.00	0.78	18.87
zone5	1.8	1.80	4.53	2.13	44.24	21.39	0.03	0.00	0.58	16.14
zone5	1.9	1.88	6.70	2.62	50.42	18.58	0.00	0.00	0.45	13.40
zone5	2	1.97	8.69	2.24	56.67	16.67	0.00	0.00	0.38	10.86
zone5	2.1	2.05	9.12	2.17	62.70	15.16	0.00	0.00	0.35	8.15
zone5	2.2	2.14	14.01	1.90	69.46	13.75	0.00	0.00	0.31	5.62
zone5	9.99	2.26	37.05	1.19	78.06	12.64	0.00	0.00	2.58	2.67

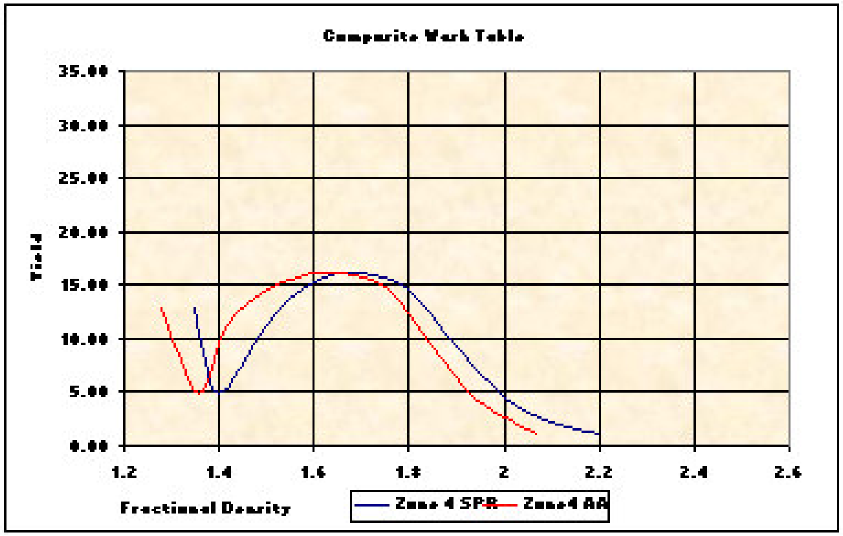




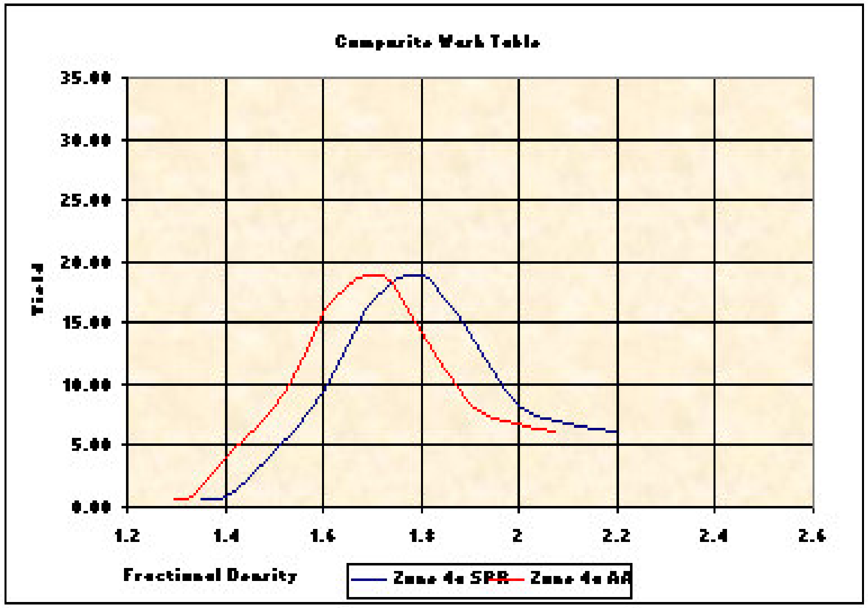


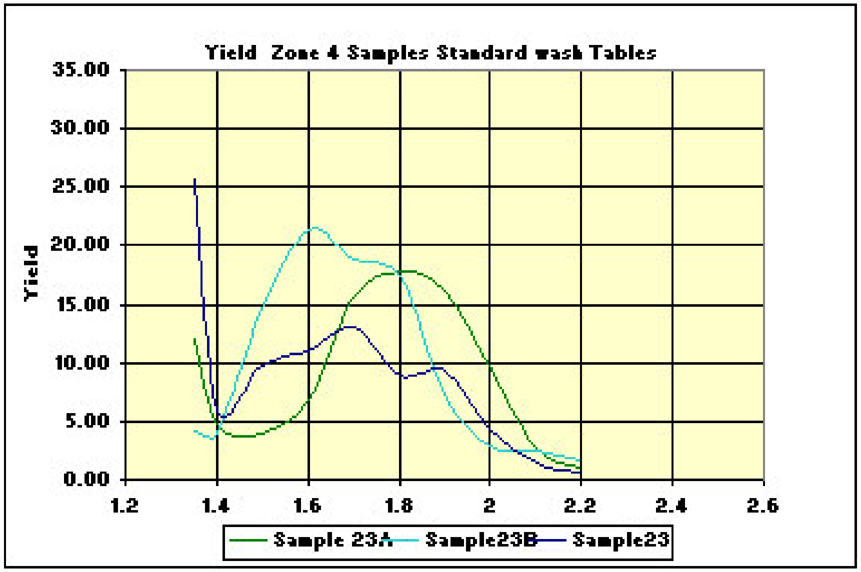
	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone 4	1.35	1.28	12.91	2.17	6.04	36.38	4.71	65.00	0.83	31.50
zone 4	1.4	1.36	4.83	2.01	11.82	32.23	1.42	21.00	0.74	29.02
zone 4	1.5	1.42	11.21	1.81	16.10	27.05	1.00	15.00	0.64	27.02
zone 4	1.6	1.53	15.34	1.75	24.54	23.66	0.50	14.00	0.57	23.51
zone 4	1.7	1.65	16.27	1.55	33.46	21.63	0.00	0.00	0.45	20.08
zone 4	1.8	1.76	14.51	1.59	41.02	19.76	0.00	0.00	0.39	17.01
zone 4	1.9	1.85	9.38	1.55	48.03	18.78	0.00	0.00	0.39	14.23
zone 4	2	1.94	4.52	1.49	54.39	17.41	0.00	0.00	0.56	11.64
zone 4	2.1	2.02	2.11	1.41	60.40	17.12	0.00	0.00	1.37	8.51
zone 4	2.2	2.07	1.19	1.41	64.25	17.00	0.00	0.00	2.19	7.04



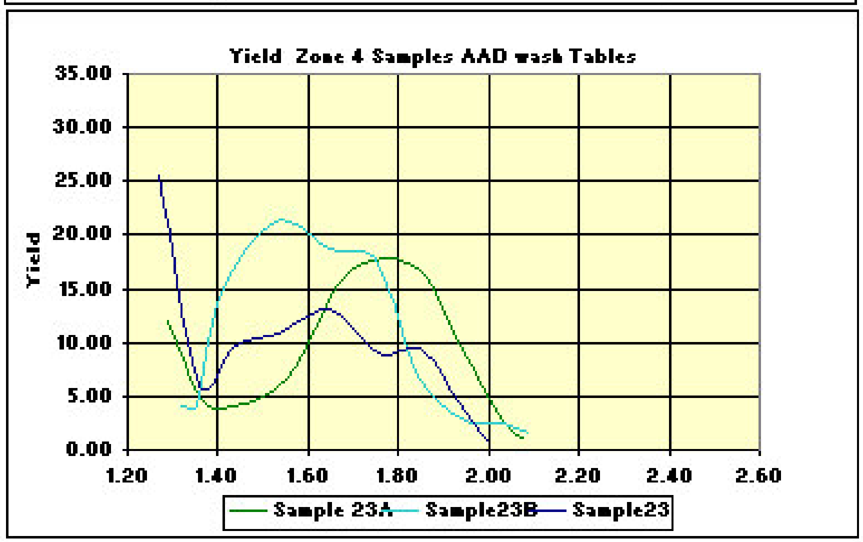


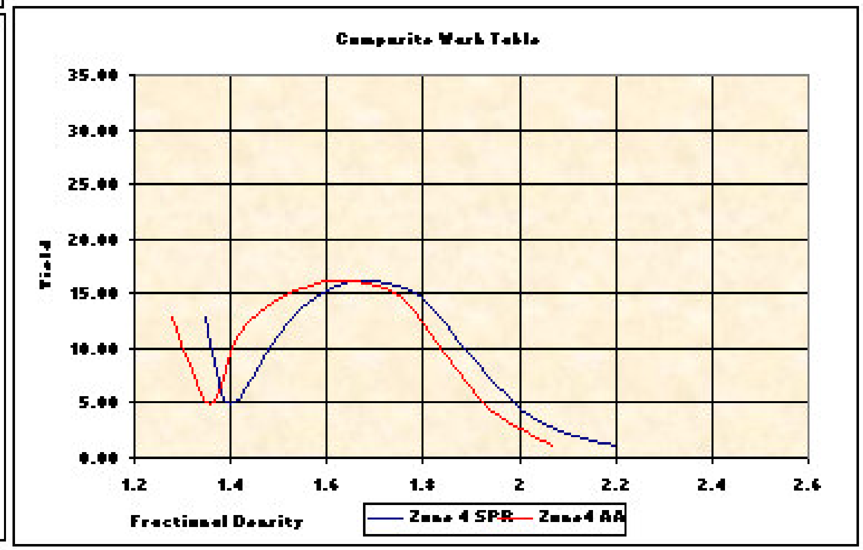
	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone 4a	1.35	1.30	0.73	2.67	7.17	32.17	2.50	28.00	0.53	30.36
zone 4a	1.4	1.33	0.86	2.73	9.95	29.69	1.00	17.00	0.50	28.97
zone 4a	1.5	1.41	4.53	2.50	15.69	25.21	0.50	9.00	0.45	26.57
zone 4a	1.6	1.52	9.43	2.43	23.65	22.33	0.50	3.00	0.49	23.45
zone 4a	1.7	1.62	16.77	2.25	30.75	20.89	0.00	0.00	0.56	20.68
zone 4a	1.8	1.72	18.92	2.06	38.26	19.69	0.00	0.00	0.49	17.69
zone 4a	1.9	1.80	14.23	1.75	44.32	19.35	0.00	0.00	0.53	15.14
zone 4a	2	1.90	8.23	1.95	51.89	18.44	0.00	0.00	0.65	12.18
zone 4a	2.1	1.99	6.81	1.61	58.50	18.30	0.00	0.00	0.79	9.18
zone 4a	2.2	2.08	6.08	1.71	64.60	16.36	0.00	0.00	0.49	6.47
zone 4a	9.99	2.12	13.42	1.45	67.66	18.36	0.00	0.00	11.62	5.98

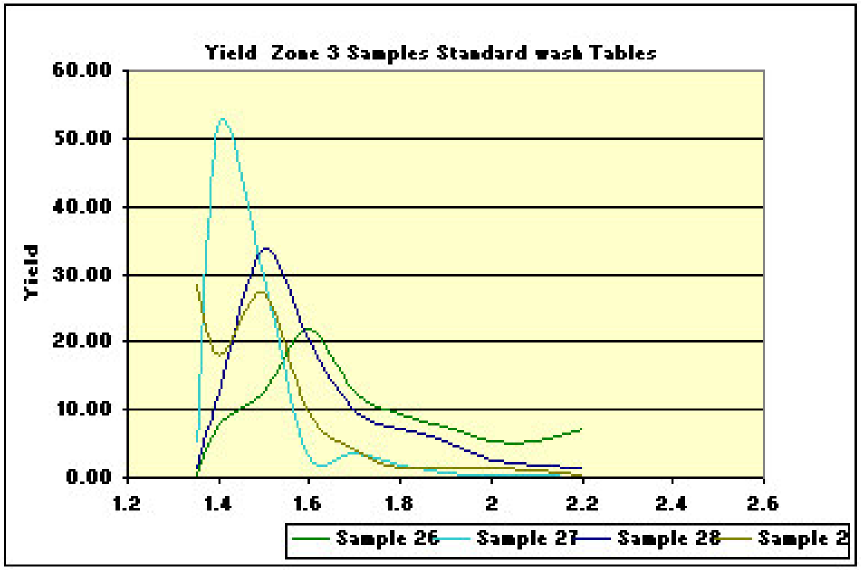




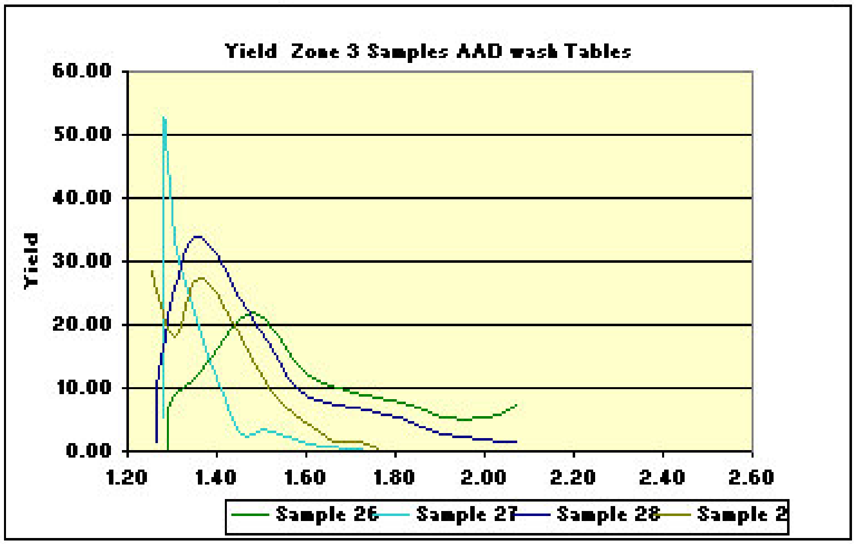
	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone4	1.35	1.28	12.91	2.17	6.04	36.38	4.71	65.00	0.83	31.50
zone4	1.4	1.36	4.83	2.01	11.82	32.23	1.42	21.00	0.74	29.02
zone4	1.5	1.42	11.21	1.81	16.10	27.05	1.00	15.00	0.64	27.02
zone4	1.6	1.53	15.34	1.75	24.54	23.66	0.50	14.00	0.57	23.51
zone4	1.7	1.65	16.27	1.55	33.46	21.63	0.00	0.00	0.45	20.08
zone4	1.8	1.76	14.51	1.59	41.02	19.76	0.00	0.00	0.39	17.01
zone4	1.9	1.85	9.38	1.55	48.03	18.78	0.00	0.00	0.39	14.23
zone4	2	1.94	4.52	1.49	54.39	17.41	0.00	0.00	0.56	11.64
zone4	2.1	2.02	2.11	1.41	60.40	17.12	0.00	0.00	1.37	8.51
zone4	2.2	2.07	1.19	1.41	64.25	17.00	0.00	0.00	2.19	7.04

