

# **THE MAIN FACTORS WHICH AFFECT PRODUCTIVITY AND COSTS ON SOUTH AFRICAN GOLD MINES.**

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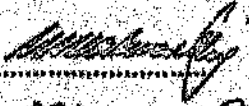
**A project report to the Faculty of Engineering, University of the Witwatersrand, Johannesburg,  
in fulfillment of the requirements for the degree of Master of Science.**

**Johannesburg, 1994.**

## DECLARATION

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

Signed.....



Dated this 25th day of August 1994.

## ABSTRACT.

A detailed analysis was performed on statistics obtained from twenty two gold mines in different mining districts, to determine the parameters which affect labour productivity and working costs.

The following appear to be the most important: —

shaft, development and stope layout; stoping method; effective shift time; management policy; rock and environmental constraints; level of technology; geological factors; depth; grade; payability; dilution; face advance and production rate.

Some of these parameters are fixed during the planning stages of the mine and leave little scope for further improvements. Others are beyond the control of management. Management is left with the following parameters which it must manipulate to improve labour productivity and costs: —

the stoping method and development layout; effective shift time; policy (soft issues); environmental constraints; face advance and dilution.

A description of an ideal mine is submitted as an aid to design for maximum labour productivity and minimum operating costs.

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## 1 SYNOPSIS.

A subjective and objective analysis was carried out on statistics derived from twenty two gold mines in five different mining districts, to determine the main parameters which affect labour productivity and working costs.

The following items appear to be the most influential ones:-

shaft, development and stope layout; stoping method; effective shift time; management philosophy and policy; rock and environmental engineering considerations; degree of mechanization and level of technology; geological factors; depth of mining; grade of ore mined and percentage payability; face advance rate; dilution; production rate.

Some of these parameters are fixed during the planning and design stages of the mine and leave little scope for management to create improvements.

Others are totally beyond the control of management. Management is therefore left with the following parameters which it must manipulate to improve labour productivity and costs:- the stoping layout and method; effective shift time; philosophy and policy (soft issues); environmental and rock conditions; face advance rate and dilution.

A description of an ideal mine is submitted as an aid to design for maximum labour productivity and minimum operating costs.

## 2 INTRODUCTION.

In the prevailing economic climate of a low gold price and inflationary pressures, profit margins on deep level gold mines are rapidly decreasing (if not already extinct). This has served to focus the attention of stakeholders (owners, employees, unions and government) as never before, on the ability of management to ameliorate the present situation or even to survive the crisis.

There is a wide variation in the apparent level of efficiency at which different deep level gold mines operate. Stakeholders have not been slow to use this information as ammunition to force management to make changes to improve the economic position on their individual operations.

As is common in this type of scenario, labour reductions are the first manifestation of managements response to the external pressure.

Also in response to an increase in working costs and hence the pay limit, there usually follows an increase in the grade of ore sent to the mills (Gold Fields Review, 1991). This inevitably leads to a decrease in the available ore reserves and therefore managements flexibility to carry on its operation.

To what extent the criticism, of the gold mining industry (and its management) as "fat cats", is justified has led to this investigation into the main factors governing the variation (in efficiency) between one mine and the other.

### 3 STATEMENT OF THE PROBLEM AND THE PROPOSED SOLUTION.

Before we can determine the factors which affect productivity and costs, we must consider what is meant by the terms efficiency, productivity and costs.

Efficiency is usually measured in financial terms . These are revenue, working expenditure, profit and productivity.

The term productivity, in the past, has been used as a measure of human output, for example, tons produced per employee. In recent times the meaning of the term has been enlarged to encompass the ratio of total output to total input. Thus, productivity can be increased by increasing the total output, for the same or even a smaller input or maintaining the same output for a smaller input.

For a gold mine, the total output for all practical purposes is gold, which is sold for revenue. On the other hand, the total input now includes labour, stores, equipment (including capital expenditure), power, water and external charges. Although it can be argued, that the gold produced can be increased, for the purpose of this investigation and because of certain practical constraints, this option (to increase output and therefore productivity) is dealt with in less detail. Instead, it was decided to concentrate on the input side of the equation and in particular, on the cost and labour productivity aspects only.

The main parameters which impact on operating costs and labour productivity would appear to be : - age of mine and extent of mining operations, average depth of workings, inclination (dip) of the ore

body, thickness of the ore body, mining layout and method, the value and areal extent of the payable ore, other geological factors, the degree of mechanisation, the use of new technology and even management philosophy. It will be obvious that the effect of each of these parameters (on costs and productivity) can be estimated but will be difficult to assess in precise terms, either in isolation or in relation to one another because of the other variables. At best, the solution presented will of necessity be a fairly subjective one.

Because of the nature of mining and the differences which exist even between neighboring mines and because of the large number of factors involved, it is suggested that the main factors be identified (in the first instance) by comparing one mine with another in terms of one factor only. This can then be done for each factor in turn. In this way, some statistically significant evidence may present itself to validate the importance of that factor. Another way to determine the main factors is by intuition using the benefit of past experience as an aid to judgement. As the whole project is basically a subjective analysis both methods will be used as deemed appropriate.

Because we are interested in productivity in its broadest sense, the main criteria against which the major factors will be assessed will be working costs and labour productivity.

We can summarise the above section by saying that the main objective is to determine the factors which affect productivity and costs on gold mines. The other objectives are:-

- \* to identify the important and limiting factors and their inter-relationships and how they affect the productivity on each of the mines under consideration
- \* to evaluate the effect of these factors by statistical or subjective estimation or sensitivity tests, whichever is appropriate
- \* to produce graphs or tables showing how these factors impact on productivity
- \* to use these to predict the productivity which can be expected on a hypothetical mine.

Information was obtained from twenty two mines, in five different mining districts, regarding their mining layouts, working costs and labour productivities. The results are given in Tables 3.1, 3.2 and 3.3.

This information was analysed in terms of the main parameters. Conclusions are drawn as to which of the parameters have the greatest impact on each mine. Finally, general conclusions are drawn about the relative impact of the various parameters in different situations.

# COST AND PRODUCTIVITY STATISTICS GENERAL SUMMARY

| DIS. DIST.                         | CENTRAL RAND. |          | WEST WITS JUNE |          |          |          |          |          |          |             | KLERKSDORP | ORANGE FREE STATE |          |                   |          | EVANDER  |          |                   |         |          |
|------------------------------------|---------------|----------|----------------|----------|----------|----------|----------|----------|----------|-------------|------------|-------------------|----------|-------------------|----------|----------|----------|-------------------|---------|----------|
| MINE                               | GRITVLE       | WACONS   | DEELRIJ        | DOORN    | NESTORIE | BLAND'S  | KLOOF    | LEAGON   | VENTERS  | WESTONHEATH | STILFRIT   | VAALSE            | BEATRICE | FRERED            | STHELEN  | WESTHOL  | CLACKEN  | WAGONS            | LESLIE  | WINKEL   |
| TOTAL MINING COSTS (000's)         | 7600          | 5056     | 14313          | 10961    | 28385    | 20718    | 31020    | 16340    | 10210    | 50723       | 17348      | 127143            | 18531    | 127118            | 24310    | 42401    | 1070     | 16037             | 6431    | 20370    |
| TONS MINED (000's)                 | 55.1          | 32.7     | 166.902        | 153.258  | 321.524  | 251      | 274.125  | 216.523  | 182.75   | 310.275     | 429        | 7013              | 1038     | 223               | 447      | 172      | 233      | 58                | 205     | 230      |
| TONS MILED (000's)                 | 70            | 75       | 125            | 135      | 240      | 165      | 193      | 145      | 152      | 245         | 222        | 371               | 233      | 181.008           | 228      | 187      | 233      | 51                | 178     | 65       |
| COST PER TON MILED (JUN '91)       | 127.21        | 76.44    | 106.42         | 152.76   | 103.85   | 137.85   | 178.76   | 180.41   | 123.3    | 143.83      | 123.71     | 73.53             | 144.47   | 110.53            | 101.01   | 145.77   | 127.23   | 105.30            | 107.40  | 110.71   |
| DITTO (MARCH 1991)                 | 144.38        | 81.28    | 148.97         | 170.74   | 180.08   | 145.82   | 226.14   | 147.35   | 123.77   | 176.87      | 147.40     | 82.7              | 155.82   | 143.18            | 110.62   | 182.40   | 107.09   | 124.61            | 122.32  | 106.29   |
| % INCREASE                         | 15.0534       | 7.741261 | 40.81122       | 17.0468  | 21.9487  | 0.713412 | 25.21603 | 12.9652  | 0.116228 | 15.43385    | 18.21423   | -14.7838          | 10.4483  | 13.39160          | 10.0858  | 24.0372  | 0.139333 | 23.01024          | 23.1363 | 25.78102 |
| STOPPING STATISTICS                |               |          |                |          |          |          |          |          |          |             |            |                   |          |                   |          |          |          |                   |         |          |
| SQUARE METERS                      | 10208         | 5.197    | 24.425         | 28.572   | 40.810   | 34.434   | 40.025   | 33.123   | 30.183   | 85.768      | 10328      | 14.830            | 171.202  | 41.024            | 22.74    | 23.27    | 20.134   | 15.015            | 37.078  | 14.555   |
| STOPES WORTH                       | 1.01          | 1.12     | 1.40           | 1.15     | 1.81     | 1.4      | 1.51     | 1.43     | 1.47     | 1.31        | 1.08       | 1.4               | 1.33     | 1.41              | 1.30     | 1.27     | 1.57     | 1.08              | 3.11    | 1.01     |
| STOPES TONS                        | 57.278        | 28.351   | 110.487        | 142.218  | 183.901  | 133.78   | 137.74   | 156.494  | 127.049  | 224.884     | 482.174    | 65.10             | 827.072  | 182.405           | 220.428  | 122.171  | 272.881  | 43.698            | 169.807 | 40.100   |
| FACE ADVANCE                       | 0.02          | 0.30     | 5.6            | 4.7      | 4.7      | 0.5      | 5.4      | 5.7      | 8.2      | 6           | 8.34       | 12.03             | 0.5      | 11.05             | 7.57     | 6.15     | 6.82     | 6                 | 7.55    | 8.1      |
| SQ. METERS/STOPES A.V.G.           | 0.41          | 1223     | 0.03           | 0.74     | 733      | 0.5      | 0.25     | 0.28     | 0.28     | 0.24        | 1020       |                   |          | 1.827             | 0.2220   | 0.18     |          | 0.1823            | 1.207   | 1.410    |
| HIGH                               | 2089          | 2223     | 2202           | 2585     | 1620     |          | 2655     | 2789     |          | 1253        |            |                   |          |                   |          |          |          |                   |         |          |
| SQ. METERS/STOPES EMPLOYEE         | 0.31          | 22.1     | 11.83          | 13.37    | 3.42     | 10.23    | 7.69     | 14.44    | 11.8     | 17.89       | 11.25      | 18.18             | 12.22    | 21.2              | 13.3     | 8.05     | 7.21     | 17.76             | 13.44   | 15.7     |
| STOPES EMPLOYEE                    | 2578          | 412      | 2037           | 2015     | 4302     | 2833     | 4305     | 2592     | 2565     | 4772        | 5688       | 635               | 14040    | 1633              | 2034     | 3052     | 343      | 2033              | 629     | 2316     |
| TONS/STOPES EMPLOYEE               | 38.43         | 33.3     | 54.24          | 48.23    | 44.14    | 63.74    | 38.07    | 52.73    | 40.0     | 42.06       | 40.17      |                   |          | 63.63             | 34.233   | 26.41    | 16.10    | 72.89             |         | 01.3     |
| SQ. METERS/DEV. METER              | 17.09         | 28.64    | 28.43          | 20.42    | 18.88    |          | 14.01    | 20.45    | 20.11    | 10.38       | 14.48      |                   |          | 13.16             | 10.03    | 20.91    | 22.2     | 24.91             | 23.44   | 30.84    |
| TOTAL STOPPING COSTS (R000's)      | 954.78        | 347.38   | 3541.18        | 4506.01  | 7502.76  |          | 7852.03  | 1633.07  | 3077.25  | 8342.04     | 18034      | 2245.88           | 4081.00  | 10223.01          | 4015.05  | 10403.34 | 1307.53  | 4450.22           | 140.02  | 2384.8   |
| STOPPING COSTS/SQ. METER (R's)     |               |          |                |          |          |          |          |          |          |             |            |                   |          |                   |          |          |          |                   |         |          |
| SKILLED WAGES                      | 2.88          | 3.07     | 5.78           | 6.03     | 11.87    |          | 8.50     | 7.53     | 8.89     | 11.04       |            | 4.12              |          | INCLOSUS          | 15.041   |          | 7.58     | 17.17             | 3.75    | 1.81     |
| UNSKILLED WAGES                    | 33.34         | 42.52    | 30.15          | 33.18    | 79.34    |          | 33.03    | 48.91    | 62.63    | 54.40       |            | 35.04             |          | 13.03             | 62.10    |          | 33.04    | 62.07             | 72.13   | 30.01    |
| STOCKS EXPLOSIVES                  | 2.85          | 11.18    | 6.07           | 6.33     | 11.47    |          | 10.92    | 11.01    | 9.25     | 6.88        | 12.69      | 0.27              | 8.91     | 0.25              | 10.08    |          | 0.64     | 8.12 (INCLOSUS)   |         | 0.28     |
| TIMBER                             | 2.85          | 4.46     | 37.58          | 22.32    | 43.86    |          | 33.59    | 55.41    | 84.88    | 33.23       | 43.23      | 10.33             | 12.87    | 42.24             | 18.04    |          | 11.43    | 0.84 (INCLOSUS)   |         | 4.48     |
| OTHER                              | 5.27          |          | 16.70          | 14.3     | 18.55    |          | 12.53    | 18.31    | 6.1      | 20.81       |            | 3.43              | 15.47    | 13.94             | 24.00    |          | 4.03     | 18.03             |         | 13.10    |