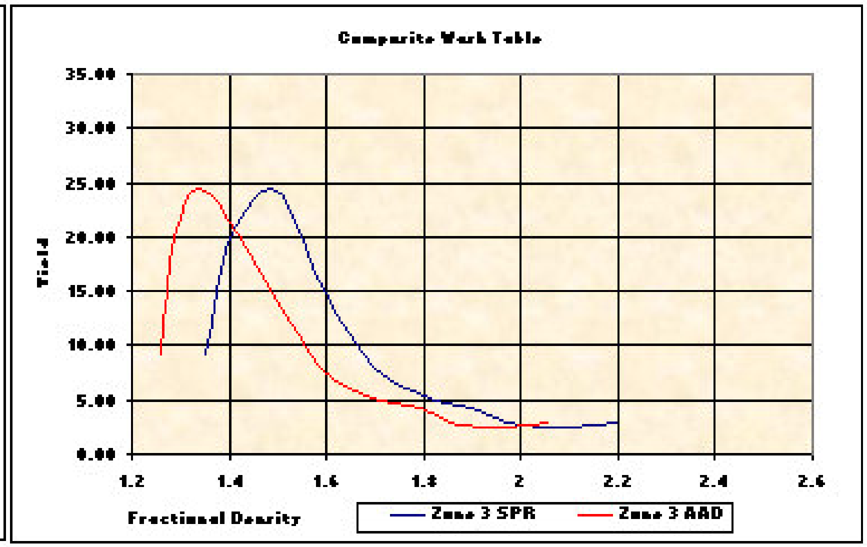




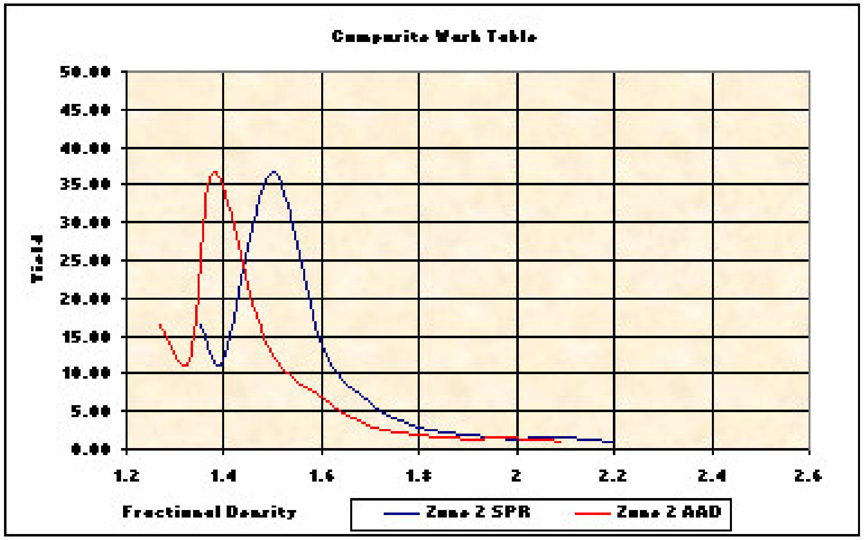


	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone3	1.35	1.26	9.22	2.39	4.48	30.11	1.29	18.00	0.85	31.52
zone3	1.4	1.29	19.89	2.65	6.53	22.45	0.00	0.00	0.60	30.51
zone3	1.5	1.35	24.23	2.50	11.23	21.54	0.00	0.00	0.57	28.49
zone3	1.6	1.49	14.81	2.20	21.30	20.19	0.00	0.00	0.51	24.21
zone3	1.7	1.59	7.84	1.96	28.94	20.91	0.00	0.00	0.46	20.68
zone3	1.8	1.68	5.39	1.74	35.63	21.34	0.00	0.00	0.49	17.60
zone3	1.9	1.79	4.22	1.45	43.64	20.17	0.00	0.00	0.50	14.63
zone3	2	1.88	2.77	1.32	49.81	20.14	0.00	0.00	0.48	11.87
zone3	2.1	1.97	2.50	1.10	56.90	18.65	0.00	0.00	0.56	8.64
zone3	2.2	2.06	2.92	1.20	63.40	16.73	0.00	0.00	0.51	6.56

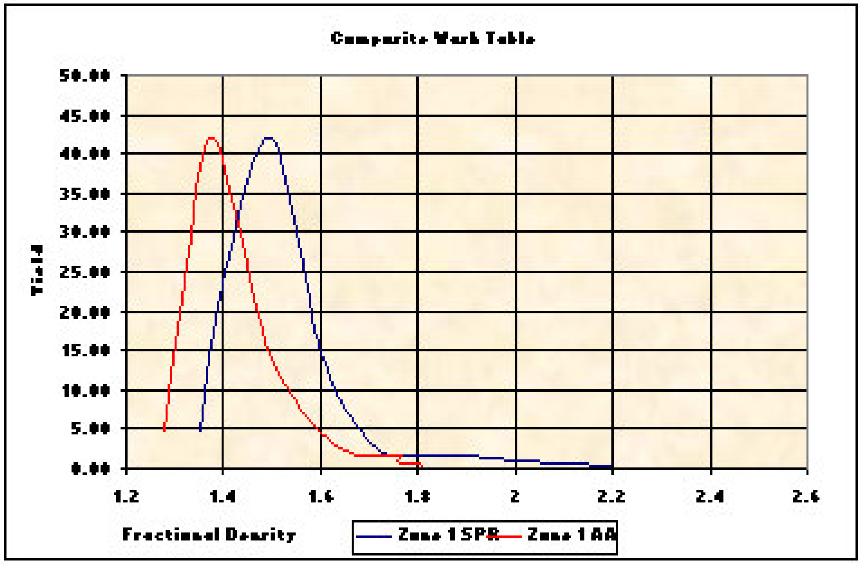




	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone2	1.35	1.27	16.49	2.21	5.16	32.17	2.02	24.00	0.82	31.52
zone2	1.4	1.33	11.61	2.12	9.66	25.33	0.29	5.00	0.78	29.53
zone2	1.5	1.38	36.68	1.99	13.30	22.35	0.00	0.00	0.63	28.00
zone2	1.6	1.49	13.46	1.87	21.61	20.99	0.00	0.00	0.57	24.51
zone2	1.7	1.62	6.08	1.64	30.87	21.11	0.00	0.00	0.57	20.53
zone2	1.8	1.71	2.87	1.45	37.53	22.61	0.00	0.00	0.54	17.38
zone2	1.9	1.80	1.91	1.15	44.41	22.77	0.00	0.00	0.54	14.16
zone2	2	1.92	1.27	1.05	53.32	18.97	0.00	0.00	0.78	11.54
zone2	2.1	1.96	1.48	0.98	55.82	20.74	0.00	0.00	1.05	9.18
zone2	2.2	2.10	0.85	0.78	65.96	16.18	0.00	0.00	1.50	6.81



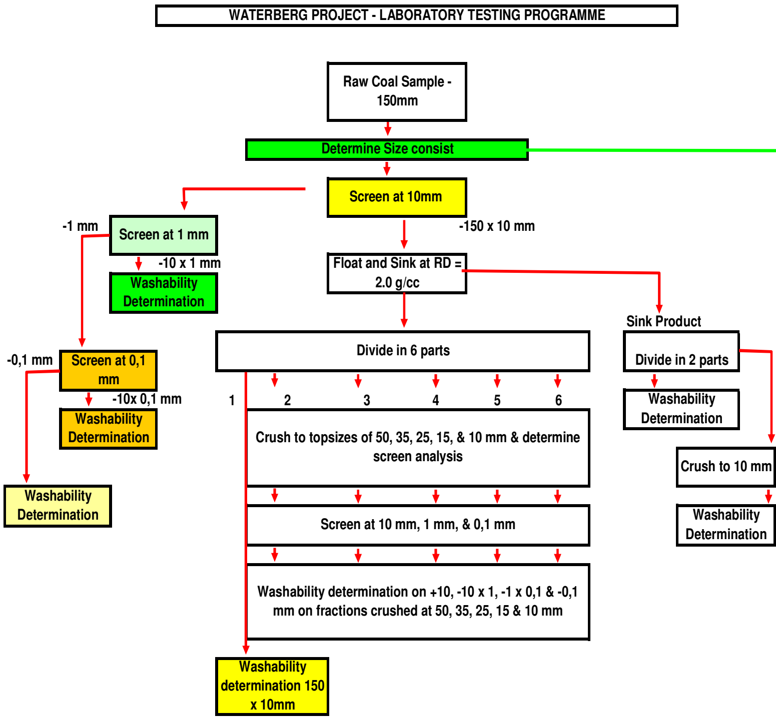
	RD_2	AAD-Rd	YIELD	MOIST	ASH	VOL	SWELL	ROGA	S	CV
zone1	1.35	1.28	4.80	2.22	5.79	30.00	1.00	17.00	0.62	31.41
zone1	1.4	1.32	23.29	2.15	8.98	24.44	0.00	0.00	0.53	29.83
zone1	1.5	1.38	41.92	2.18	13.32	21.03	0.00	0.00	0.48	27.94
zone1	1.6	1.49	14.61	2.11	21.71	19.29	0.00	0.00	0.48	24.64
zone1	1.7	1.62	3.17	1.53	31.28	18.81	0.00	0.00	0.51	21.03
zone1	1.8	1.72	1.72	1.42	38.05	19.34	0.00	0.00	0.62	17.86
zone1	1.9	1.77	1.61	1.24	41.75	23.38	0.00	0.00	0.92	15.14
zone1	2	1.76	0.94	1.10	41.05	31.68	0.00	0.00	1.60	13.81
zone1	2.1	1.78	0.62	0.92	42.58	34.90	0.00	0.00	2.41	10.79
zone1	2.2	1.81	0.35	0.94	45.04	35.19	0.00	0.00	2.76	9.33



APPENDIX F

ADDENDUM TO REPORT ON THE APPLICATION OF METHODOLOGY TO GG6 BENEFICIATION PLANT

During 1991 and 1992 work was conducted by G J De Korte and published in a report sponsored by THE NATIONAL ENERGY COUNCIL, REF No 234/89,"THE UTILIZATION POTENTIAL OF COAL FROM THE WATERBERG COALFIELD ". The main objective of this report was to synthesize beneficiation data on Waterberg coal in order to assist decision makers in planning and design from a sound database. The work done here was based on a bulk sample obtained from mining bench 2 at Grootegeluk coal mine and was subjected to a carefully formulated project entailing, sampling, screening and analysis of different size fractions accordingly. The outline sketched below illustrates the breakdown of this project.

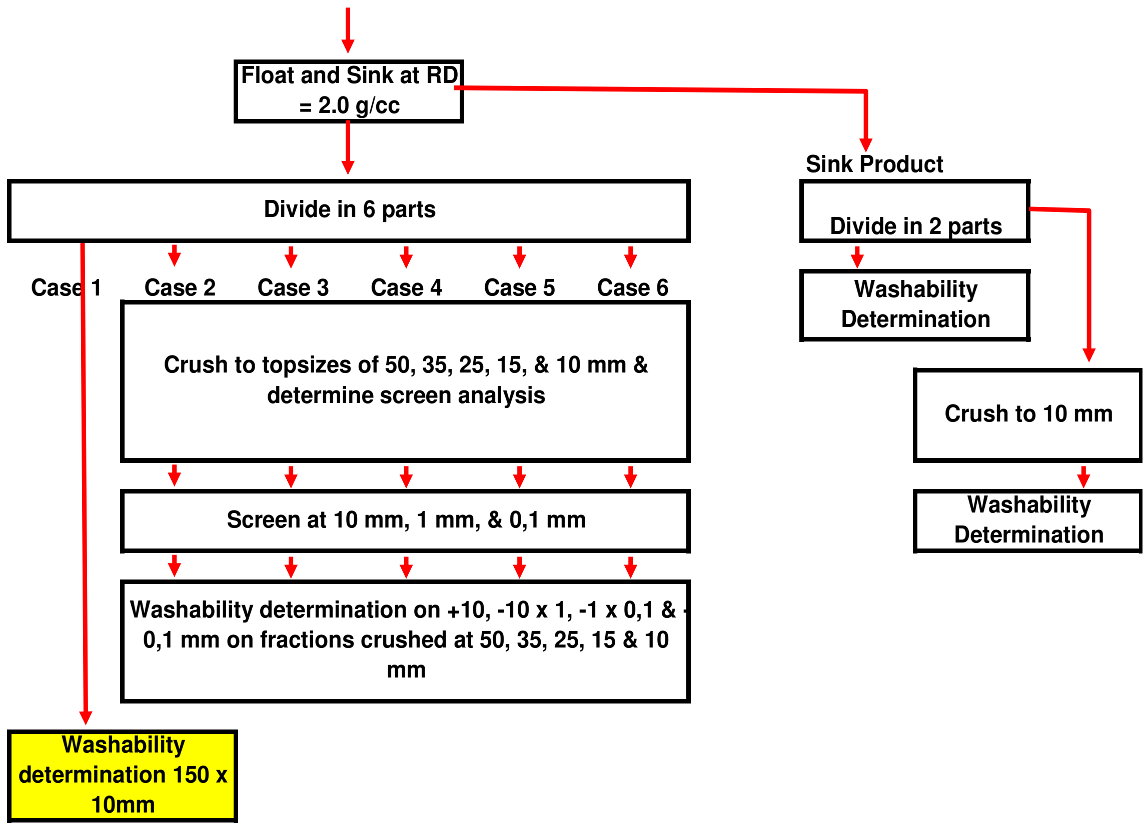


Sieve Size	Fractional yield	Cumulative Yield
-150 + 100	3.08	3.08
-100 + 75	5.56	8.64
-75 + 50	11.63	20.27
-50 + 35	11.30	31.57
-35 + 25	10.24	41.81
-25 + 15	14.23	56.04
-15 +10	11.77	67.81
-10 + 3	13.92	81.73
-3 +1	9.08	90.81
-1 +0.8	0.65	91.46
-0.8 +0.5	2.04	93.50
-0.5 +0.2	2.99	96.49
-0.2 +0.1	1.46	97.95
-0.1 + 0	2.05	100.00

67.81	Bath type Dense Medium separation
23	Dense Medium Cyclone
7.14	Spirals
2.05	Froth Flotation

I have taken the liberty of using this data to formulate a better understanding of the processes employed at Grootegeluk Coal Mine and more specifically problems encountered in the GG6 beneficiation plant with respect to the low ash coal or conversely the semi soft coking coal products and the influence of size fractions on yields of this product in this process. Thus the main area of concentration is based on the section pertaining to the division of bulk material in the size range <150mm and > 10mm into six equal samples and their concomitant wash tables and analysis.

CONSIDERING GG6 Plant



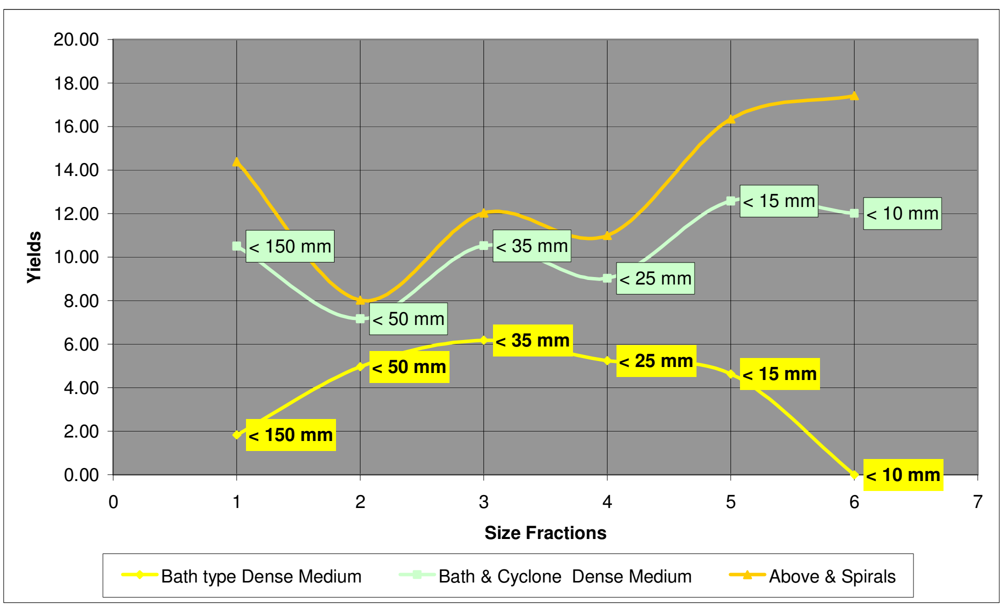
A Summary of the wash data from the tables in the appendix, in the tables below gives some indication of the optimal size fraction for economical extraction. The first table again represents the original fractional/size breakdown, yields obtained with the various methods of beneficiation and the actual methods utilized. The second small intermediary table cumulates the yields obtained by the individual methods and the last table shows cumulative yields for combinations of the methods. The beneficiation methods excluding froth flotation are applicable to both GG1 and GG6 plants at Grootegeluk.