| TOTAL                              | 11.16         | 15.63    | 22.91          | 12.65    | 73.81    |          | 63.03    | 85.24    | 41.01    | 89.78       |            | 24.03             | 35.03    | 58.10             | 51.23    |          | 23.83    | 53.74             | 27.87   | 25.63    |
| SUNDARY ITEMS                      | 5.57          | 8.67     | 27.44          | 11.42    | 31.46    |          | 14.83    | 11.01    | 8.01     | 12.33       |            |                   | 30.53    |                   |          |          |          | 8.03              |         |          |
| TOTAL                              | 16.69         | 24.32    | 50.35          | 24.07    | 82.27    |          | 77.86    | 77.94    | 50.22    | 72.11       |            | 24.03             | 70.57    | 72.11             | 71.23    |          | 33.85    | 62.03             | 27.87   | 25.63    |
| STOPPING COST/TON (R's)            | 14.92         | 22.45    | 29.05          | 31.82    | 39.33    |          | 30.18    | 30.76    | 30.74    | 37.14       | 44.02      |                   |          | 41.72             | 34.95    | 34.03    | 23.48    | 31.12             | 23.05   | 29.4     |
| DEVELOPMENT STATISTICS             |               |          |                |          |          |          |          |          |          |             |            |                   |          |                   |          |          |          |                   |         |          |
| METERS ADVANCED                    | 532           | 318      | 659            | 1003     | 2207     |          | 2558     | 1796     | 1033     | 7386        |            | 12718             | 2823     | 2850              | 1011     | 3048.5   | 441.6    | 1033              | 470     | 2009     |
| DEVELOPMENT TONS (000's)           | 14656         | 3.003    | 51.204         | 41.1     | 65.188   |          | 72.8815  | 33.933   | 21.401   | 74.314      | 217.705    |                   |          | 63.0              | 22.433   | 103.41   | 51.05    | 23.020            | 17.834  | 32.204   |
| METERS/DEVELOPER                   | 56.7          | 82.5     | 96             | 105      | 28       |          | 53       | 130      | 131      | 85          | 105        |                   |          | 127.23            | 65.7     | 94.91    | 63.0     | 119.0             | 56.9    | 56.9     |
| METERS/DEV. EMPLOYEE               | 3.7           | 3.6      | 1.89           | 2.42     | 2.34     | 4.07     | 1.57     | 2.83     | 2.8      | 2.83        | 3.03       | 3.32              | 0.94     | 2.49              | 1.908    | 2.02     | 3.5      | 2.8               | 3.01    | 3.01     |
| DEV. EMPLOYEES                     | 237           | 86       | 455            | 789      | 943      |          | 1624     | 636      | 408      | 273         | 2750       | 3332              | 777      | 1403              | 1070     | 1102     | 120      | 403               |         | 655      |
| TONS/DEV. EMPLOYEE                 | 63            | 42.1     | 65.05          | 57.74    | 72.37    |          | 88.78    | 33.26    | 45.7     | 78.36       | 75.14      |                   |          | 60.8              | 30.33    | 13.28    | 51.10    | 60.65             |         | 62.2     |
| TOTAL DEV. COSTS (R000's)          | 445.648       | 143.447  | 218.287        | 1896.006 | 2110.426 |          | 4102.224 | 1378.136 | 334.073  | 2320.033    | 6221       | 3321.200          | 2023.881 | 2701.139          | 1620.882 | 1704.018 | 235.328  | 1244.233          | 254.21  | 1382.024 |
| SKILLED WAGES                      | 17.91         | 24.58    | 62.82          | 41.06    | 48.8     |          | 48.51    | 27.83    | 47.24    | 43.11       |            | 38.32             |          | INCLOSUS          | 57.45    |          | 23.04    | 45.15             | 57.233  | 26.02    |
| UNSKILLED WAGES                    | 269.85        | 310.42   | 410.44         | 323.58   | 306.18   |          | 660.14   | 281.00   | 330.13   | 293.05      |            | 309.33            |          | 130.1             | 330.88   |          | 227.8    | 422.81            | 225.01  | 404.01   |
| STOCKS EXPLOSIVES                  | 33.15         | 67.53    | 105.80         | 77.14    | 128.41   |          | 142.97   | 111.78   | 117.08   | 80.23       | 84.08      | 75.01             | 4.89     | 132.78            | 102.06   |          | 35.23    | 103.84 (INCLOSUS) |         | 70.63    |
| PERMANENT EQUIPMENT                |               |          | 151.58         | 96.88    | 350.81   |          | 189.06   | 144.45   | 74.03    | 189.04      |            | 59.31             |          | 59.37             |          |          |          |                   |         |          |
| OTHER STOKES                       | 139.20        |          | 150.73         | 337.88   | 39.35    |          | 345.22   | 147.73   | 105.34   | 123.07      |            | 11.11             | 240.81   | 218.13 (INCLOSUS) |          |          | 87.54    | 153.91            |         | 105.43   |
| TOTAL                              | 102.42        | 57.8     | 703.24         | 511.07   | 429.87   |          | 877.23   | 408.86   | 300.92   | 412.28      |            | 187.23            | 388.47   | 242.02            | 423.73   |          | 101.72   | 405.18            | 138.84  | 238.23   |
| SUNDARY ITEMS                      | 32.52         | 23.07    | 325.31         | 119.08   | 163.72   |          | 30.06    | 63.53    | 54.8     | 81.87       |            |                   | 46.91    |                   |          |          |          | 158.01            |         |          |
| TOTAL                              | 472.51        | 45.11    | 1341.31        | 834.76   | 595.24   |          | 1407.53  | 775.81   | 605.88   | 606.03      | 842.70     | 733.03            | 789.24   | 575.92            | 1011.78  | 638.09   | 625.30   | 1181.23           | 840.87  | 603.27   |
| DEV. COST/METER INC. OF HEAD (R's) |               |          | 3484           | 2788     | 2888     |          | 3477     | 2341     | 2510     | 2605        |            |                   |          | 1035              | 1881.59  |          |          | 1627              |         |          |
| DEVELOPMENT COST/TON (R's)         | 30.08         | 59.81    | 38.85          | 41.89    | 30.88    |          | 57.78    | 35.55    | 33.36    | 34.37       | 33.88      |                   |          | 30.21             | 30.33    |          | 35.87    | 34.02             |         | 30.56    |
| OTHER STATISTICS                   |               |          |                |          |          |          |          |          |          |             |            |                   |          |                   |          |          |          |                   |         |          |
| TOTAL MILES EMPLOYED               |               |          | 4084           | 6781     | 8385     |          | 11802    | 5579     | 3326     | 10294       | 28831      |                   |          | 8859              | 18597    | 14533    | 2133     | 6008              |         | 7187     |
| TOTAL EMPLOYED                     |               |          | 6121           | 8343     | 11614    |          | 19789    | 8913     | 7333     | 13409       | 33205      |                   |          | 16118             | 24573    | 14826    | 2488     | 7236              |         | 9328     |
| TONS/DEV. EMPLOYEE                 |               |          | 32.85          | 27.82    | 34.37    | 35.00    | 23.40    | 29.17    | 25.1     | 30.14       | 25.13      | 18.88             |          | 28.73             | 27.60    |          | 24.33    | 24.63             |         | 28.59    |
| TONS/TOTAL EMPLOYED                | 27.01         | 21.48    | 25.37          | 22.35    | 27.77    | 21.54    | 19.59    | 21.31    | 20.85    | 23.02       | 16.57      | 31.87             |          | 23.89             | 23.89    |          | 21.11    | 22.31             |         | 24.28    |

TABLE 3.1

# STATISTICS GENERAL SUMMARY

| STATISTICS GENERAL SUMMARY     |               |          |           |          |                 |         |          |          |          |          |          |           |             |          |                    |          |          |          |          |          |          |
|--------------------------------|---------------|----------|-----------|----------|-----------------|---------|----------|----------|----------|----------|----------|-----------|-------------|----------|--------------------|----------|----------|----------|----------|----------|----------|
| DISTRICT                       | CENTRAL RAND. |          |           |          | WEST WITS LINE. |         |          |          |          |          |          |           | KLERKSDORP. |          | ORANGE FREE STATE. |          |          |          | EVANDER. |          |          |
| MINE                           | GRUYERE       | WROONS   | DEELKRIJL | DOORN    | HEASTDRE        | ELANDSD | KLOOF    | LEBANDH  | VENTERST | WESTDRE  | WESTDRE  | STILFONTS | VAN REEF    | BEATRIX  | PRESSERA           | STHELENS | WESTHOL  | SPADKEN  | KURCHES  | LESLIE   | WINKELK  |
| TOTAL MINING COSTS (000'S).    | 7600          | 5639     | 14318     | 19881    | 29538           | 22712   | 81940    | 10910    | 19210    | 39759    | 89849    | 12884     | 192193      | 21595    | 193118             | 24510    | 42501    | 8975     | 19087    | 8421     | 20579    |
| TONS MINED (000'S).            | 92.04         | 97       | 160.888   | 188.486  | 322.621         | 211.12  | 270.125  | 216.523  | 152.888  | 310.275  | 485.1    | 76.55     | 1083        | 268      | 385                | 216      | 382      | 52       | 204      | 72       | 218      |
| TONS MILLED (000'S).           | 70            | 76       | 155       | 150      | 240             | 165     | 180      | 145      | 192      | 3.5      | 562      | 171       | 694         | 101.692  | 8                  | 3.06     | 107      | 51       | 178      | 56       | 170      |
| GRADE OF ORE MILLED.           | 8.05          | 2.6      | 5.8       | 5.64     | 8.39            | 6.76    | 12.8     | 4.5      | 8.08     | 10.2     | 6.31     | 2.97      | 8.82        | 8        | 5.31               | 6.57     | 3.48     | 5.7      | 4.01     | 3.9      | 3.6      |
| COST PER TON MILLED (JUN '89). | 127.91        | 75.44    | 108.02    | 182.78   | 123.08          | 197.66  | 178.78   | 130.41   | 122.8    | 148.83   | 123.71   | 73.53     | 141.47      | 110.89   | 403.01             | 146.77   | 127.89   | 105.90   | 107.08   | 110.71   | 121.05   |
| OUTPUT (MARCH 1989).           | 148.38        | 81.28    | 148.87    | 179.74   | 150.09          | 148.92  | 220.14   | 147.35   | 192.77   | 170.47   | 147.46   | 82.7      | 185.02      | 150.15   | 116.00             | 182.95   | 187.89   | 184.91   | 198.32   | 180.28   | 148.4    |
| % INCREASE.                    | 15.05384      | 7.741251 | 40.51122  | 17.84628 | 21.84507        | 0.93912 | 25.23909 | 12.55093 | 0.118992 | 18.45293 | 18.21426 | -14.7882  | 16.64963    | 9.499019 | 19.09639           | 24.65782 | 9.183789 | 28.01024 | 30.19293 | 55.79108 | 16.88344 |
| GENERAL STATISTICS.            |               |          |           |          |                 |         |          |          |          |          |          |           |             |          |                    |          |          |          |          |          |          |
| WEIGHTED ROCK BREAK DEPTH.     | 629           | 484      | 2088      | 2594     | 2085            | 2051    | 2335     | 1815     | 1818     | 1488     | 2817     | 1011      | 1825        | 787      | 1574               | 1969     | 1808     | 622      | 1535     | 226      | 1121     |
| VIRGIN ROCK TEMPERATURE.       | 25            | 19       | 37.5      | 40.1     | 39.2            | 39      | 44       | 38.2     | 38.1     | 35       | 44.8     | 34.2      | 41.0        | 34.8     | 42.0               | 40.1     | 53.1     | 0        | 61.8     | 30.9     | 34.2     |
| DOWNCAST AIR.                  | 390           | 418      | 424       | 860      | 1423            | 1006    | 1137     | 346      | 690      | 1260     | 2259     | 338       | 4301        | 517      | 2408               | 1963     | 1749     | 325      | 856      | 299      | 823      |
| COMPRESSED AIR.                | 8.1           | 9.8      | 55        | 42       | 74              | 40.4    | 93       | 92       | 64       | 74       | 109      | 25        | 215.0       | 40       | 59.5               | 70       | 92.5     | 15       | 23.9     | 18       | 89       |
| NUMBER OF PERSONS:             |               |          |           |          |                 |         |          |          |          |          |          |           |             |          |                    |          |          |          |          |          |          |
| UNDERGROUND                    | 3159          | 409      | 5785      | 6343     | 8182            | 7014    | 13767    | 5393     | 6039     | 11782    | 16222    | 1905      | 29273       | 8930     | 12460              | 15821    | 18392    | 2135     | 8419     | 2830     | 7137     |
| IN STOPS                       | 1191          | 337      | 2529      | 2967     | 3570            | 2503    | 5184     | 2911     | 2669     | 5348     | 6069     | 358       | 10011       | 1893     | 5410               | 2470     | 6163     | 1110     | 2859     | 829      | 3011     |
| IN DEVELOPMENT.                | 377           | 72       | 436       | 1055     | 847             | 1099    | 2273     | 855      | 464      | 2270     | 2390     | 427       | 8910        | 892      | 2129               | 960      | 1160     | 194      | 778      | 231      | 731      |
| OTHER LABOUR.                  | 1589          | 0        | 2800      | 2821     | 4753            | 5473    | 9310     | 2217     | 2893     | 4159     | 7893     | 5         | 14782       | 2893     | 7842               | 8183     | 8287     | 891      | 3276     | 1169     | 8298     |
| STOPE TONS.                    | 48.53         | 27.23    | 114.09    | 139.5    | 200.8           | 160.4   | 170.41   | 154.48   | 125.92   | 217.5    | 244.79   | 50.65     | 654.96      | 155.03   | 120.07             | 133.84   | 270.78   | 48.69    | 187.12   | 45.04    | 193.27   |
| AIR/MAN/PERSONS (M/M/S)        | 124           | 1022     | 74        | 140      | 188             | 156     | 83       | 152      | 114      | 107      | 147      | 287       | 183         | 87       | 197                | 145      | 153      | 192      | 147      | 128      | 129      |
| DOWNCAST AIR/TON MINED.        | 5             | 4.4      | 2.6       | 4.7      | 4.7             | 6.5     | 4.2      | 4.1      | 4.3      | 4        | 5.4      | 8.8       | 4.4         | 2.6      | 5.3                | 6.8      | 4.6      | 5.8      | 4.7      | 4.8      | 4.4      |
| REFRIGERATION/TON MINED.       | 0             | 0        | 63        | 57       | 48              | 221     | 127      | 58       | 44       | 51       | 142      | 0         | 121         | 82       | 110                | 07       | 16       | 0        | 101      | 0        | 84       |
| AVG. FACE VEL. /CTY.           | 0.43          | 0.49     | 0.54      | 1.28     | 0.5             | 0.6     | 0.7      | 0.52     | 0.8      | 0.8      | 0.81     | 0.46      | 0.79        | 1.02     | 0.6                | 0.8      | 0.6      | 0.88     | 1.27     | 4.5      | 4.2      |
| AVG. WET BLK. / TEMP. AT FACE. | 21.5          | 19.6     | 31.1      | 30.1     | 30.3            | 25.4    | 31       | 26.4     | 25.6     | 27.8     | 28.9     | 28.9      | 29.5        | 28.1     | 25.3               | 28.1     | 29.2     | 24.9     | 28.8     | 29.2     | 29       |
| AVG. KATA IN STOPS.            | 16.8          | 21.2     | 8         | 13.4     | 8.9             | 17.2    | 7.3      | 11.7     | 10.4     | 14.5     | 12       | 12.3      | 11.8        | 18.0     | 12.8               | 13.3     | 10.9     | 15.1     | 15.5     | 8.8      | 10.9     |
| ELECTRICAL ENERGY CONSUMED:    |               |          |           |          |                 |         |          |          |          |          |          |           |             |          |                    |          |          |          |          |          |          |
| MAN/HOUR/MONTH.                | 21224         | 5336     | 12112     | 15390    | 58454           | 47150   | 26200    | 11272    | 1420     | 5700     | 136785   | 8160      | 142200      | 28704    | 46628              | 33379    | 10857    | 417      | 7888     | 2174     | 27528    |
| MAXIMUM DEMAND (MW).           | 35.74         | 17.79    | 22        | 27       | 90.80           | 73.01   | 87       | 63       | 17       | 39       | 171.53   | 16.42     | 317.4       | 47.19    | 143.59             | 59.82    | 20.7     | 18.1     | 53.4     | 15.8     | 89       |
| TOTAL RATING DIESEL UNITS (KW) | 204           | 0        | 1000      | 4255     | 8120            | 2450    | 8931     | 5094     | 3028     | 4351     | 6394     | 4402      | 13354       | 1578     | 32.3               | 1533     | 1189     | 1591     | 8421     | 1233     | 1828     |
| AVG. FACE ADVANCE.             | 0.8           | 0.2      | 6.1       | 4.8      | 5.1             | 8.5     | 5        | 8.8      | 6.8      | 6.1      | 10       | 12        | 8           | 9        | 7.8                | 6.1      | 8.7      | 8        | 7.4      | 6.1      | 7.4      |
| AVERAGE STOPPING WIDTH.        | 0.69          | 1.31     | 1.47      | 1.16     | 1.55            | 1.4     | 1.54     | 1.47     | 1.47     | 1.32     | 1.19     | 1.4       | 1.30        | 1.43     | 1.53               | 1.37     | 1.87     | 1.18     | 1.11     | 1.83     | 1.13     |