Sieve Size	Fractional yield	Cumulative Yield		
-150 + 100	3.08	3.08	67.81	Bath type Dense Medium separation
-100 + 75	5.56	8.64		
-75 + 50	11.63	20.27		
-50 + 35	11.30	31.57		
-35 + 25	10.24	41.81		
-25 + 15	14.23	56.04		
-15 +10	11.77	67.81		
-10 + 3	13.92	81.73	23	Dense Medium Cyclone
-3 +1	9.08	90.81		
-1 +0.8	0.65	91.46	7.14	Spirals
-0.8 +0.5	2.04	93.50		
-0.5 +0.2	2.99	96.49		
-0.2 +0.1	1.46	97.95		
-0.1 + 0	2.05	100.00	2.05	Froth Flotation

CUMULATIVE TABLE

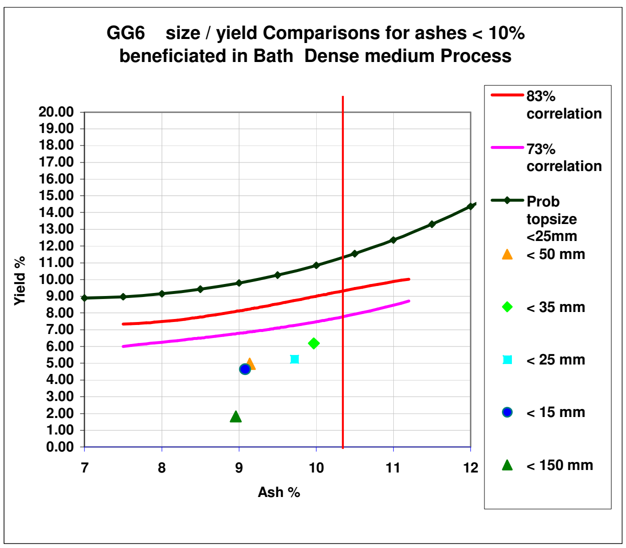
Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1.83	4.96	6.18	5.24	4.63	
8.67	2.21	4.35	3.79	7.94	12.01
3.88	0.86	1.50	1.96	3.76	5.40
0.56					

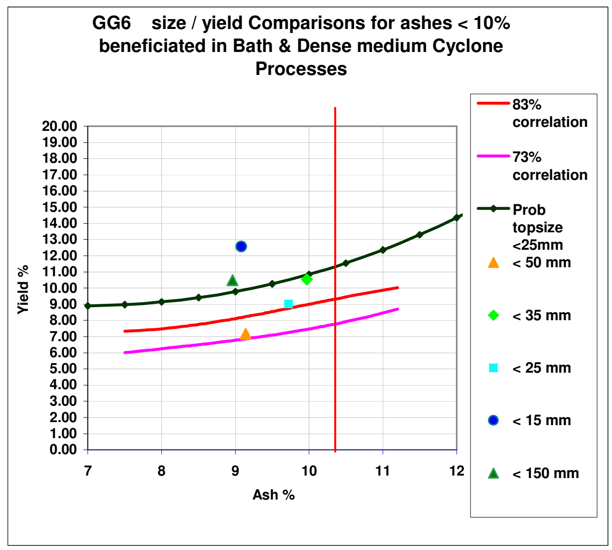
		< 150 mm	< 50 mm	< 35 mm	< 25 mm	< 15 mm	< 10 mm	Max Yields
Bath type Dense Medium	Yield=	1.83	4.96	6.18	5.24	4.63	0.00	6.18
Bath & Cyclone Dense Medium	Yield=	10.50	7.17	10.53	9.03	12.58	12.01	12.58
Above & Spirals	Yield=	14.38	8.03	12.03	10.99	16.34	17.41	17.41
& Froth Flotation	Yield=	14.93						

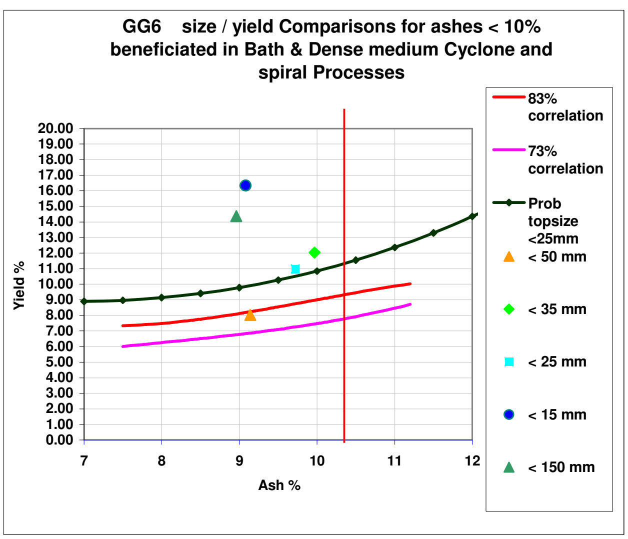


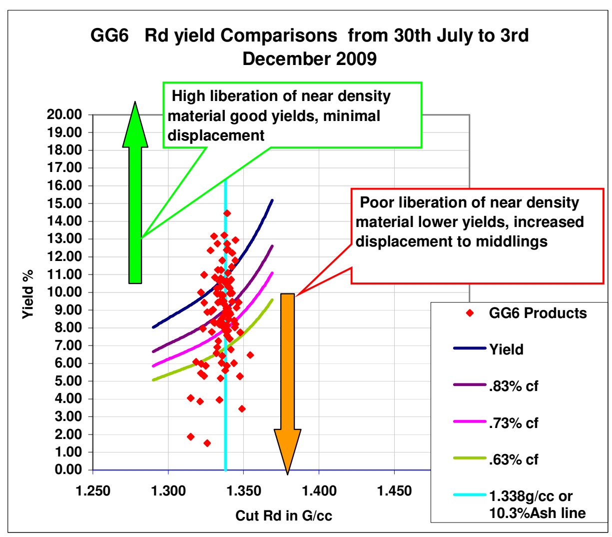
The plot above reflects the results of the six subdivided samples at their various top sizes and the beneficiation mediums used for separation. The yield distributions shown should not be misconstrued with any trends, the erratic nature may be attributable to the initial subdivision of the bulk sample since it may have been extremely difficult to obtain a relatively homogenous representative blend given the top sizes of the raw material.

From the above however, and as stated by G J De Korte, the 15mm top size in this exercise appears to be optimal, our own standards for laboratory analysis on exploration borehole core samples require the core to be broken to 13mm, this too, fits in the range between 10mm and 15mm. The loss of low ash coal to fines and super fines however increases as the top size is reduced and at these low top sizes, the loss at 15mm is less than that at 10mm, 15mm loss is approximately 2% while the loss, should the size be further reduced to 10mm increases to 5%+, therefore I too would be inclined to suggest that 15mm would be more acceptable.

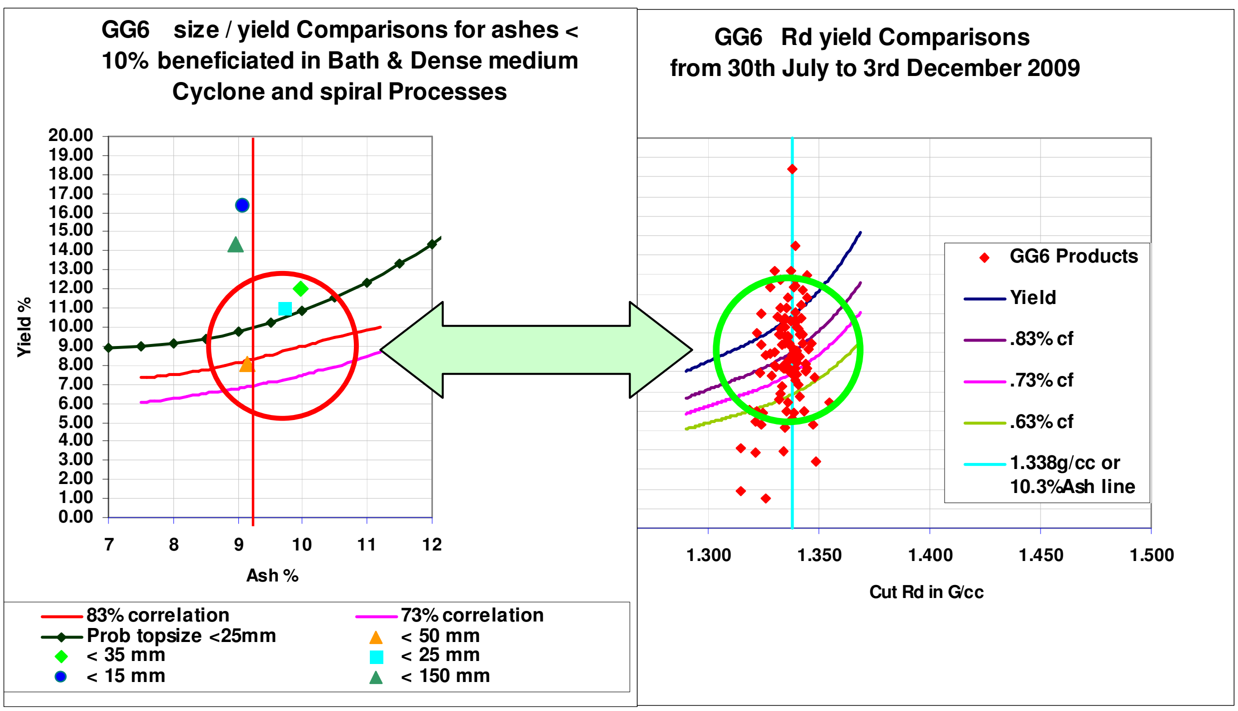








The above plots are a visual portrayal of the cumulative effects of the beneficiation processes starting with the drum/bath dense medium process, combining this with dense medium cyclones and lastly introducing spirals. The interesting phenomenon noted is that the current production results portrayed in the fourth plot appear to have their largest concentration between values from a 73% to 83% correlation. Comparing this with the size fraction plots, this cluster appears to fall in the 25mm to 50mm range and does not show a vast improvement in yield for the larger particles, while smaller fractions show greater yield increases as the size decreases. The 25mm to 35mm fractions exhibit a 1.5% to 2% yield improvement, while the 15mm fractions show a dramatic increase from 4.5% to 12.5% when only the drum and cyclone dense medium separation is considered and a further increase to approximately 16%+ when spirals are introduced, this represents another 3.5% increase in yield due to better liberation of low density material in the smaller size fraction. Most of the low ash coals are in the density range of 1.305g/cc and 1.334g/cc, this being lower than a 10.3% ash at 1.338g/cc.



Assessing the foregoing, GG6 plant cannot do any better than it currently is and a 73% correlation factor applied to predicted yields is attainable and justifiable given the top size distribution at present, some smaller fractions generated within the process may compliment the yields being obtained and result in higher than predicted yields, this however is not the norm. A reduction in top size would definitely benefit and if one could reduce this to the same top size as the exploration borehole cores or as close as possible to this, i.e. to 15mm, then an acceptable loss of approximately 2% to super fines can be accommodated and predicted yields for this plant would not require a correlation factor. The same can be said for GG1, which is currently using an 83% correlation factor and has a top size of 20mm.

L. Roux. 5th January 2010.

(Acting Resident Geologist)

Mineral Resources Management, Grootegeluk Coal Mine

APPENDIX F-A

The following sets of tables represent the different size fractions, their wash data and for the purpose of this exercise only ash has been included in the analysis, the tables on the left represent the actual laboratory data while the tables on the right have been adjusted to accommodate the AAD theory and give a more accurate representation of the true densities of the various products.

150 x 10 mm Fraction					
	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	0.3	3.1	0.3	3.1
f	1.35	2.4	9.7	2.7	8.966667
f	1.4	9.3	15.8	12	14.2625
f	1.45	11.1	24.5	23.1	19.18182
f	1.5	7.6	26.5	30.7	20.99349
f	1.55	3.9	31.1	34.6	22.13266
f	1.6	5.2	37	39.8	24.07513
f	1.65	2.9	40	42.7	25.15667
f	1.7	2.9	44.6	45.6	26.3932
f	1.75	2.2	48.7	47.8	27.41987
f	1.8	1.4	49.1	49.2	28.03679
f	1.85	0.5	54.2	49.7	28.3
f	1.9	1.6	55.7	51.3	29.15458
f	1.95	2.7	62.6	54	30.82685
f	2	2.1	81.5	56.1	32.72371
s	2	43.9	82.8	100	54.7072

150 x 10 mm Fraction					
	AAD RD	AAD Yield	AAD Ash	Cum Yld	Cum Ash
f	1.240	0.3	3.1	0.3	3.1
f	1.330	2.4	9.7	2.7	8.966667
f	1.413	9.3	15.8	12	14.2625
f	1.531	11.1	24.5	23.1	19.18182
f	1.558	7.6	26.5	30.7	20.99349
f	1.621	3.9	31.1	34.6	22.13266
f	1.701	5.2	37	39.8	24.07513
f	1.742	2.9	40	42.7	25.15667
f	1.805	2.9	44.6	45.6	26.3932
f	1.860	2.2	48.7	47.8	27.41987
f	1.866	1.4	49.1	49.2	28.03679
f	1.935	0.5	54.2	49.7	28.3
f	1.956	1.6	55.7	51.3	29.15458
f	2.049	2.7	62.6	54	30.82685
f	2.306	2.1	81.5	56.1	32.72371
s	2.324	43.9	82.8	100	54.7072

10 x 1 mm Fraction					
	RD	Yield	Ash	Cum Yld	Cum Ash
f	1.3	12.6	2.8	12.6	2.8
f	1.35	12.7	8.7	25.3	5.76166
f	1.4	12.4	15.1	37.7	8.833156
f	1.45	7.3	20.9	45	10.79067
f	1.5	6.7	25.9	51.7	12.74874
f	1.55	2.8	31.7	54.5	13.72239
f	1.6	2.6	34.9	57.1	14.68669
f	1.65	1.8	39.7	58.9	15.4511
f	1.7	1.9	40.5	60.8	16.23388
f	1.75	1.2	45.1	62	16.79258
f	1.8	1.1	47.1	63.1	17.32092
f	1.85	0.1	51.4	63.2	17.37484
f	1.9	0.1	55.9	63.3	17.4357
f	1.95	1.9	65.8	65.2	18.84509
f	2	3	75.3	68.2	21.32845
s	2	31.8	81.6	100	40.4948

10 x 1 mm Fraction					
	RD	Yield	Ash	Cum Yld	Cum Ash
f	1.236	12.6	2.8	12.6	2.8
f	1.316	12.7	8.7	25.3	5.76166
f	1.403	12.4	15.1	37.7	8.833156
f	1.482	7.3	20.9	45	10.79067
f	1.550	6.7	25.9	51.7	12.74874
f	1.629	2.8	31.7	54.5	13.72239
f	1.673	2.6	34.9	57.1	14.68669
f	1.738	1.8	39.7	58.9	15.4511
f	1.749	1.9	40.5	60.8	16.23388
f	1.811	1.2	45.1	62	16.79258
f	1.839	1.1	47.1	63.1	17.32092
f	1.897	0.1	51.4	63.2	17.37484
f	1.958	0.1	55.9	63.3	17.4357
f	2.093	1.9	65.8	65.2	18.84509
f	2.222	3	75.3	68.2	21.32845
s	2.308	31.8	81.6	100	40.4948

1 x 0.1 mm Fraction					
	RD	Yield	Ash	Cum Yld	Cum Ash
f	1.3	35.6	3	35.6	3
f	1.35	7.3	16.7	42.9	5.331235
f	1.4	11.4	23.1	54.3	9.061694
f	1.45	4.4	23.9	58.7	10.17394
f	1.5	3.1	27.2	61.8	11.02799
f	1.55	1.9	31.6	63.7	11.6416
f	1.6	1.6	35.4	65.3	12.22374
f	1.65	1.5	39.5	66.8	12.83623
f	1.7	1	47.6	67.8	13.34897
f	1.75	0.9	53.4	68.7	13.87365
f	1.8	1.2	53.6	69.9	14.55565
f	1.85	1.8	65.2	71.7	15.82706
f	1.9	2.4	72.8	74.1	17.67233
f	1.95	2.5	73.9	76.6	19.50744
f	2	4.2	76.4	80.8	22.46473
s	2	19.2	79.8	100	33.4731

1 x 0.1 mm Fraction					
	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.239	35.6	3	35.6	3
f	1.425	7.3	16.7	42.9	5.331235
f	1.512	11.4	23.1	54.3	9.061694
f	1.523	4.4	23.9	58.7	10.17394
f	1.568	3.1	27.2	61.8	11.02799
f	1.628	1.9	31.6	63.7	11.6416
f	1.679	1.6	35.4	65.3	12.22374
f	1.735	1.5	39.5	66.8	12.83623
f	1.845	1	47.6	67.8	13.34897
f	1.924	0.9	53.4	68.7	13.87365
f	1.927	1.2	53.6	69.9	14.55565
f	2.085	1.8	65.2	71.7	15.82706
f	2.188	2.4	72.8	74.1	17.67233
f	2.203	2.5	73.9	76.6	19.50744
f	2.237	4.2	76.4	80.8	22.46473
s	2.283	19.2	79.8	100	33.4731

0.1 x 0 mm Fraction					
	RD	Yield	Ash	Cum Yld	Cum Ash
f	1.3	10.2	4.6	10.2	4.6
f	1.35	1.5	7.5	11.7	4.971795
f	1.4	3.3	10.5	15	6.188
f	1.45	3.7	11.5	18.7	7.239037
f	1.5	4	12.5	22.7	8.166079
f	1.55	4.4	14.7	27.1	9.226937
f	1.6	4.8	16.9	31.9	10.3815
f	1.65	5.2	19.1	37.1	11.6035
f	1.7	5.5	19.3	42.6	12.59718
f	1.75	5.8	20.2	48.4	13.50826
f	1.8	6	21.6	54.4	14.40074
f	1.85	6.1	21.9	60.5	15.15686
f	1.9	6	23.9	66.5	15.94571
f	1.95	5.8	24.1	72.3	16.59986
f	2	5.6	29.4	77.9	17.52003
s	2	22.1	82.8	100	31.9469

0.1 x 0 mm Fraction					
	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.261	10.2	4.6	10.2	4.6
f	1.300	1.5	7.5	11.7	4.971795
f	1.341	3.3	10.5	15	6.188
f	1.354	3.7	11.5	18.7	7.239037
f	1.368	4	12.5	22.7	8.166079
f	1.398	4.4	14.7	27.1	9.226937
f	1.428	4.8	16.9	31.9	10.3815
f	1.458	5.2	19.1	37.1	11.6035
f	1.460	5.5	19.3	42.6	12.59718
f	1.473	5.8	20.2	48.4	13.50826
f	1.492	6	21.6	54.4	14.40074
f	1.496	6.1	21.9	60.5	15.15686
f	1.523	6	23.9	66.5	15.94571
f	1.526	5.8	24.1	72.3	16.59986
f	1.598	5.6	29.4	77.9	17.52003
s	2.324	22.1	82.8	100	31.9469