TABLE 8.2

# A SURVEY OF GOLD MINES (COMSA)

## STOPING AND DEVELOPMENT LAYOUTS

| MINE            | S<br>L | INT. LVL<br>SPACING | DIP   | X/CUT<br>SPACING | BACK<br>LENGTH | PANEL<br>LENGTH | NO. OF<br>PANELS | NO. OF<br>BOXHOLE/<br>GULLIES |
|-----------------|--------|---------------------|-------|------------------|----------------|-----------------|------------------|-------------------------------|
| <b>CENTRAND</b> |        |                     |       |                  |                |                 |                  |                               |
| GRVLEI          | S      | 68                  | 13    | 180              | 263            | 30              | 8                | 1/CG                          |
| WRCONS.         | S      | 90/60               | 15    | 120              | 130            | 9               | 12               | 1/CG/SG                       |
| ER.P.M.         | L      | 40                  | 22    | 80               | 180/270        | 45/(60)         | 4/6              | 4/2                           |
| <b>WESTWITS</b> |        |                     |       |                  |                |                 |                  |                               |
| DEELKRIJL       | L      | 72                  | 28    | 60               | 170            | 34              | 5                | 3/2                           |
| DOONEN          | L      | 91                  | 24    | 60               | 224            | 28              | 8                | 3/5                           |
| EASTORIE        | L      | 48                  | 22    | 60               | 132            | 33              | 4                | 3/1                           |
| WESTORIE        | L      | 91                  | 22    | 60               | 240            | 30              | 8                | 3/6                           |
| RIJCK           | L      | 68                  | 30    | 60               | 136            | 27              | 5                | 3/2                           |
| LIBANON         | L      | 65                  | 38    | 60               | 105            | 35              | 3                | 2/1                           |
| WESTDEEP        | L      | 50                  | 21    | 60               | 240            | 10              | 6                | 5/1                           |
| <b>KLERSDOP</b> |        |                     |       |                  |                |                 |                  |                               |
| SUFFELS'N       | S      | 70                  | 17    | 150              | 240            | 23              | 12               | 8/4                           |
| HARTBEN         | S      | 45                  | 10    | 150              | 260            | 37              | 7                | 7                             |
| STILFONT'N      | S      | 70                  | 30/45 | 150              | 98/140         | 20/25           | 4/7              | 2/CG                          |
| VAALEHEFS       | S      | 47                  | 15    | 180              | 175            | 30              | 5                | 5/0                           |
| <b>O.F.S.</b>   |        |                     |       |                  |                |                 |                  |                               |
| BEATRIX         | S      | 50                  | 5     | 100              | 280            | 0               | 9                | 8/1                           |
| PRES.BRAND      | S      | 63                  | 27    | 120              | 139            | 35              | 4                | 4/0                           |
| ST.HELENA       | S      |                     |       |                  |                |                 |                  |                               |
| WESTHOLD        | S      | 58                  | 15    | 120              | 224            | 37              | 6                | 3/CG                          |
| <b>EVANDER</b>  |        |                     |       |                  |                |                 |                  |                               |
| BRACKEN         | S      | 71                  | 34    | 180              | 127            | 9               | 14               | 1/CG                          |
| KINROSS         | S      | 61                  | 15    | 180              | 270            | 24              | 10               | 5/CG                          |
| LESLIE          | S      | 66                  | 19    | 200              | 187            | 9               | 22               | 1/CG                          |
| WINKEL'K        | S      | 77                  | 29    | 175              | 158            | 9/18            | 18/9             | 1/CG                          |

NOTE:

S - SCATTERED MINING.

L - LONGWALL MINING.

TABLE 3.3

#### 4 FURTHER DISCUSSION ON TERMINOLOGY AND DEFINITIONS.

This section deals with the identification and definition of all the items which can in any way affect productivity and costs on a gold mine.

##### **DEFINITION OF COSTS.**

Profit is obtained when one deducts costs from revenue ( $Pr = R - C$ ). In this context,  $Pr$  is the working profit,  $R$  is the revenue from the sale of gold and  $C$  is the operating or working costs incurred in the production of the gold. Costs are also synonymous with the terms expenditure or working expenditure.

Although the title of the report requires that the factors which affect productivity and costs be identified, this will be done in the context used and understood by the mines. The reason for doing this, is mines still regard working costs as one of the main control parameters for management and productivity as only one of many items which affect those costs. In the mines' context, productivity refers to human output only. For example, management monitors the centares per stoper or per stoper employee. The statistics given by the mines is in this format and will be analysed as such because the numbers of people involved can be readily estimated. The modern definition of productivity is far broader than this, as shown in the next section.

##### **DEFINITION OF PRODUCTIVITY.**

Productivity is the ratio of total output to total input.

In the context of this report and for all practical purposes "output" is the gold produced, which yields the revenue of the mine. "Input" is the sum of all the resources employed by the mine and can be effectively represented by the total expenditure. The main components of the expenditure are labour costs, material and equipment costs, power, water and external charges. The statistics given by the mines do not always indicate whether the costs are direct costs only or include varying degrees of overhead expenditure. In any case, the difference in accounting systems between one mine and another would preclude any exact comparison. This adds to the subjective nature of the analysis.

## THE ITEMS WHICH MAKE UP THE "INPUT".

The items which make up the input are people, equipment, material and the environment or to put it another way, the 6 M's of business:- men, material, management, money, method and machinery. In mining one should add another "M" namely, mineral or rather ore reserve.

## PEOPLE.

There are 2 categories of people:- managers and workers. The former category comprises certain levels of supervision (senior and middle management), while the latter can be further divided into front line supervisors, (including lower levels of management), skilled and unskilled employees. People contribute to the costs to the extent that they earn wages, bonuses and overtime pay. They also add to the costs because they are paid pensions and are provided with housing and medical services and other fringe benefits such as motor cars. The wages and other benefits are, to a large extent, fixed as a result of competitive forces in a market economy and the collective bargaining process, which forms an integral part of the South African industrial relations system. There is little one can do to reduce the level of reimbursement once these have been set, although there is some scope to limit further increases when an employer is faced with a loss making situation. This is the case at present in the gold mining industry. Another recourse in these circumstances is to reduce the numbers of people in employment, by retrenchment or early retirement or combinations of these.

## EQUIPMENT.

While people can be disposed of with relative ease, thus providing almost immediate savings in working costs (severance packages will have to be paid), the same cannot be done with the other cost items.

Reducing the scale of operations will lead to certain items of equipment becoming redundant and these may be disposed of for a short term (one - off) gain. However, if this is done the value is usually only a fraction of the value or even replacement cost, should this become necessary at a later date. On the other hand a decision to change the mining method and hence the type of equipment in use may well be a beneficial one if that equipment has become uneconomical. (For example, with the rand dollar exchange rate the cost of imported mechanised mining equipment such as load-haul-dumpers has tripled in recent years).

## MATERIAL.

Like equipment, the amount or cost of material can only be substantially reduced by reducing the scale of operations. This is not to say that efforts to reduce wastage in whatever form it occurs, should not be encouraged. What is being said, is that savings of the order of magnitude possible with people will not be realised.

## ENVIRONMENT.

Those items which comprise the environment include ventilation, refrigeration, pumping, engineering and mining services to name only a few. As in the case with equipment and material, savings can be achieved by reducing the scale of operations and more efficient usage. However, as in the case with those items, the magnitude is not likely to be very large (unless major changes in mining methods are introduced).

## METHODS.

The type of mining method chosen does have the potential to affect the working costs by an order of magnitude, particularly if the method forms part of an integrated system of mining.

For example, a highly mechanised system employing trackless mechanised mining equipment (TM3), impact breakers and reciprocating face conveyors or even continuous scrapers can have a very significant effect on mining costs. For a start, the amount of labour and footwall development can be halved.

In the case of the first two items mentioned above, the potential for waste removal is also present (packing or dumping). This means that the value of the ore being sent to the reduction works can be increased and the additional hoisting and milling capacity can be utilised to mine more gold bearing ore. The saving in footwall development waste is also important if shaft hoisting capacity is a constraint. If the plant capacity is a limiting factor, it is generally a viable proposition to increase either the waste sorting capacity or even the milling and extraction capacity, if this means that more gold bearing ore can be processed. (D.A.Immelman, 1983; A.L.Hinde, 1985/86 etc.).

For these savings to be realised, the basic infrastructure must also be in place. By this is meant that shafts, haulages, transport and maintenance facilities must also be capable of supporting the newer, more advanced, (technologically speaking), equipment. Hydro-power and backfill both have the

potential to improve efficiency and productivity. Again, to maximise the benefits of these technologies they should be incorporated into the mining system from the start rather than replace other forms of power and support which may already be in place and functional.

## RESERVE.

For a given pay-limit (cut-off grade), the tonnage and average value of the (payable) ore reserve which can be mined is fixed. On the other hand, because the pay-limit changes with the price of gold and the cost per ton milled, both the ore reserve tonnage and value are constantly changing. In recent times, because of a strengthening of the Rand Dollar exchange rate and inflation, the pay-limit has tended to move upwards rather than fluctuate. This has reduced the ore reserve tonnage and increased the average value. In the case of marginal mines the average value of the ore to the mills has not always increased to the extent hoped for. This can be explained as follows:- the tonnage which is sent to the mills does not only come from the ore reserve but also from several other sources; as the tonnage in the official ore reserve decreases so does the flexibility of management to plan its operations and produce the ore; thus the tonnage reporting to the mills comprises less of the now higher grade ore reserve tonnage and more of the tonnage from the other sources. (South African Mine Valuation, C.D.Storror, 1977).

Those marginal mines which have succeeded in increasing their grade of ore to the plant, have usually reduced the tonnage treated. They have tended to maintain the tonnage from the ore reserve but reduced that from other sources (usually marginal ore, classified as "not in reserve - NIR", "green blocks" etc).

Where a mine is making a profit, each additional ton treated, will contribute an additional amount to the profit, provided that the cost of mining and treatment (extraction) is more than covered. On the other hand, where the mine is making a loss, each additional ton treated, will further add to that loss. The paradox exists: to reduce working losses one must reduce the scale of operations even though this means that the unit cost of mining and treating the ore will increase.

## 5. SELECTING THOSE ITEMS WHICH HAVE THE GREATEST IMPACT ON PRODUCTIVITY AND COSTS

From the previous discussion, a definition of productivity has emerged, in the broader sense as well as the more restricted version (labour productivity) used in this report. In the following paragraphs, the terminology used on the mines will be used:- people are classified into management/supervision, skilled and unskilled labour; equipment and material are referred to as stores; the environment consists of mining and general services (such as pumping and ventilation), the costs of which are also made up by people and stores. The importance of each of these can be seen from an analysis of working expenditure from the mines, of one of the major mining groups for June 1989. Here the breakdown of expenditure is into the main categories of skilled and unskilled labour, stores, power and water and sundry expenditure.

The percentages average out as follows:-

Skilled labour 16.7 (from 15 to 20), unskilled labour 27.7 (from 25 to 31), stores 33.4 (from 29 to 37), power 12.5 (from 10.5 to 15.5), sundries 9.4 (from 7.4 to 12.4). Combining the two categories of labour one can see that labour makes up between 40 and 50 percent of the total expenditure. Stores and labour makes up nearly 80 percent. Stores and power together make up 46 percent (varies from 40 to 49). Capital expenditure (including sundry persons) averages out at 8.5 percent of total expenditure (varies from 5 to 15). Capital expenditure is also made up of labour and stores, including machinery. Capital items include shaft sinking and other new and major installations and are not regarded as normal working expenditure (there is also a tax implication).

From the preceding paragraphs it can be seen that an analysis, which is based on the cost of labour, stores and power only, (representing over 90 percent of the total expenditure, excluding capital) should be sufficiently broad based for the purpose of this project. The parameters to be investigated will thus include any item which can affect the number of people employed on a mine or the amount of stores consumed. In each instance the analysis is done for all the mines comprising the general group and then again for those mines in the select group (West Wits mines).

## 5.1 AGE OF MINE.

The age of a mine as such, does not directly affect the costs or productivity. Certain old mines operate at higher levels of productivity than newer ones and vice versa. Where these mines are also operating at great depths and at the extreme limits of their mining lease area, these factors will directly affect productivity.

The costs of transporting men, material, equipment, rock and services (electricity, compressed air, water and ventilation) over large distances and in all directions can be exorbitant. The cost of maintaining these long lines of communication is equally expensive and the time wasted in travelling to and from the production areas cannot be recovered. Total shift times are measured from surface and limited by legislation and union agreements.

Figure 5.1, illustrates the relationship between the relative age of a mine and productivity, for the mines in the general group. The mines are arranged in descending order of age (i.e. from the oldest to the youngest). Using Lotus 123r3, and carrying out a regression analysis (R squared), there is no apparent correlation between the age of a mine and labour productivity or cost statistics. There are 20 mines in the general group so the results are fairly conclusive. The only exception (highest value of R squared = 0.292) is in the category of Age vs Stope cost/ton. The relationship is an inverse one, which one can accept on the basis that older mines are in general more marginal and therefore cost conscious.

There are insufficient mines in the select group to provide a good sample but once again there is no apparent correlation between age of mine and productivity or costs. The highest value of R squared (0.277) for the select group is in the category of Age vs square meters/stope employee (see Figure 5.2). Here the relationship is a direct one and again the logic would seem to be acceptable (the average for the three older mines is also greater than that for the four younger ones, however the latter group is influenced by Kloof and East Driefontein, both of which have high stoping widths).

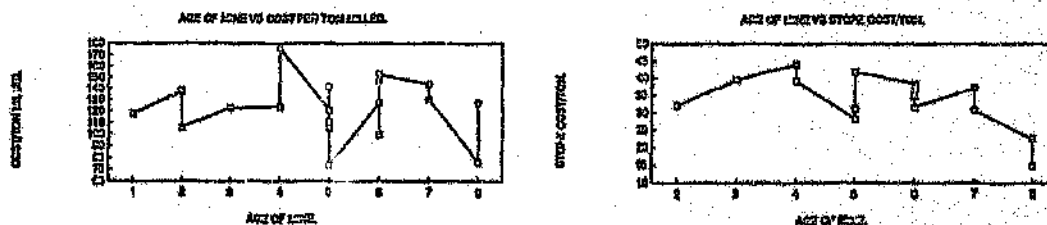
If one considers the influence of age logically, one could reasonably expect that there would be longer lines of communication, greater temperatures and pressures, all of which could impact negatively on productivity and costs. In practice however, this is not always the case. The oldest mines, including the very low cost producers, Grootvlei and West Rand Cons. sometimes have other factors