Case 2 Crushed to 50mm

Sieve Size	Fractional yield	Cumulative Yield
-50 + 10	93.63	93.63
-10 + 1	5.06	98.69
-1 + 0.1	1.16	99.85
-0.1 + 0.00	0.15	100.00

50 x 10 mm Fraction					
	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	0.6	4	0.6	4
f	1.35	4.7	9.8	5.3	9.143396
f	1.4	15.5	16.2	20.8	14.40192
f	1.45	16.1	22.1	36.9	17.7607
f	1.5	20.9	27.3	57.8	21.21003
f	1.55	7.6	30.4	65.4	22.27798
f	1.6	7	36.4	72.4	23.64337
f	1.65	5.2	38.6	77.6	24.64562
f	1.7	5.5	46	83.1	26.05897
f	1.75	7.9	47.8	91	27.94637
f	1.8	3	51.6	94	28.70128
f	1.85	1.3	55.3	95.3	29.06411
f	1.9	1.1	57.4	96.4	29.38745
f	1.95	1.2	61.1	97.6	29.77736
f	2	1.4	64.2	99	30.26414
s	2	1	65.3	100	30.6145

50 x 10 mm Fraction					
	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.252	0.6	4	0.6	4
f	1.331	4.7	9.8	5.3	9.14339623
f	1.418	15.5	16.2	20.8	14.4019231
f	1.499	16.1	22.1	36.9	17.7607046
f	1.569	20.9	27.3	57.8	21.2100346
f	1.611	7.6	30.4	65.4	22.2779817
f	1.693	7	36.4	72.4	23.6433702
f	1.723	5.2	38.6	77.6	24.6456186
f	1.824	5.5	46	83.1	26.0589651
f	1.848	7.9	47.8	91	27.9463736
f	1.900	3	51.6	94	28.7012766
f	1.950	1.3	55.3	95.3	29.0641133
f	1.979	1.1	57.4	96.4	29.3874481
f	2.029	1.2	61.1	97.6	29.7773566
f	2.071	1.4	64.2	99	30.2641414
s	2.086	1	65.3	100	30.6145

10 x 1.0 mm Fraction					
	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	12.4	3.4	12.4	3.4
f	1.35	15.9	9.4	28.3	6.771025
f	1.4	15.3	14.9	43.6	9.623624
f	1.45	11.4	20.3	55	11.83655
f	1.5	7.7	25.5	62.7	13.51451
f	1.55	6.4	30.4	69.1	15.07844
f	1.6	5.7	34.8	74.8	16.58128
f	1.65	4.5	38.7	79.3	17.83644
f	1.7	3.6	42.8	82.9	18.92051
f	1.75	3.5	46.7	86.4	20.04583
f	1.8	3.4	50.2	89.8	21.18753
f	1.85	0.9	52.7	90.7	21.50022
f	1.9	2.2	56.5	92.9	22.32906
f	1.95	2	59.3	94.9	23.10822
f	2	2.1	64.8	97	24.01082
s	2	3	75.3	100	25.5495

10 x 1.0 mm Fraction					
	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.244	12.4	3.4	12.4	3.4
f	1.326	15.9	9.4	28.3	6.77102473
f	1.401	15.3	14.9	43.6	9.62362385
f	1.474	11.4	20.3	55	11.8365455
f	1.545	7.7	25.5	62.7	13.5145136
f	1.611	6.4	30.4	69.1	15.078437
f	1.671	5.7	34.8	74.8	16.5812834
f	1.724	4.5	38.7	79.3	17.8364439
f	1.780	3.6	42.8	82.9	18.9205066
f	1.833	3.5	46.7	86.4	20.0458333
f	1.881	3.4	50.2	89.8	21.1875278
f	1.915	0.9	52.7	90.7	21.5002205
f	1.966	2.2	56.5	92.9	22.3290635
f	2.004	2	59.3	94.9	23.1082192
f	2.079	2.1	64.8	97	24.0108247
s	2.222	3	75.3	100	25.5495

1 x .1 mm Fraction					
	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	34.7	2.3	34.7	2.3
f	1.35	17.64	9	52.34	4.558082
f	1.4	6.09	16.1	58.43	5.761065
f	1.45	5.98	20.8	64.41	7.15732
f	1.5	5.07	27.3	69.48	8.627145
f	1.55	4.42	32.2	73.9	10.03705
f	1.6	2.79	36.4	76.69	10.99614
f	1.65	2.51	39.9	79.2	11.91216
f	1.7	2.89	43.5	82.09	13.02422
f	1.75	1.85	48	83.94	13.79507
f	1.8	2.29	49.1	86.23	14.73266
f	1.85	1.22	54.6	87.45	15.28884
f	1.9	1.26	59.2	88.71	15.91254
f	1.95	1.36	60.8	90.07	16.59031
f	2	0.97	60.9	91.04	17.06241
s	2	8.97	72.3	100.01	22.01673

1 x .1 mm Fraction					
	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.229	34.7	2.3	34.7	2.3
f	1.320	17.64	9	52.34	4.55808177
f	1.417	6.09	16.1	58.43	5.76106452
f	1.481	5.98	20.8	64.41	7.15732029
f	1.569	5.07	27.3	69.48	8.6271445
f	1.636	4.42	32.2	73.9	10.0370501
f	1.693	2.79	36.4	76.69	10.9961403
f	1.741	2.51	39.9	79.2	11.9121591
f	1.790	2.89	43.5	82.09	13.0242173
f	1.851	1.85	48	83.94	13.7950679
f	1.866	2.29	49.1	86.23	14.7326568
f	1.941	1.22	54.6	87.45	15.2888393
f	2.003	1.26	59.2	88.71	15.9125352
f	2.025	1.36	60.8	90.07	16.5903075
f	2.026	0.97	60.9	91.04	17.0624121
s	2.181	8.97	72.3	100.01	22.0167283

Case 3 Crushed to 35 mm

Sieve Size	Fractional yield	Cumulative Yield
-35 + 10	86.54	86.54
-10 + 1	10.92	97.46
-1 + 0.1	2.15	99.61
-0.1 + 0.00	0.39	100.00

35 x 10 mm Fraction

	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	0.61	3.2	0.61	3.2
f	1.35	6.53	10.6	7.14	9.967787
f	1.4	16.52	16.8	23.66	14.73821
f	1.45	17.3	22.7	40.96	18.10098
f	1.5	12.82	28.3	53.78	20.53221
f	1.55	10.25	33.3	64.03	22.57609
f	1.6	8.37	34.9	72.4	24.00083
f	1.65	5.82	40.9	78.22	25.25822
f	1.7	5.71	48.5	83.93	26.83943
f	1.75	3.64	52.3	87.57	27.89774
f	1.8	3.53	55.1	91.1	28.95179
f	1.85	1	55.4	92.1	29.23896
f	1.9	1.91	56.6	94.01	29.79485
f	1.95	2.09	58.2	96.1	30.41261
f	2	2.34	59.2	98.44	31.09691
s	2	1.55	65.8	99.99	31.63486

35 x 10 mm Fraction

	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.242	0.61	3.2	0.61	3.2
f	1.342	6.53	10.6	7.14	9.9677871
f	1.426	16.52	16.8	23.66	14.738208
f	1.507	17.3	22.7	40.96	18.100977
f	1.583	12.82	28.3	53.78	20.532205
f	1.651	10.25	33.3	64.03	22.576089
f	1.673	8.37	34.9	72.4	24.000829
f	1.754	5.82	40.9	78.22	25.25822
f	1.858	5.71	48.5	83.93	26.839426
f	1.909	3.64	52.3	87.57	27.897739
f	1.947	3.53	55.1	91.1	28.951789
f	1.951	1	55.4	92.1	29.238958
f	1.968	1.91	56.6	94.01	29.794852
f	1.990	2.09	58.2	96.1	30.412612
f	2.003	2.34	59.2	98.44	31.096912
s	2.093	1.55	65.8	99.99	31.634863

10 x 1.0 mm Fraction

	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	11.05	3.9	11.05	3.9
f	1.35	16.84	9.3	27.89	7.160523
f	1.4	11.93	16.2	39.82	9.868734
f	1.45	15.27	20.7	55.09	12.87097
f	1.5	9.32	27.9	64.41	15.04565
f	1.55	5.9	33.5	70.31	16.59423
f	1.6	5.2	37	75.51	17.99947
f	1.65	4.76	41.4	80.27	19.38712
f	1.7	4.23	46.1	84.5	20.72434
f	1.75	4.96	51.8	89.46	22.44729
f	1.8	2.44	57.7	91.9	23.38328
f	1.85	0.99	52.4	92.89	23.69253
f	1.9	1.83	56	94.72	24.31671
f	1.95	1.81	61.3	96.53	25.01017
f	2	1.16	63.6	97.69	25.4684
s	2	2.32	68.8	100.01	26.47359

10 x 1.0 mm Fraction

	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.251	11.05	3.9	11.05	3.9
f	1.324	16.84	9.3	27.89	7.1605235
f	1.418	11.93	16.2	39.82	9.8687343
f	1.480	15.27	20.7	55.09	12.870975
f	1.577	9.32	27.9	64.41	15.045645
f	1.654	5.9	33.5	70.31	16.594226
f	1.701	5.2	37	75.51	17.99947
f	1.761	4.76	41.4	80.27	19.387118
f	1.825	4.23	46.1	84.5	20.724343
f	1.902	4.96	51.8	89.46	22.447295
f	1.983	2.44	57.7	91.9	23.383275
f	1.911	0.99	52.4	92.89	23.692529
f	1.960	1.83	56	94.72	24.316712
f	2.032	1.81	61.3	96.53	25.010173
f	2.063	1.16	63.6	97.69	25.4684
s	2.134	2.32	68.8	100.01	26.473593

1 x .1 mm Fraction

	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	38.71	3.6	38.71	3.6
f	1.35	13.74	12.2	52.45	5.852888
f	1.4	9.74	18.7	62.19	7.864962
f	1.45	4.9	22.9	67.09	8.963065
f	1.5	2.84	26.3	69.93	9.667153
f	1.55	3.07	32	73	10.60636
f	1.6	2.94	35.6	75.94	11.57398
f	1.65	2.7	36.5	78.64	12.42978
f	1.7	2.94	39.8	81.58	13.41616
f	1.75	2.62	49.8	84.2	14.54829
f	1.8	2.28	52	86.48	15.53568
f	1.85	2.17	57.2	88.65	16.55556
f	1.9	1.74	60.6	90.39	17.40341
f	1.95	1.73	64.4	92.12	18.286
f	2	3.24	65.3	95.36	19.88337
s	2	4.64	66.3	100	22.0371

1 x .1 mm Fraction

	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.247	38.71	3.6	38.71	3.6
f	1.364	13.74	12.2	52.45	5.8528885
f	1.452	9.74	18.7	62.19	7.8649622
f	1.509	4.9	22.9	67.09	8.9630645
f	1.556	2.84	26.3	69.93	9.6671529
f	1.633	3.07	32	73	10.606356
f	1.682	2.94	35.6	75.94	11.573979
f	1.694	2.7	36.5	78.64	12.429781
f	1.739	2.94	39.8	81.58	13.416156
f	1.875	2.62	49.8	84.2	14.54829
f	1.905	2.28	52	86.48	15.535685
f	1.976	2.17	57.2	88.65	16.555556
f	2.022	1.74	60.6	90.39	17.403407
f	2.074	1.73	64.4	92.12	18.285997
f	2.086	3.24	65.3	95.36	19.883368
s	2.100	4.64	66.3	100	22.0371

Case 4 Crushed to 25 mm

Sieve Size	Fractional yield	Cumulative Yield
-25 + 10	81.60	81.60
-10 + 1	15.07	96.67
-1 + 0.1	2.82	99.49
-0.1 + 0.00	0.51	100.00

25 x 10 mm Fraction

	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	0.53	3.3	0.53	3.3
f	1.35	5.89	10.3	6.42	9.722118
f	1.4	14.84	17	21.26	14.80226
f	1.45	24.65	22	45.91	18.66687
f	1.5	7.09	27.8	53	19.88864
f	1.55	14.84	38.5	67.84	23.95988
f	1.6	6.69	39.8	74.53	25.38173
f	1.65	6.18	46.2	80.71	26.97579
f	1.7	6.27	50.7	86.98	28.68596
f	1.75	2.93	51.5	89.91	29.42943
f	1.8	2.91	51.8	92.82	30.13077
f	1.85	0.63	56.6	93.45	30.30921
f	1.9	0.97	58.7	94.42	30.60088
f	1.95	2.07	61.8	96.49	31.27019
f	2	1.96	64.6	98.45	31.93374
s	2	1.56	67.8	100.01	32.4932

25 x 10 mm Fraction

	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.243	0.53	3.3	0.53	3.3
f	1.338	5.89	10.3	6.42	9.72211838
f	1.429	14.84	17	21.26	14.8022578
f	1.497	24.65	22	45.91	18.66687
f	1.576	7.09	27.8	53	19.8886415
f	1.722	14.84	38.5	67.84	23.9598762
f	1.739	6.69	39.8	74.53	25.3817255
f	1.826	6.18	46.2	80.71	26.9757899
f	1.888	6.27	50.7	86.98	28.6859623
f	1.898	2.93	51.5	89.91	29.4294294
f	1.902	2.91	51.8	92.82	30.1307692
f	1.968	0.63	56.6	93.45	30.3092135
f	1.996	0.97	58.7	94.42	30.6008791
f	2.038	2.07	61.8	96.49	31.2701938
f	2.077	1.96	64.6	98.45	31.933743
s	2.120	1.56	67.8	100.01	32.4932007

10 x 1.0 mm Fraction

	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	11.52	4.3	11.52	4.3
f	1.35	13.61	9.7	25.13	7.224552
f	1.4	15.03	16.2	40.16	10.58364
f	1.45	12.92	21.8	53.08	13.31377
f	1.5	4.82	28.6	57.9	14.5863
f	1.55	8.74	32.7	66.64	16.96196
f	1.6	5.52	36.8	72.16	18.4795
f	1.65	4.05	42.7	76.21	19.76664
f	1.7	5.58	46.2	81.79	21.57002
f	1.75	4.98	53.9	86.77	23.42554
f	1.8	3.47	55	90.24	24.63967
f	1.85	1.18	57.4	91.42	25.06252
f	1.9	1.65	58	93.07	25.64646
f	1.95	2.37	62.3	95.44	26.55665
f	2	1.82	65.4	97.26	27.28352
s	2	2.73	68	99.99	28.39519

10 x 1.0 mm Fraction

	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.256	11.52	4.3	11.52	4.3
f	1.330	13.61	9.7	25.13	7.22455233
f	1.418	15.03	16.2	40.16	10.5836404
f	1.494	12.92	21.8	53.08	13.3137717
f	1.587	4.82	28.6	57.9	14.586304
f	1.643	8.74	32.7	66.64	16.9619598
f	1.698	5.52	36.8	72.16	18.4795039
f	1.779	4.05	42.7	76.21	19.7666448
f	1.826	5.58	46.2	81.79	21.5700208
f	1.931	4.98	53.9	86.77	23.4255388
f	1.946	3.47	55	90.24	24.639672
f	1.979	1.18	57.4	91.42	25.0625246
f	1.987	1.65	58	93.07	25.6464597
f	2.045	2.37	62.3	95.44	26.5566534
f	2.087	1.82	65.4	97.26	27.2835184
s	2.123	2.73	68	99.99	28.3951895

1 x .1 mm Fraction

	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	31.38	2.6	31.38	2.6
f	1.35	16.19	8.9	47.57	4.744145
f	1.4	9.35	16.2	56.92	6.625949
f	1.45	7.47	23.2	64.39	8.548734
f	1.5	5.19	28.5	69.58	10.03691
f	1.55	3.15	32.2	72.73	10.99681
f	1.6	3.07	39.1	75.8	12.13503
f	1.65	1.78	44.3	77.58	12.87302
f	1.7	2.7	45.3	80.28	13.96361
f	1.75	2.7	48.8	82.98	15.09712
f	1.8	1.83	52	84.81	15.8934
f	1.85	2.96	54.4	87.77	17.19201
f	1.9	1.23	60.5	89	17.79054
f	1.95	2.44	60.9	91.44	18.94088
f	2	4.87	63.5	96.31	21.19405
s	2	3.68	70.3	99.99	23.00133

1 x .1 mm Fraction

	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.233	31.38	2.6	31.38	2.6
f	1.319	16.19	8.9	47.57	4.74414547
f	1.418	9.35	16.2	56.92	6.6259487
f	1.514	7.47	23.2	64.39	8.54873428
f	1.586	5.19	28.5	69.58	10.0369072
f	1.636	3.15	32.2	72.73	10.9968101
f	1.730	3.07	39.1	75.8	12.1350264
f	1.800	1.78	44.3	77.58	12.8730214
f	1.814	2.7	45.3	80.28	13.9636148
f	1.862	2.7	48.8	82.98	15.0971198
f	1.905	1.83	52	84.81	15.893397
f	1.938	2.96	54.4	87.77	17.1920132
f	2.021	1.23	60.5	89	17.7905393
f	2.026	2.44	60.9	91.44	18.9408793
f	2.062	4.87	63.5	96.31	21.1940505
s	2.154	3.68	70.3	99.99	23.0013301