## AGE OF MINE AND PRODUCTIVITY STATISTICS

| MINE     | RELATIVE COST/TON | SCI.MET./ TONS/ | SCI.MET./ | STO.COST TONS/    | DEV.COST TONS/    | TONS/             |       |       |       |       |
|----------|-------------------|-----------------|-----------|-------------------|-------------------|-------------------|-------|-------|-------|-------|
| AGE      | MILL '89          | STO.EMP.        | STO.EMP.  | DEV.MET. /TON (R) | DEV.EMP. /TON (R) | UDG.EMP. TOT.EMP. |       |       |       |       |
| GRTVLEI  | 8                 | 127.21          | 8.31      | 20.48             | 17.06             | 14.92             | 83    | 30.08 | 27.61 | 21.48 |
| WROONS   | 8                 | 75.94           | 22.1      | 88.5              | 28.84             | 22.49             | 42.1  | 39.91 |       |       |
| LIBANON  | 7                 | 180.41          | 14.44     | 82.73             | 20.48             | 30.78             | 88.88 | 36.85 | 39.17 | 31.81 |
| WESTDRIE | 7                 | 149.08          | 11.89     | 47.09             | 19.34             | 37.14             | 78.94 | 31.37 | 30.14 | 23.02 |
| DOORNEN  | 6                 | 182.78          | 13.87     | 48.68             | 20.42             | 31.62             | 57.74 | 41.88 | 27.62 | 22.55 |
| FREBBRA  | 6                 | 100.01          | 18.2      | 55.68             | 18.08             | 34.65             | 48.6  | 38.21 | 19.13 | 20.51 |
| STHELENA | 6                 | 148.77          | 8.675     | 84.086            | 20.81             | 35.43             | 30.33 | 50.28 |       |       |
| WESTHOLD | 5                 | 127.39          | 7.21      | 32.41             | 22.2              | 38.45             | 93.28 |       | 27.88 | 28.08 |
| STILFOOT | 5                 | 73.59           |           |                   |                   |                   |       |       |       |       |
| VAALBEEF | 5                 | 141.47          | 12.22     | 58.0              | 13.5              | 41.74             |       |       | 28.28 | 21.57 |
| BRACKEN  | 5                 | 105.38          | 17.75     | 51.19             | 34.01             | 31.12             | 51.19 | 35.97 |       | 42.67 |
| KINROSS  | 5                 | 102.06          | 18.48     | 77.25             | 35.44             | 28.03             | 60.65 | 33.98 | 30.58 | 26.31 |
| LESUE    | 5                 | 110.71          |           |                   |                   |                   |       |       |       |       |
| WINKELK  | 5                 | 124.05          | 15        | 61.8              | 20.94             | 28.2              | 66.2  | 30.08 | 21.4  | 15.6  |
| KLOOF    | 4                 | 178.78          | 7.69      | 36.07             | 14.31             | 39.18             | 38.78 | 57.78 | 23.48 | 18.58 |
| WESTDEEP | 4                 | 123.21          | 11.85     | 48.17             | 14.48             | 44.08             | 78.14 | 28.58 | 25.13 | 19.37 |
| EASTDRIE | 6                 | 123.08          | 8.41      | 44.14             | 18.35             | 39.68             | 72.87 | 30.88 | 34.37 | 27.77 |
| DEELKHL  | 4                 | 106.82          | 11.88     | 54.24             | 28.43             | 32.05             | 65.85 | 29.23 | 32.55 | 25.97 |
| ELANDSD  | 2                 | 137.85          | 10.26     | 68.74             |                   |                   |       |       | 28.08 | 21.84 |
| BEATRIX  | 1                 | 118.38          |           |                   | 16.14             | 24.88             |       |       |       |       |

| Age vs Cost/mil ton,<br>Regression Output:      | Age vs Sq. Met./Stope Emp.<br>Regression Output:  | Age vs Tons/Stope Emp.<br>Regression Output: |
|-------------------------------------------------|---------------------------------------------------|----------------------------------------------|
| Constant 127.1421                               | Constant 9.982169                                 | Constant 59.79851                            |
| Std Err of Y Est 25.23614                       | Std Err of Y Est 4.280942                         | Std Err of Y Est 14.68879                    |
| R Squared 0.005485                              | R Squared 0.041133                                | R Squared 0.038970                           |
| No. of Observations 20                          | No. of Observations 17                            | No. of Observations 17                       |
| Degrees of Freedom 18                           | Degrees of Freedom 15                             | Degrees of Freedom 15                        |
| X Coefficient(s) -0.95228                       | X Coefficient(s) 0.471435                         | X Coefficient(s) -1.57271                    |
| Std Err of Coef. 3.022272                       | Std Err of Coef. 0.587706                         | Std Err of Coef. 2.016534                    |
| Age vs Sq. Met./Dev. Met.<br>Regression Output: | Age vs Stope Cost/ton. (R).<br>Regression Output: | Age vs Tons/Dev. Emp.<br>Regression Output:  |
| Constant 22.09949                               | Constant 46.29289                                 | Constant 70.51440                            |
| Std Err of Y Est 6.974101                       | Std Err of Y Est 6.505474                         | Std Err of Y Est 16.77034                    |
| R Squared 0.000330                              | R Squared 0.292447                                | R Squared 0.036833                           |
| No. of Observations 16                          | No. of Observations 16                            | No. of Observations 15                       |
| Degrees of Freedom 14                           | Degrees of Freedom 14                             | Degrees of Freedom 13                        |
| X Coefficient(s) -0.07220                       | X Coefficient(s) -2.41649                         | X Coefficient(s) -1.82263                    |
| Std Err of Coef. 1.051487                       | Std Err of Coef. 1.004564                         | Std Err of Coef. 2.895975                    |
| Age vs Dev. Cost/ton.<br>Regression Output:     | Age vs Tons/Udg. Emp.<br>Regression Output:       | Age vs Tons/Total Emp.<br>Regression Output: |
| Constant 34.40013                               | Constant 27.82289                                 | Constant 23.70140                            |
| Std Err of Y Est 8.855708                       | Std Err of Y Est 5.419204                         | Std Err of Y Est 6.514037                    |
| R Squared 0.008053                              | R Squared 0.000518                                | R Squared 0.002281                           |
| No. of Observations 14                          | No. of Observations 14                            | No. of Observations 15                       |
| Degrees of Freedom 12                           | Degrees of Freedom 12                             | Degrees of Freedom 13                        |
| X Coefficient(s) 0.429448                       | X Coefficient(s) 0.034818                         | X Coefficient(s) 0.169318                    |
| Std Err of Coef. 1.875856                       | Std Err of Coef. 0.816975                         | Std Err of Coef. 0.882033                    |

From the regression analysis of Age versus Costs and Labour Productivity there does not appear to be any correlation, with the possible exception of Age vs. Slope Cost/ton.



### Figure 5.1

# AGE OF MINE AND PRODUCTIVITY STATISTICS.

WEST WIS MINE ONLY.

| NE      | RELATIVE<br>AGE | COST/TON<br>MILL '69 | SQ.MET./<br>STO.EMP. | TONS/<br>STO.EMP. | SQ.MET./<br>DEV.MET. | STO.COST TONS/<br>DEV.EMP. | DEV.COST TONS/<br>TON (R) | TONS/<br>UDG.EMP. | TONS/<br>TOT.EMP. |
|---------|-----------------|----------------------|----------------------|-------------------|----------------------|----------------------------|---------------------------|-------------------|-------------------|
| ESTDRI  | 7               | 133.83               | 11.89                | 57.05             | 19.64                | 97.14                      | 78.35                     | 31.97             | 30.14             |
| BANCN   | 7               | 130.41               | 14.44                | 62.79             | 20.46                | 30.79                      | 69.69                     | 35.85             | 39.17             |
| JORNPH  | 8               | 152.78               | 19.37                | 48.89             | 20.42                | 31.62                      | 67.74                     | 41.66             | 27.32             |
| DOF     | 4               | 176.79               | 7.69                 | 53.07             | 14.01                | 39.18                      | 39.76                     | 57.76             | 25.49             |
| ESTDEE  | 4               | 129.71               | 11.83                | 43.17             | 14.49                | 44.08                      | 78.14                     | 29.59             | 26.13             |
| ASTORIE | 5               | 123.09               | 9.49                 | 43.14             | 16.30                | 39.53                      | 72.97                     | 30.26             | 34.97             |
| ELKPTL  | 2               | 103.02               | 11.99                | 54.25             | 23.43                | 32.03                      | 66.86                     | 29.25             | 32.55             |

|                         |          |                                      |          |                             |          |
|-------------------------|----------|--------------------------------------|----------|-----------------------------|----------|
| Age vs Cost/Ton Milled. |          | Age vs Square meters/stops employee. |          | Age vs Tons/Stops Employee. |          |
| Regression Output:      |          | Regression Output:                   |          | Regression Output:          |          |
| Constant                | 113.2216 | Constant                             | 3.522317 | Constant                    | 42.58445 |
| Std Err of Y Est        | 23.01975 | Std Err of Y Est                     | 2.130489 | Std Err of Y Est            | 8.605751 |
| R Squared               | 0.184572 | R Squared                            | 0.276802 | R Squared                   | 0.098511 |
| No. of Observations     | 7        | No. of Observations                  | 7        | No. of Observations         | 7        |
| Degrees of Freedom      | 5        | Degrees of Freedom                   | 5        | Degrees of Freedom          | 5        |
| X Coefficient(s)        | 0.719939 | X Coefficient(s)                     | 0.606902 | X Coefficient(s)            | 1.514207 |
| Std Err of Coef.        | 0.765662 | Std Err of Coef.                     | 0.440166 | Std Err of Coef.            | 1.777934 |