Case 5 Crushed to 15 mm

Sieve Size	Fractional yield	Cumulative Yield
-15 + 10	52.90	52.90
-10 + 1	39.57	92.47
-1 + 0.1	6.16	98.63
-0.1 + 0.00	1.37	100.00

15 x 10 mm Fraction

	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	3.97	8.7	3.97	8.7
f	1.35	4.79	9.4	8.76	9.082763
f	1.4	15.27	17.4	24.03	14.368
f	1.45	13.26	23.9	37.29	17.7575
f	1.5	13.26	30.1	50.55	20.99511
f	1.55	8.12	32.5	58.67	22.5874
f	1.6	7.27	36.2	65.94	24.08822
f	1.65	6.42	41.6	72.36	25.64192
f	1.7	5.48	44.5	77.84	26.96954
f	1.75	4.19	45.7	82.03	27.92627
f	1.8	7.58	48.8	89.61	29.69195
f	1.85	0.22	53.4	89.83	29.75002
f	1.9	1.95	54	91.78	30.26524
f	1.95	3.59	59.2	95.37	31.35443
f	2	2.52	63.8	97.89	32.18968
s	2	2.14	66.1	100.03	32.91515

15 x 10 mm Fraction

	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.316	3.97	8.7	3.97	8.7
f	1.326	4.79	9.4	8.76	9.082762557
f	1.435	15.27	17.4	24.03	14.36799834
f	1.523	13.26	23.9	37.29	17.75749531
f	1.607	13.26	30.1	50.55	20.99511375
f	1.640	8.12	32.5	58.67	22.58740412
f	1.690	7.27	36.2	65.94	24.08821656
f	1.764	6.42	41.6	72.36	25.64191542
f	1.803	5.48	44.5	77.84	26.96954008
f	1.820	4.19	45.7	82.03	27.92627088
f	1.862	7.58	48.8	89.61	29.69195402
f	1.924	0.22	53.4	89.83	29.7500167
f	1.932	1.95	54	91.78	30.26524297
f	2.003	3.59	59.2	95.37	31.35443011
f	2.066	2.52	63.8	97.89	32.1896823
s	2.097	2.14	66.1	100.03	32.91514546

10 x 1.0 mm Fraction

	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	5.83	4.2	5.83	4.2
f	1.35	14.24	10.2	20.07	8.4571
f	1.4	13.86	16.5	33.93	11.74253
f	1.45	13.52	23.8	47.45	15.17808
f	1.5	17.88	32.7	65.33	19.97361
f	1.55	6.85	37.2	72.18	21.60842
f	1.6	5.28	41.6	77.46	22.97113
f	1.65	4.69	43.5	82.15	24.14314
f	1.7	3.72	44.2	85.87	25.01203
f	1.75	4.23	50	90.1	26.18516
f	1.8	5.71	53.8	95.81	27.83093
f	1.85	0.15	56.1	95.96	27.87511
f	1.9	0.8	56.6	96.76	28.11261
f	1.95	1.23	57.9	97.99	28.48651
f	2	1.06	63	99.05	28.85586
s	2	0.97	66	100.02	29.21609

10 x 1.0 mm Fraction

	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.255	5.83	4.2	5.83	4.2
f	1.337	14.24	10.2	20.07	8.457100149
f	1.422	13.86	16.5	33.93	11.74252874
f	1.522	13.52	23.8	47.45	15.17808219
f	1.643	17.88	32.7	65.33	19.9736109
f	1.704	6.85	37.2	72.18	21.60842339
f	1.764	5.28	41.6	77.46	22.97113349
f	1.790	4.69	43.5	82.15	24.1431406
f	1.799	3.72	44.2	85.87	25.01202981
f	1.878	4.23	50	90.1	26.18516093
f	1.930	5.71	53.8	95.81	27.83092579
f	1.961	0.15	56.1	95.96	27.87511463
f	1.968	0.8	56.6	96.76	28.11260852
f	1.985	1.23	57.9	97.99	28.48650883
f	2.055	1.06	63	99.05	28.85586068
s	2.096	0.97	66	100.02	29.21608678

1 x .1 mm Fraction

	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	26.6	2.9	26.6	2.9
f	1.35	17.02	10.2	43.62	5.748372
f	1.4	8.14	15.1	51.76	7.219049
f	1.45	9.35	23	61.11	9.633579
f	1.5	6	26.7	67.11	11.15941
f	1.55	3.5	30.6	70.61	12.12304
f	1.6	2.95	33.8	73.56	12.99236
f	1.65	2.35	36.5	75.91	13.7201
f	1.7	2.17	43	78.08	14.53385
f	1.75	3.33	45	81.41	15.78004
f	1.8	2.19	45.4	83.6	16.55597
f	1.85	3.23	52.8	86.83	17.90422
f	1.9	1.9	57.4	88.73	18.74995
f	1.95	2.91	61.6	91.64	20.11064
f	2	2.6	65.3	94.24	21.35737
s	2	5.75	68.9	99.99	24.09135

1 x .1 mm Fraction

	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.237	26.6	2.9	26.6	2.9
f	1.337	17.02	10.2	43.62	5.748372306
f	1.403	8.14	15.1	51.76	7.219049459
f	1.511	9.35	23	61.11	9.633578792
f	1.561	6	26.7	67.11	11.15940992
f	1.614	3.5	30.6	70.61	12.12304206
f	1.658	2.95	33.8	73.56	12.99235998
f	1.694	2.35	36.5	75.91	13.72010275
f	1.783	2.17	43	78.08	14.5338499
f	1.810	3.33	45	81.41	15.78003931
f	1.815	2.19	45.4	83.6	16.5559689
f	1.916	3.23	52.8	86.83	17.90421513
f	1.979	1.9	57.4	88.73	18.74994928
f	2.036	2.91	61.6	91.64	20.11063946
f	2.086	2.6	65.3	94.24	21.35737479
s	2.135	5.75	68.9	99.99	24.09134913

Case 6 Crushed to 10 mm

Sieve Size	Fractional yield	Cumulative Yield
-10 + 10	0.00	0.00
-10 + 1	87.08	87.08
-1 + 0.1	8.32	95.40
-0.1 + 0.00	4.60	100.00

	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3				
f	1.35				
f	1.4				
f	1.45				
f	1.5				
f	1.55				
f	1.6				
f	1.65				
f	1.7				
f	1.75				
f	1.8				
f	1.85				
f	1.9				
f	1.95				
f	2				
s	2				

10 x 10 mm Fraction					
	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.198				
f	1.198				
f	1.198				
f	1.198				
f	1.198				
f	1.198				
f	1.198				
f	1.198				
f	1.198				
f	1.198				
f	1.198				
f	1.198				
f	1.198				
f	1.198				
f	1.198				
s	1.198				

10 x 1.0 mm Fraction					
	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	3.71	3.8	3.71	3.8
f	1.35	10.08	9.4	13.79	7.893401
f	1.4	12.32	16.2	26.11	11.81287
f	1.45	15.45	23.6	41.56	16.19475
f	1.5	8.52	25.9	50.08	17.84589
f	1.55	7.83	30.7	57.91	19.58389
f	1.6	8.27	37.5	66.18	21.82273
f	1.65	6.07	39.5	72.25	23.30786
f	1.7	4.82	44.9	77.07	24.65825
f	1.75	4.86	49.7	81.93	26.1437
f	1.8	6.03	53.4	87.96	28.01222
f	1.85	1.84	55.5	89.8	28.57545
f	1.9	2.09	57.8	91.89	29.24015
f	1.95	3.17	59.8	95.06	30.25924
f	2	1.94	65	97	30.95405
s	2	3	67.1	100	32.03843

10 x 1.0 mm Fraction					
	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.250	3.71	3.8	3.71	3.8
f	1.326	10.08	9.4	13.79	7.893401
f	1.418	12.32	16.2	26.11	11.812869
f	1.519	15.45	23.6	41.56	16.194755
f	1.550	8.52	25.9	50.08	17.845887
f	1.616	7.83	30.7	57.91	19.583889
f	1.708	8.27	37.5	66.18	21.822726
f	1.735	6.07	39.5	72.25	23.307862
f	1.809	4.82	44.9	77.07	24.658246
f	1.874	4.86	49.7	81.93	26.143696
f	1.924	6.03	53.4	87.96	28.012221
f	1.953	1.84	55.5	89.8	28.575445
f	1.984	2.09	57.8	91.89	29.240146
f	2.011	3.17	59.8	95.06	30.259236
f	2.082	1.94	65	97	30.954052
s	2.111	3	67.1	100	32.03843

1 x .1 mm Fraction					
	RD	Lab Yield	Ash	Cum Yld	Cum Ash
f	1.3	44.81	5.3	44.81	5.3
f	1.35	3.21	11.8	48.02	5.734506
f	1.4	9.06	17.3	57.08	7.570235
f	1.45	7.85	24.8	64.93	9.653304
f	1.5	5.93	29.6	70.86	11.32257
f	1.55	4.4	34.2	75.26	12.66007
f	1.6	3.79	39.2	79.05	13.93251
f	1.65	3.34	41.2	82.39	15.03791
f	1.7	2.02	45.2	84.41	15.75971
f	1.75	1.82	48.4	86.23	16.44863
f	1.8	1.72	51.8	87.95	17.13998
f	1.85	1.99	55.9	89.94	17.99758
f	1.9	1.2	59.8	91.14	18.54797
f	1.95	1.49	64.1	92.63	19.2807
f	2	1.55	35.9	94.18	19.55422
s	2	5.82	66.2	100	22.269

1 x .1 mm Fraction					
	AAD RD	AAD Yield	Ash	Cum Yld	Cum Ash
f	1.270	44.81	5.3	44.81	5.3
f	1.358	3.21	11.8	48.02	5.7345065
f	1.433	9.06	17.3	57.08	7.5702348
f	1.535	7.85	24.8	64.93	9.6533036
f	1.601	5.93	29.6	70.86	11.322566
f	1.663	4.4	34.2	75.26	12.660072
f	1.731	3.79	39.2	79.05	13.932511
f	1.758	3.34	41.2	82.39	15.037905
f	1.813	2.02	45.2	84.41	15.759709
f	1.856	1.82	48.4	86.23	16.448626
f	1.902	1.72	51.8	87.95	17.139977
f	1.958	1.99	55.9	89.94	17.997576
f	2.011	1.2	59.8	91.14	18.54797
f	2.070	1.49	64.1	92.63	19.280697
f	1.686	1.55	35.9	94.18	19.554215
s	2.098	5.82	66.2	100	22.269

APPENDIX G

GEOLOGICAL GRADE CONTROL

GEOPHYSICS

COKING AND MIDDLING COAL YIELD INVESTIGATION

TEST BLAST BLOCK B03/78/04

INRODUCTION

As a result of declining coking coal yields and uncertainty with regard to "constraints " leading to lower yields being realized, a similar exercise to an investigation launched during 1995 has been planned on bench 3. The block mentioned above was selected for this exercise and will be loaded exclusively for the duration of this exercise, so that only bench 3 material will be beneficiated during this period. This should negate the effects of material with other metallurgical properties being blended with bench 3 material and should also result in better correlation factors relating to plant efficiency being derived for bench 3 material, thus theoretical modelled values can be adjusted for yield prediction and planning purposes.

The geophysical grade control approach to yield determination and prediction for this particular exercise has been intensified to utilize more information than would normally be the case in standard procedures.

STANDARD PROCEDURE

Normally every second blast-hole of a particular blast block, on the back row, would be logged with a large crystal natural gamma probe for improved response resolution after drilling to the predicted geological contacts for that blast. The individual logs are processed, interpreted and evaluated along the line of section representing the back row or the unexposed advance face in the direction of face advance. Information obtained from this interpretation includes:

- Roof elevation, surface profile and roof samples along section, highlighting the upper bench floor deviations
- Individual sample identification and correlation along line of section
- Basic structural interpretation along line of section
- Actual geological contacts of floor contacts in blast-holes for geological contact database update
- Marker recognition for equivalent stratigraphical extraction from geological database for yield determination
- Blast hole drilling floor profile, highlighting drilling deviations and the possible effect on the floor after the blast has been mined out

The relevant information for each blast-hole is then used for yield calculation to the prescribed mining elevation, PME (geological contact elevation predicted from contact database and extrapolated in the direction of face advance for the required blast block or north-south, east-west or diagonal section). Blast block and exploration borehole positional data is acquired by obtaining a midpoint for the blast block and locating the four closest exploration boreholes to that blast block, with the relevant stratigraphy and analytical data to satisfy the stratigraphical package represented in each blast-hole, i.e. roof to prescribed mining floor, to that point, determining the distances of the blast-holes from these exploration boreholes and extracting the raw data from the geological database, compiling cumulative wash tables for each of the exploration borehole's equivalent package per blast-hole. Products are then extruded at the required control parameters and an inverse distance squared interpolation algorithm is applied to the products to obtain representative yields for that particular blast-hole.

If the yield values thus obtained per blast-hole are relatively constant along the line of section, an arithmetical average yield is determined for the entire block. These yield values are then forwarded to mine planning for scheduling purposes. Should the values however differ, the blast block is subdivided into sections representing concentrations of similar yields and reported as such in the yield information made available for scheduling with co-ordinate cut-off values also included so that sub-blocking can be applied.

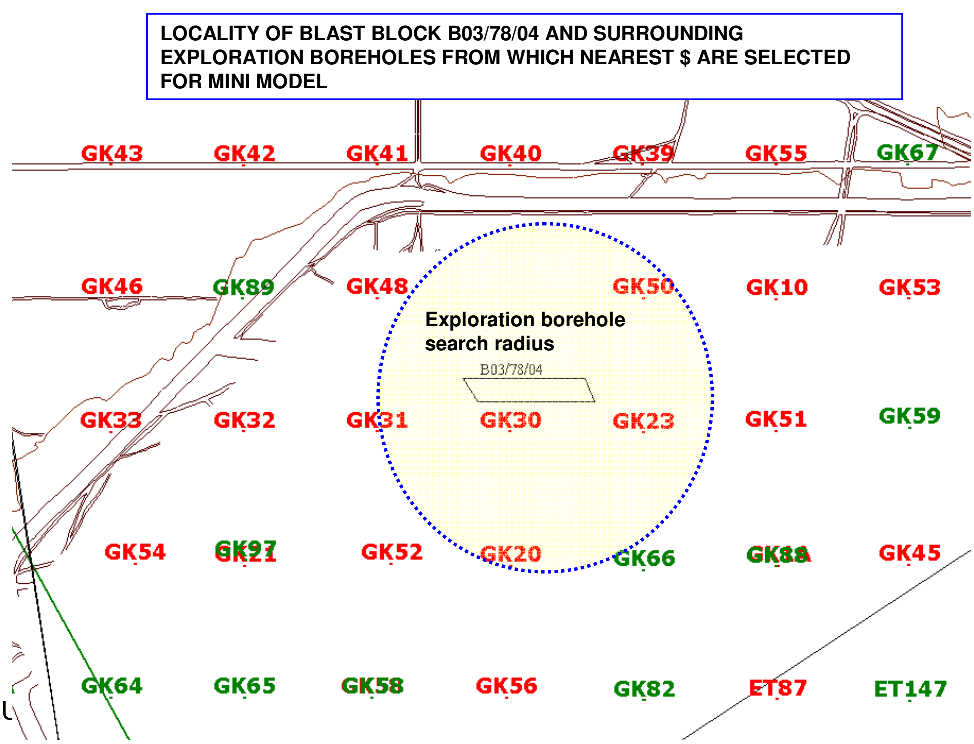
PROCEDURE FOR BLAST BLOCK B03/78/04 UNDER INVESTIGATION

The back row of the blast block as well as the middle row were logged geophysically and evaluated on the same basis as in the standard procedure. The back row from the preceding blast block immediately in front of the current blast was also incorporated in the evaluation, allowing a broader spread across the width of the block to be evaluated.

Yields for all three rows were obtained using the mini blast block model method as described previously and averaged for the new block.

Direct geophysically derived yields were also obtained from the normalization of each individual blast-hole's gamma log to represent ash content per depth increment in the blast-hole and an ash yield value equivalent to product ash yield values, i.e. 10.3% ash for coking coal and 33% ash for middling obtained. (Note that the quoted ash value is 2% lower than the theoretical 35% ash normally used, this is because of the cut density during primary separation. Grootegeluk 1 plant was designed for a primary separation at 1.80g/cc Rd and not at a specified ash, the plant however very seldom reaches this maximum value of 1.80Rd)

Exploration boreholes used in the determination of coking coal and middling coal yields for this particular blast block in the mini blast block model were GK459LQ30, GK23, GK459LQ50 and GK20. The data obtained from GK459LQ30 would have the greatest influence on the interpolated values since this hole is in closest proximity to the block of interest.



EVALU

The tables below summarize the information obtained for the 3 sections logged and evaluated. A quick comparison of data obtained directly from the logs and data calculated for the equivalent stratigraphical profile indicates some radical differences between modelled values and actual derivations from the ash normalized logs. These differences can be attributed to subtle

lithological changes laterally across the line of section and vertically in profile, reflective of depositional environment and source material available at the time of deposition.

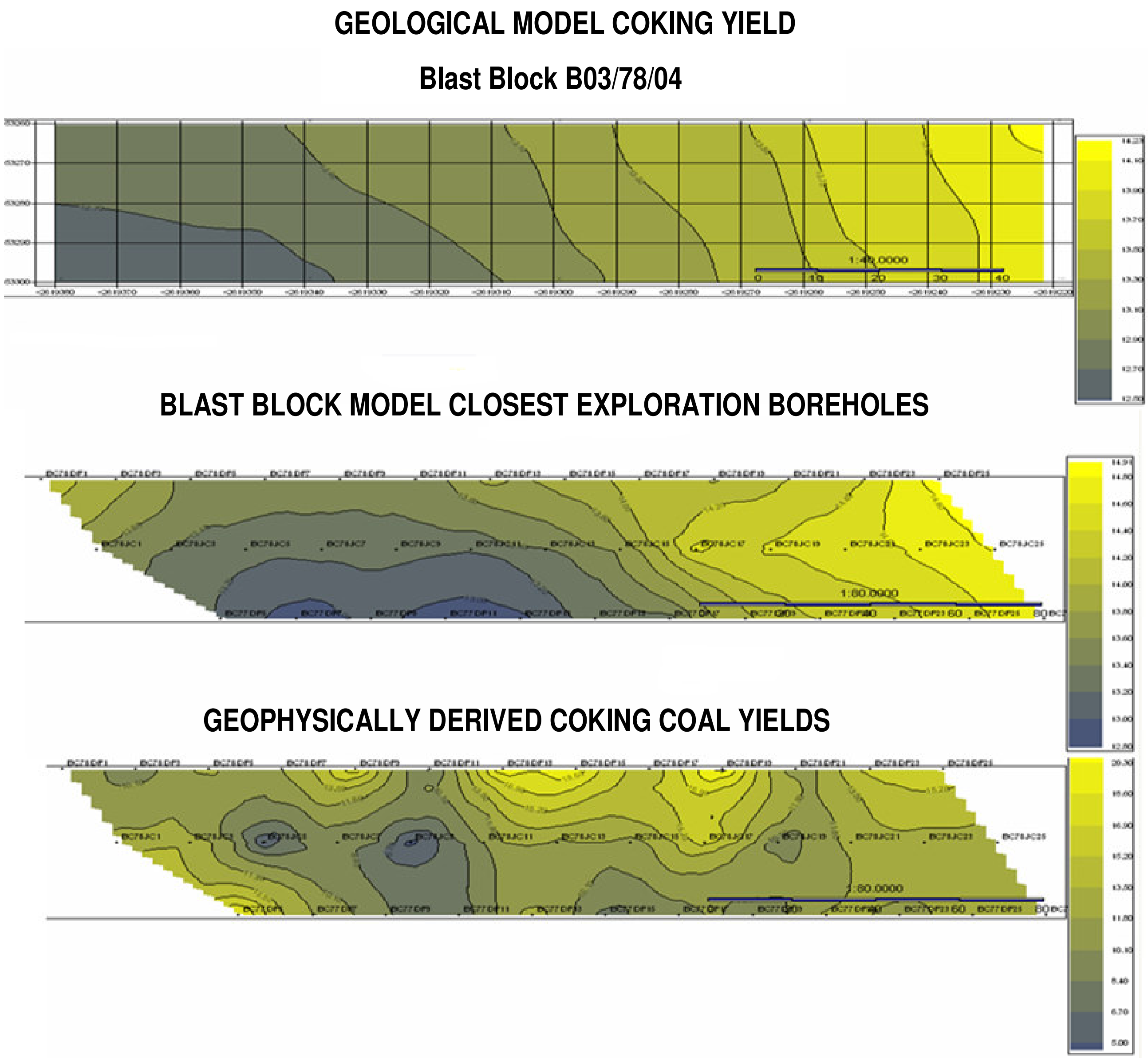
DIRECT GEOPHYSICAL DERIVATION							MINI MODEL		
Blast Block B 03/77/04							Blast Block B 03/77/04		
Blast Hole	Coking Coal 10.3% ash	Middlings Coal Primary - Coking	Total Primary cut at 1.80 Rd	Coal% in stratigraphic column	Shale% in stratigraphical column	Bench Rd	Coking Coal Yield	Middlings Yield	Total Yield
BC77DF1	12.05	36.14	48.19	48.10	51.81	1.80	13.62	25.86	39.48
BC77DF3	11.24	39.64	50.89	50.80	49.11	1.80	13.50	25.95	39.45
BC77DF5	20.00	20.65	40.65	40.60	59.35	1.80	13.16	25.33	38.49
BC77DF7	12.05	31.33	43.37	43.30	56.63	1.80	12.80	24.60	37.40
BC77DF9	8.82	41.76	50.59	50.50	49.41	1.80	13.01	24.68	37.69
BC77DF11	6.94	48.55	55.49	55.40	44.51	1.80	12.84	24.59	37.43
BC77DF13	12.96	40.74	53.70	53.70	46.30	1.80	12.92	24.18	37.10
BC77DF15	7.47	45.98	53.45	53.40	46.55	1.80	13.27	24.77	38.04
BC77DF17	9.09	47.73	56.82	56.80	43.18	1.80	13.28	24.32	37.60
BC77DF19	8.88	39.64	48.52	48.50	51.48	1.80	13.93	25.67	39.60
BC77DF21	12.12	36.97	49.09	49.00	50.91	1.80	14.20	25.92	40.12
BC77DF23	11.46	33.76	45.22	45.20	54.78	1.90	14.27	25.97	40.24
BC77DF25	11.90	34.52	46.43	46.40	53.57	1.80	14.50	25.79	40.29
BC77DF27	13.53	30.59	44.12	44.10	55.88	1.80	14.75	25.64	40.38

DIRECT GEOPHYSICAL DERIVATION							MINI MODEL		
Blast Block B 03/78/04 Row 3							Blast Block B 03/78/04		
Blast Hole	Coking Coal 10.3% ash	Middlings Coal Primary - Coking	Total Primary cut at 1.80 Rd	Coal% in stratigraphic column	Shale% in stratigraphical column	Bench Rd	Coking Coal Yield	Middlings Yield	Total Yield
BC78JC1	12.43	40.68	53.11	53.10	46.89	1.80	13.57	25.79	39.36
BC78JC3	12.94	38.82	51.76	51.70	48.24	1.80	13.38	24.36	37.74
BC78JC5	4.62	43.93	48.55	48.50	51.45	1.90	13.29	24.32	37.60
BC78JC7	9.47	40.83	50.30	50.30	49.70	1.80	13.29	24.30	37.58
BC78JC9	4.14	48.52	52.66	52.60	47.34	1.80	13.33	24.45	37.78
BC78JC11	10.24	33.73	43.98	43.90	56.02	1.80	13.22	24.67	37.89
BC78JC13	11.24	33.73	44.97	44.90	55.03	1.80	13.38	25.07	38.45
BC78JC15	10.92	39.66	50.57	50.50	49.43	1.80	13.64	25.19	38.83
BC78JC17	16.28	31.98	48.26	48.20	51.74	1.80	14.50	26.52	41.02
BC78JC19	8.54	41.46	50.00	50.00	50.00	1.90	14.44	26.38	40.82
BC78JC21	12.35	31.18	43.53	43.50	56.47	1.80	14.56	26.21	40.77
BC78JC23	12.57	32.34	44.91	44.90	55.09	1.80	14.67	26.16	40.83
BC78JC25	12.65	40.36	53.01	53.00	46.99	1.80	14.82	25.93	40.75

DIRECT GEOPHYSICAL DERIVATION							MINI MODEL		
Blast Block B 03/78/04 Row 6							Blast Block B 03/78/04		
Blast Hole	Coking Coal 10.3% ash	Middlings Coal Primary - Coking	Total Primary cut at 1.80 Rd	Coal% in stratigraphic column	Shale% in stratigraphic al column	Bench Rd	Coking Coal Yield	Middlings Yield	Total Yield
BC78DF1	11.49	39.08	50.57	50.50	49.43	1.80	14.16	26.98	41.14
BC78DF3	8.33	37.50	45.83	45.80	54.17	1.80	14.00	26.70	40.70
BC78DF5	12.43	40.68	53.11	53.10	46.89	1.80	13.52	25.48	39.00
BC78DF7	11.86	35.59	47.46	47.40	52.54	1.90	13.53	25.40	38.93
BC78DF9	18.50	24.28	42.77	42.70	57.23	1.80	13.47	25.23	38.70
BC78DF11	8.00	38.86	46.86	46.80	53.14	1.90	13.50	25.12	38.62
BC78DF13	20.34	22.03	42.37	42.30	57.63	1.80	13.90	24.80	38.70
BC78DF15	20.33	23.63	43.96	43.90	56.04	1.80	13.87	24.97	38.84
BC78DF17	13.81	35.36	49.17	49.10	50.83	1.80	14.18	24.78	38.96
BC78DF19	21.59	26.70	48.30	48.30	51.70	1.70	13.94	24.86	38.81
BC78DF21	10.34	39.66	50.00	50.00	50.00	1.80	14.20	24.90	39.10
BC78DF23	15.98	33.14	49.11	49.10	50.89	1.80	14.38	24.63	39.01
BC78DF25	16.87	27.11	43.98	43.90	56.02	1.80	14.94	24.82	39.76

The following sets of schematics have been included to highlight the differences in yield determination between the idealized geological model, the mini blast block model and directly derived yields from ash or shaliness index normalized natural gamma logs. The natural gamma logs are more representative of the actual material in profile and give a better indication of the overall quality of the material being mined. Subtle lateral as well as vertical facies changes in the sedimentary environment are evident and structural interpretation also allows for adjustments to the actual vertical section with respect to the samples being mined, not necessarily conforming to the idealized sequence used for broader base modelling.

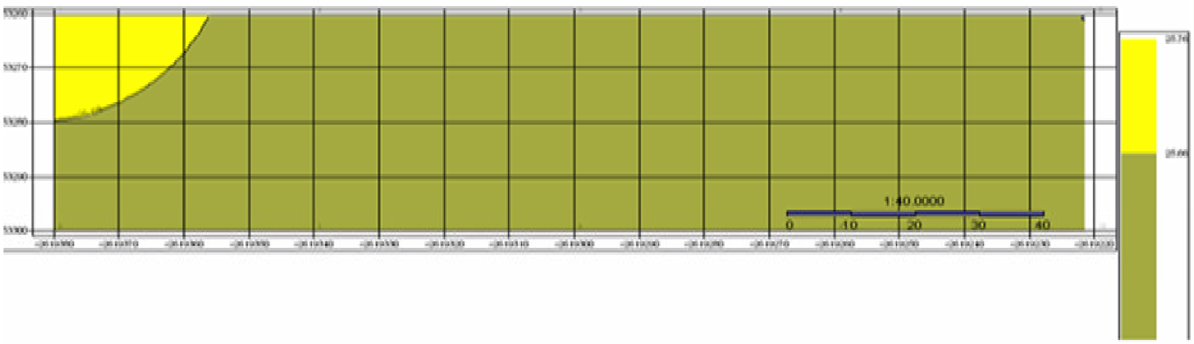
The author is of the opinion that yields obtained directly from the logs are more representative of plant yields than the modelled values, but, due to circumstances and a lack of substantive evidence as well as generally perceived misconceptions with regard to the value of geophysical interpretation and derived values, the safer, more acceptable mini modelling of a blast block using empirically derived analytical parameters has been the preferred technique for predictive purposes.



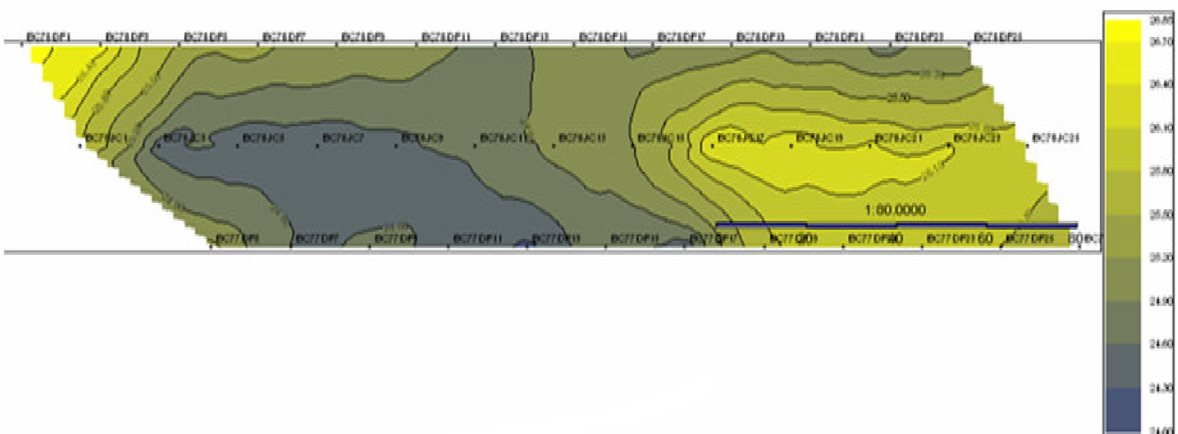
The schematic above is a comparison of contour maps of coking coal yield values obtained from three discreet techniques. The first being the overall geological model based on exploration boreholes on a 250 x 250m grid reduced to a 40 x 40m interpolative grid in the modelling process and representing the ideal stratigraphical vertical profile for the bench in question. No adjustments having been made for roof and floor elevations to account for mining practices resulting in deviations from the set geological contacts for that bench. The second profile represents coking coal yields derived from the mini modelling technique, while the last is representative of values obtained directly from the ash normalized natural gamma log. Both latter techniques take deviations in roof and floor elevations into account and data is derived on the exact representative package being mined. The following two schematics are based on the same criteria as the first but for the remainder of the products from this blast block.

GEOLOGICAL MODEL MIDDLINGS YIELD

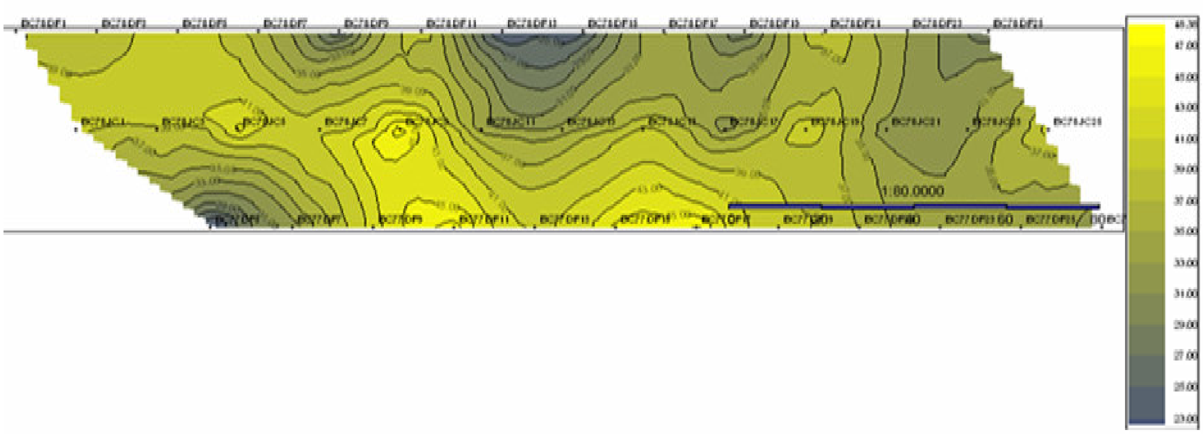
Blast Block B03/78/04



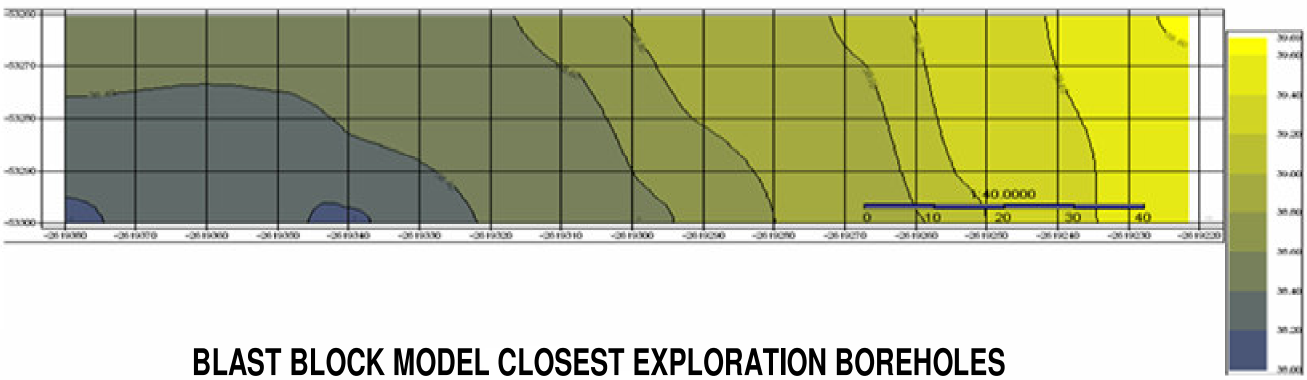
BLAST BLOCK MODEL CLOSEST EXPLORATION BOREHOLES



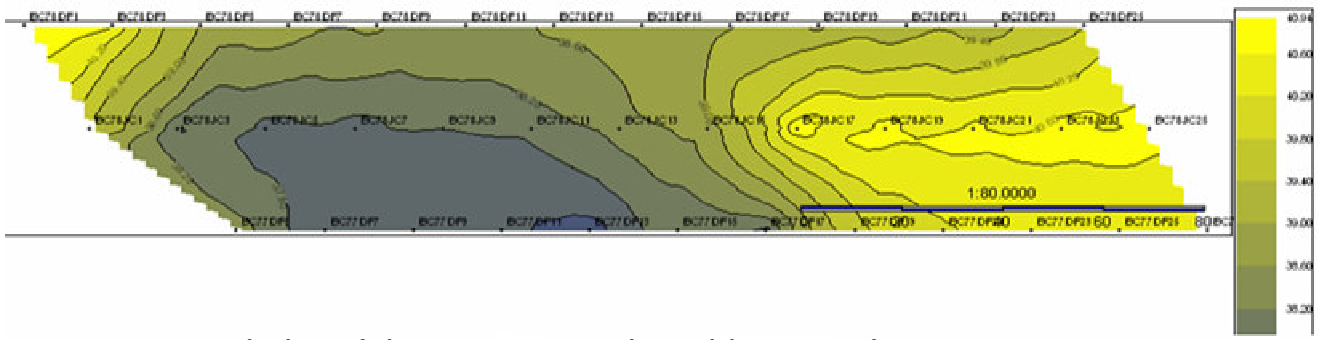
GEOPHYSICALLY DERIVED MIDDLINGS COAL YIELDS



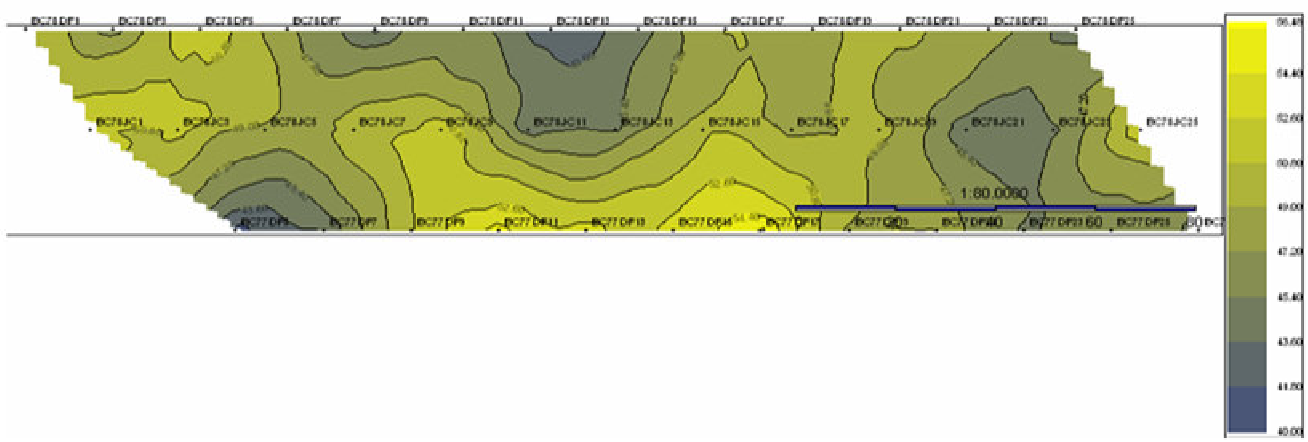
GEOLOGICAL MODEL TOTAL YIELD   Blast Block B03/78/04



BLAST BLOCK MODEL CLOSEST EXPLORATION BOREHOLES

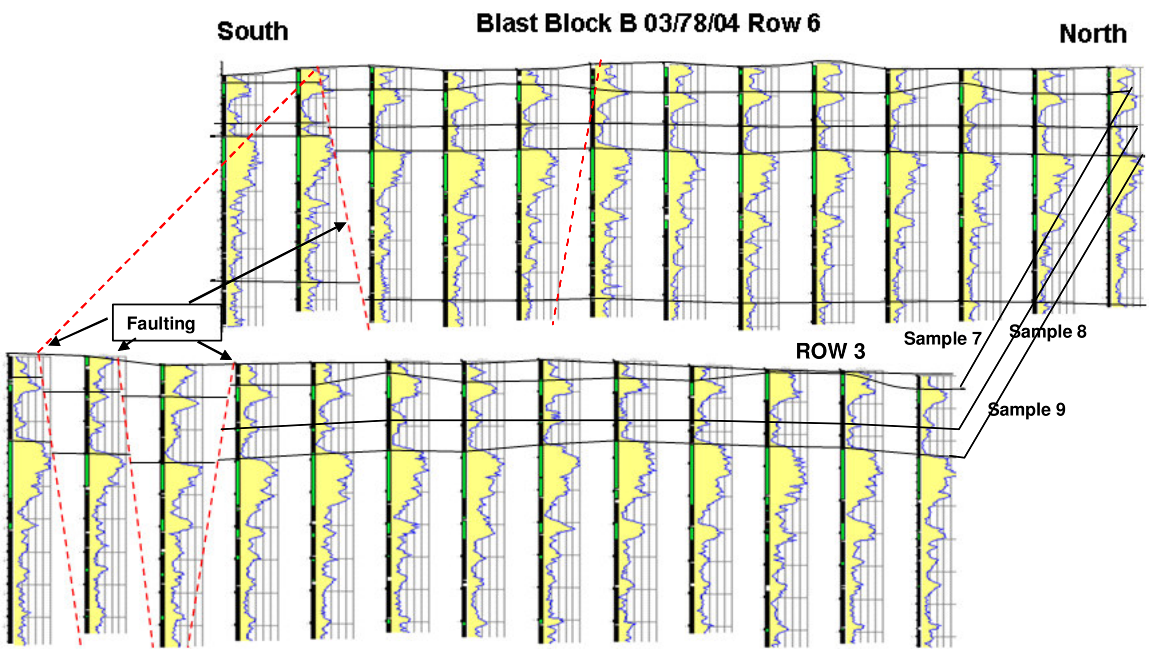


GEOPHYSICALLY DERIVED TOTAL COAL YIELDS



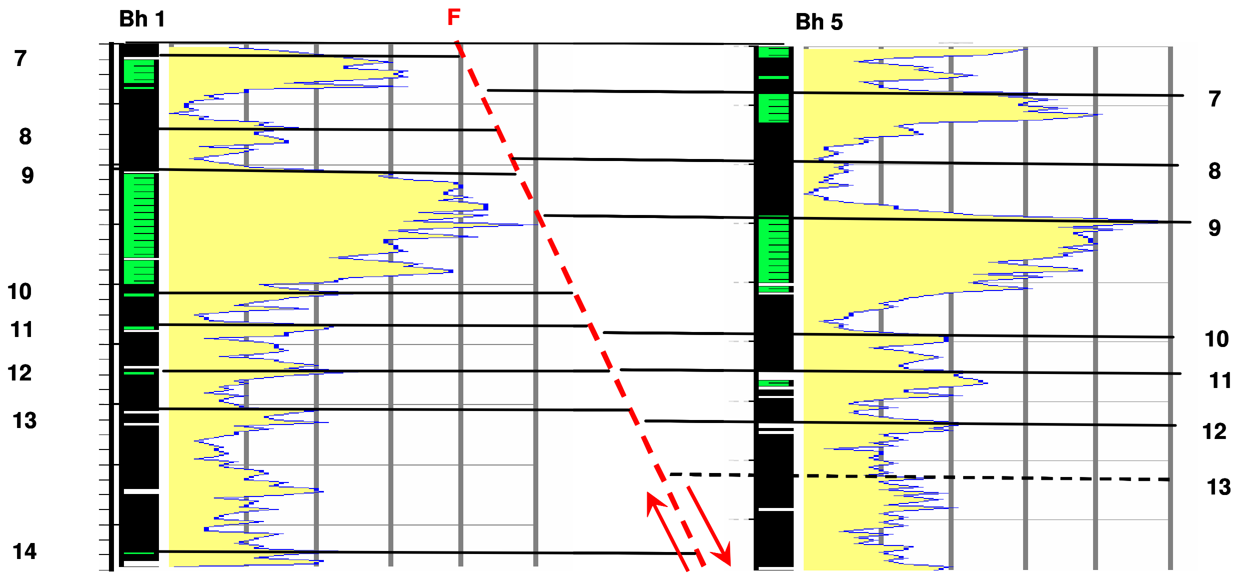
From the foregoing schematics it is obvious that the geophysically derived data portrays a more characteristic pattern of the actual depositional environment and highlights highs and lows within a particular area, only though, because of the increased density of information available for interpretation. Should the exploration grid have been of similar size much the same result could be expected, but at what cost since the boreholes from which this data was obtained, had to be drilled for blasting purposes anyway. The interpretations are based on a shaliness index related to ash and density, since previous research and development work done in this sphere has indicated an almost linear relationship between ash and density for this particular deposit.

The partial fence diagram illustrated below portraying the two lines of section logged in this blast block highlight the lateral as well as vertical changes in the coal to shale ratios in the individual blast-holes, especially the sequence below sample 9 where a very definite upward coarsening sequence can be identified from roughly the base of sample 11.



Faulting across the southern portion of this blast block has also contributed to either increased or decreased yields in the affected area due to the vertical displacement of samples resulting in inconsistency of the stratigraphical profile with its associated metallurgical properties.

Blast-holes 1 and 5 on row 6 extracted from section to illustrate correlation, faulting and samples available in stratigraphical vertical profile.



Blast-holes 1 and 5 on row 6 with the effect of the faulting removed to illustrate sample correlation and sedimentological differences between these two boreholes

Coal/Shale Ratio	1.02	
Coking Yield Geoph.	11.49%	Model 14.16
Middlings Yield Geoph.	39.08%	Model 26.98
Bench Rd	1.80g/cc	

Coal/Shale Ratio	1.13	
Coking Yield Geoph.	12.43%	Model 13.52
Middlings Yield Geoph	40.68%	Model 25.48
Bench Rd	1.80g/cc	

After having assessed all the above information and reducing the overall yield determinations of the blast holes to a single value for the block based on an assessed line of section, the averages obtained especially from the mini modelling technique resulted in minimal variation between the lines of section as indicated in the following table.

	DIRECT GEOPHYSICAL DERIVATION Blast Block B 03/77/04			MINI MODEL Blast Block B 03/77/04		
Block & Row ID	Coking Coal 10.3% ash	Middlings Coal Primary - Coking	Total Primary cut at 1.80 Rd	Coking Coal Yield	Middlings Yield	Total Yield
B037804-R6	14.61	32.59	47.19	13.97	25.28	39.25
B037804-R3	10.65	38.25	48.89	13.85	25.33	39.19
B037704-R6	11.32	37.71	49.04	13.58	25.23	38.81
Average	12.19	36.18	48.37	13.80	25.28	39.08
Standard Deviation	2.12	3.13	1.03	0.20	0.05	0.24

A similar exercise with different combinations of the evaluated lines of section results in a smaller standard deviation on the averaged values for the block as indicated below with the most conservative estimate for this block being a combination of row 6 from the preceding block B037704 and row 6 of the block being evaluated, B037804.

	DIRECT GEOPHYSICAL DERIVATION Blast Block B 03/77/04			MINI MODEL Blast Block B 03/77/04		
Block & Row ID	Coking Coal 10.3%ash	Middlings Coal Primary - Coking	Total Primary cut at 1.80 Rd	Coking Coal Yield	Middlings Yield	Total Yield
B037804-R6	14.35	33.54	47.89	13.97	25.28	39.25
B37804-R6+R3	12.63	35.42	48.04	13.91	25.31	39.22
B37804-R6+R3+B37704-R6	12.19	36.18	48.37	13.80	25.28	39.08
B037804-R6+B037704-R6	12.96	35.15	48.11	13.77	25.26	39.03
Average	13.03	35.07	48.11	13.86	25.28	39.15
Standard Deviation	0.93	1.11	0.20	0.09	0.02	0.11

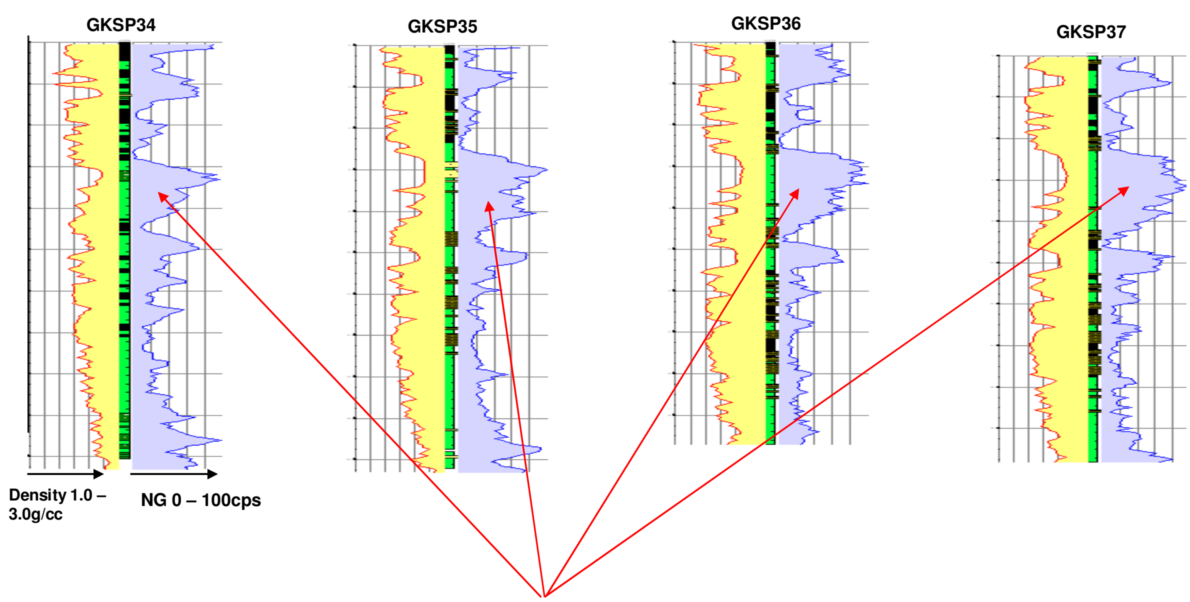
Finally a comparison between the mini model derived yields, where roof and floor deviations are taken into account and the geological model derived values pertaining to the ideal situation reveals definite differences in the yields as a result of the actual roof and floor elevations in practice. Coking coal yields are on average approximately 0.50% higher and middling <0.50%.

	MINI MODEL Blast Block B 03/78/04			GEOLOGICAL MODEL Blast Block B 03/78/04		
Block & Row ID	Coking Coal Yield	Middlings Yield	Total Yield	Coking Coal Yield	Middlings Yield	Total Yield
B037804-R6	13.97	25.28	39.25	13.02	25.64	38.66
B037804-R3	13.85	25.33	39.19			
B037704-R6	13.58	25.23	38.81	12.98	25.60	38.60

Further supplemental information for the evaluation of this blast block was obtained from four cored boreholes and four rotary drilled holes, next to the cored holes drilled on row three to effectively cover the extent of the blast block. The core was sampled to represent the bench being mined, from the existing roof to the prescribed floor and the rotary holes drilling chips were sampled. Full analysis will be done on the four cores and the chip samples to provide a basis for comparison of predicted values with representative geological sampled values from the blast as well as analysis done by the beneficiation plant on the run of mine material received from this block, products and waste generated during the test period.

The cored boreholes have been geophysically logged with both the density/caliper and large crystal natural gamma tools and evaluated. Cross sections of these boreholes are represented in the following schematics with some prominent features highlighted.

Additional CORED Boreholes on B 03/78/04



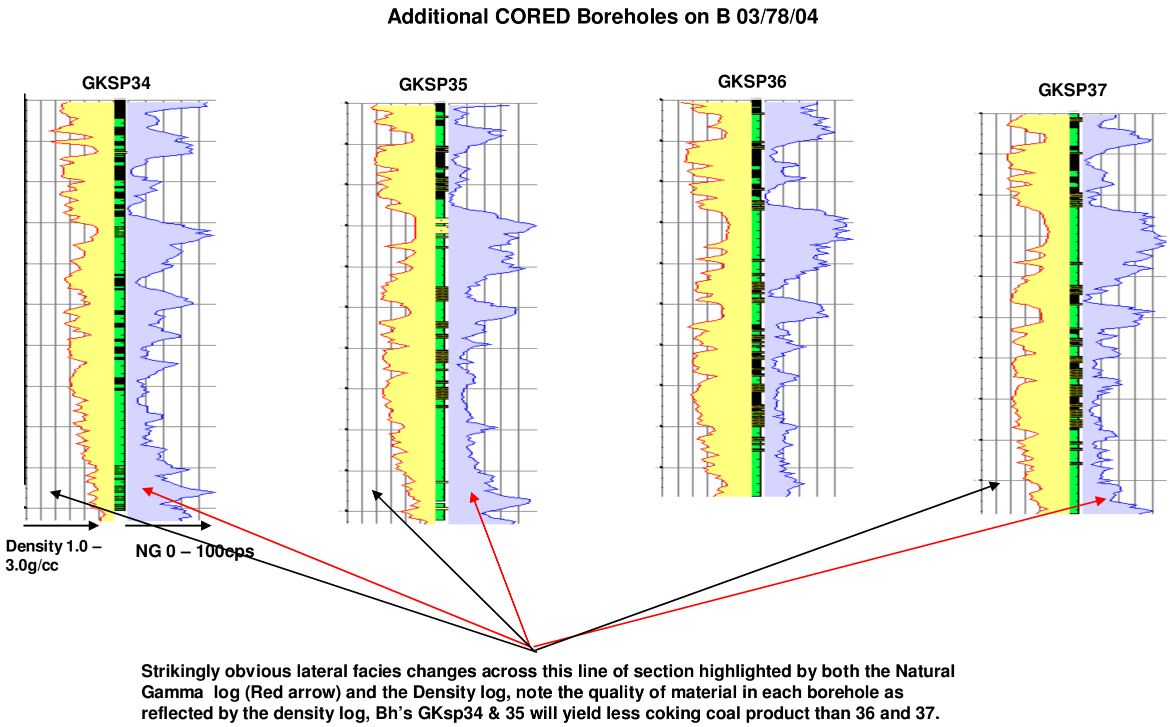
Strikingly obvious lateral facies changes across this line of section

The first of these cross sections highlights lateral facies changes below sample 9, the density log trace in red gives a rough indication of in situ rock densities which can be coupled to the quality of coal intersected and probable increases or decreases in the quantity of argillaceous sediment in the overall composition of the lithologies intersected, as well as a better lithological discrimination with regard to sediments other than coal and shale. GKSP34 and GKSP35 for example, though not apparent in this section have carbonate bands, probably correlatable with typical carbonate lenses encountered in the Volksrust Formation, in this region, at the base of the boreholes.

The natural gamma logs, having been normalized, reflect shaliness or argillaceous content within the vertical profile more profoundly than the density logs and in combination with the density logs allow better lithological discrimination and sample boundary correlation. The most relevant visual aspect noticeable in the interpretation indicates the overall quality of individual coal samples in the vertical profile and area's along section where better yields overall could be expected. Comparing the lower regions of the profiles where greater density fluctuations occur, it becomes apparent that the highest yields from these respective boreholes can be expected from borehole GKSP36 and GKSP37 while the poorest yield would emanate from GKSP34. The table below summarizes direct geophysically determined yields for the individual cored holes verifying the foregoing discussion on qualities.

	Direct Geophysical Evaluation				
Borehole	Sampled Depth	Cok Yield @ 10.3% Ash	Middlings @ 35% Ash	Bench Avg Rd g/cc	Coal/Shale Ratio
GKSP34	16.81	11.90	59.49	2.12	0.55
GKSP35	16.92	11.82	60.87	2.06	0.60
GKSP36	17.02	12.93	62.28	1.99	0.68
GKSP37	16.35	13.46	62.39	2.00	0.59

The schematic below has been discussed in the foregoing section and has merely been included for illustrative purposes.



CONCLUSION

The detailed study and additional information utilized in the interpretation and evaluation of this test block has verified the methodology used for yield prediction at Grootegeluk Coal mine and substantiated the application of our mini model and the scope of the interpretation of every second blast hole on the back row of a blast block, as sufficient representation of that block.

The hypothesis that directly determined yields from an ash normalized gamma log interpretation being closer to actual plant production results still needs to be confirmed. Should this be successful the additional information obtained from this will in future also be included in the data forwarded to mine planning for scheduling purposes.

…………………………………………

L. Roux (pr Eng Tech)

Head Geophysical Grade Control.

Geology Department.

Grootegeluk Coal Mine. 02/06/2006

Logeval

Grootegeluk Coal Mine

Log ID: **GKSP34**

Total Depth: **-20.60**

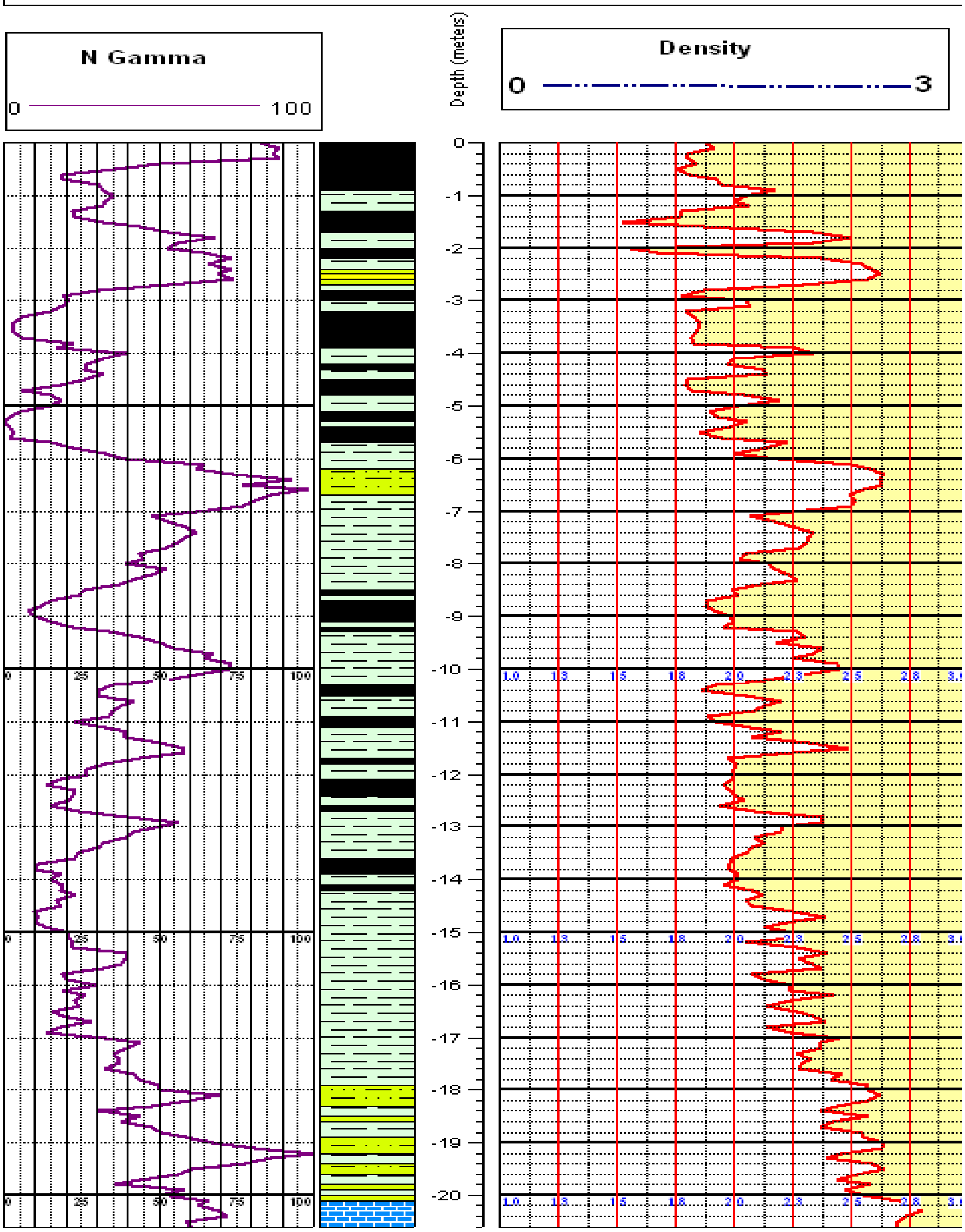
Location: **WATERBERG**

Latitude: **LATITUDE**

Longitude: **LONGITUDE**

Elevation (Ground Surface): **ELEVATION**

Drilling Date: **06/01/06**



Logeval

Grootegeluk Coal Mine

Log ID: **GKSP35**

Total Depth: **-20.60**

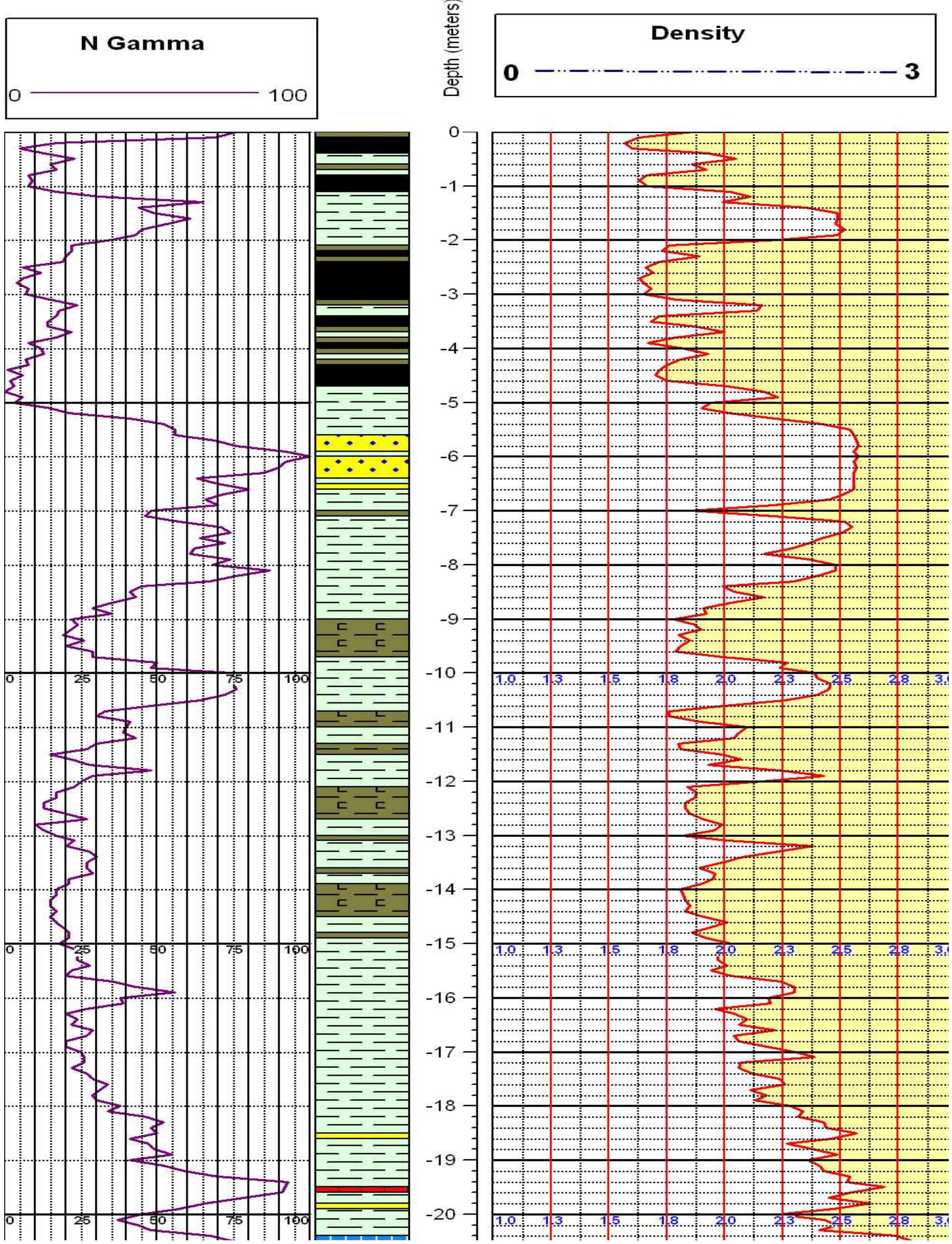
Location: **WATERBERG**

Latitude: **LATITUDE**

Longitude: **LONGITUDE**

Elevation (Ground Surface): **ELEVATION**

Drilling Date: **05/31/06**



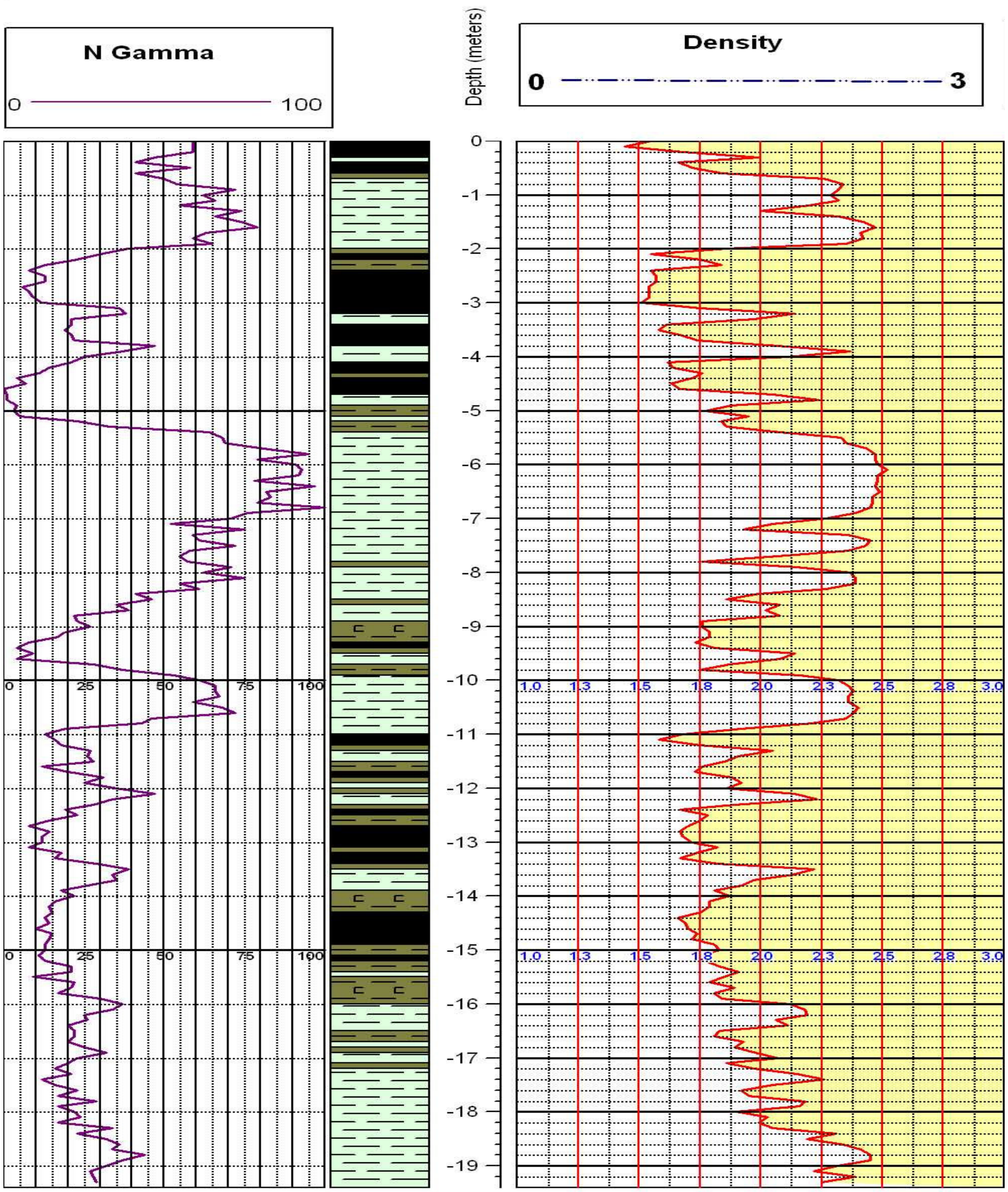
Logeval

Grootegeluk Coal Mine

Log ID: **GKSP36**

Total Depth: **-19.40**
Location: **WATERBERG**
Latitude: **LATITUDE**
Longitude: **LONGITUDE**
Elevation (Ground Surface): **ELEVATION**

Drilling Date: **05/31/06**



Logeval

Grootegeluk Coal Mine

Log ID: **GKSP37**

Total Depth: **-19.60**

Location: **WATERBERG**

Latitude: **LATITUDE**

Longitude: **LONGITUDE**

Elevation (Ground Surface): **ELEVATION**

Drilling Date: **05/31/06**