|                                |          |                        |          |                            |          |
|--------------------------------|----------|------------------------|----------|----------------------------|----------|
| Age vs Square Meters/Dev Meter |          | Age vs Stops Cost/Ton. |          | Age vs Tons/Dev. Employee. |          |
| Regression Output:             |          | Regression Output:     |          | Regression Output:         |          |
| Constant                       | 21.71039 | Constant               | 40.02894 | Constant                   | 58.817   |
| Std Err of Y Est               | 6.141450 | Std Err of Y Est       | 5.217523 | Std Err of Y Est           | 14.730   |
| R Squared                      | 0.642473 | R Squared              | 0.093170 | R Squared                  | 0.004498 |
| No. of Observations            | 7        | No. of Observations    | 7        | No. of Observations        | 7        |
| Degrees of Freedom             | 5        | Degrees of Freedom     | 5        | Degrees of Freedom         | 5        |
| X Coefficient(s)               | -0.50025 | X Coefficient(s)       | -0.76170 | X Coefficient(s)           | -0.45737 |
| Std Err of Coef.               | 1.022215 | Std Err of Coef.       | 1.077932 | Std Err of Coef.           | 3.043400 |

|                       |          |                            |          |                             |          |
|-----------------------|----------|----------------------------|----------|-----------------------------|----------|
| Age vs Dev. Cost/Ton. |          | Age vs Tons/UDG. Employee. |          | Age vs Tons/Total Employee. |          |
| Regression Output:    |          | Regression Output:         |          | Regression Output:          |          |
| Constant              | 34.02452 | Constant                   | 27.95115 | Constant                    | 22.75195 |
| Std Err of Y Est      | 11.37528 | Std Err of Y Est           | 5.807911 | Std Err of Y Est            | 4.213151 |
| R Squared             | 0.009278 | R Squared                  | 0.039569 | R Squared                   | 0.020504 |
| No. of Observations   | 7        | No. of Observations        | 7        | No. of Observations         | 7        |
| Degrees of Freedom    | 5        | Degrees of Freedom         | 5        | Degrees of Freedom          | 5        |
| X Coefficient(s)      | 0.509479 | X Coefficient(s)           | 0.509451 | X Coefficient(s)            | 0.321707 |
| Std Err of Coef.      | 2.350112 | Std Err of Coef.           | 1.220585 | Std Err of Coef.            | 0.994389 |

There is no apparent correlation between Age and Productivity for the West Wits mines other than a possible correlation with square meters per stops employee.



Figure 5.2

in their favour, (pillar support, throw blasting, shallow mining conditions and low grades of ore) which result in certain cost savings. The only conclusion which can be made regarding age of mine and productivity therefore, is that age per se, is not an influential factor.

## 5.2 THE SHAFT LAYOUT SYSTEM

The location and the number of shafts affects the productivity in a number of ways. Each shaft is a cost centre in that it utilizes labour and stores. The labour consists of supervisors, winding engine drivers, artisans, conveyers, shaft timbermen and unskilled employees. A large shaft can employ 50 or more skilled and up to 200 unskilled workers. The stores consumed consist of winding ropes, conveyances and other materials. Hoisting from great depths is a major consumer of electricity.

The location of the shafts in close proximity to the areas where production takes place, can save on overall travelling time and therefore increase the effective shift time. The location of shafts in close proximity to one another, such as a surface and sub-vertical shaft, can facilitate the transfer of people, and thereby reduce travelling time. (Capital expenditure is sometimes incurred for just this purpose).

The provision of service shafts (with small inter-level spacing) in the footwall of and in close proximity to the workings, provide excellent access for men, material and equipment, which can improve labour productivity in the stopes. On the other hand these inter-levels can absorb fairly large numbers of employees to provide the services. These service shafts can also provide savings in the amount of development required, where the main shaft is far away. They can also absorb large amounts of development (tunnelling) where the inter-levels are closely spaced.

As in the case of the age of a mine, the number of shafts per se, is not necessarily related to the level of productivity on the mine. Many shafts on the older mines are no longer functional. No statistical analysis was carried out and the conclusions which can be reached logically are that there must be a direct relationship between the number of working shafts as well as the operating capacity of those shafts and operating costs. There should also be an inverse relationship between the number of shafts and labour productivity.

### 5.3 DEVELOPMENT LAYOUT.

This refers to the development required to gain access to the reef plane, to evaluate it and to provide the facilities for stoping. It consists of footwall drives, cross-cuts, reef drives and raises or winzes and box-holes (ore-passes).

The development layout can have a major effect on productivity and costs (G.L.Smith, 1992). This is due to the high cost of tunnelling and the large numbers of people employed to service these excavations.

Trackless mechanised mining methods (TM3) and continuous scrapers allow for a reduction of 50% or more in the amount of development required.

The best indicator of the amount of tunnelling involved, is the factor "Squars meters/development meter".

The main factors affecting the development layout are the inter-level and raise spacing and the number and length of boxholes or orepasses.

Smaller inter-level and raise spacings should improve access and therefore labour productivity. One can say that the better the access provided to the stope in general and to the stope face in particular, the better the productivity of the workers and hence the lower the costs.

The amount of development required is indirectly proportional to the inter-level and cross-cut spacing and directly proportional to the number of box-holes per stope.

The development layouts for the mines in the survey are given in Table 3.3.

#### 5.3.1 FACTORS WHICH AFFECT INTER-LEVEL SPACING.

Mines select an inter-level spacing during the planning stages. The following factors influence the choice: distance of the shaft from the reef, dip of the reef, payability, rock mechanics considerations, stope width, mining method, degree of mechanisation, provision of service shafts or service inclines, geological factors, direction of mining, productivity and available cash. (This list is not necessarily comprehensive). The larger the inter-level spacing, the smaller the amount of development (and therefore cost), required to extract a given block of ground.

(1). Distance of the main shaft from the reef plane.

The greater the distance the greater the amount of development required. Where shafts are close to the reef, a smaller inter-level spacing can be tolerated. Unless it is the intention to provide service shafts, the inter-level spacing will be increased to save development and maintenance costs.

#### (2). The dip of the reef.

Where the dip of the reef exceeds 35 degrees, it becomes more difficult to inter-connect the levels using conventional mining methods. This difficulty can be overcome by reducing the inter-level spacing or using more mechanised methods (raise borers). Reducing the inter-level spacing, improves the access for people and stores. It also allows for the economic provision of a box-hole per stope panel.

The provision of a box-hole per stope panel is not of the same benefit, where the force of gravity assists in the stope cleaning process. This provides savings in development, labour and equipment. On balance however, it would appear as if the steeper dipping mines go for a smaller inter-level spacing than those with flatter dips, although there are many exceptions to this rule.

#### (3). The payability of the reef.

The payability affects the inter level spacing in two ways. Firstly, a high degree of payability allows a high (if not total) extraction rate (longwalls). Secondly, if the value of the ore is also high, one can afford to do more development. On the other hand, where the higher grade ore occurs in payshoots, which extend for reasonable distances down the dip of the reef, it is possible to increase the spacing, without fear of missing those payshoots.

#### (4). Rock engineering.

Rock engineering considerations affect the inter-level spacing in deep level mines, in that the levels must be placed between stability pillars and not beneath them. Mines like E.R.P.M. and Western Deep Levels with small spacings (40 and 50 meters respectively) have greater flexibility in locating the pillars. (See also, discussion on back length).

#### (5). Stope width.

Stope width affects the inter-level spacing as follows. The greater the width, the greater the tonnage which can be mined at that particular location, other things being equal. This means that more money can be spent on development and equipment. Again, a comparison can be made between East Driefontein and Doornfontein.

#### (6). Mining method.

The choice of the mining method affects the inter-level spacing in several ways, for example :-

##### (a). An orepass per panel.

If a decision is made to provide an orepass for every stope panel, then the spacing must be kept fairly small, otherwise the cost of providing these becomes exorbitant (examples are mines like Beatrix, Hartebeestfontein and Vaal Reefs).

##### (b). Trackless mining.

The choice of a trackless mining method means one can increase the spacing without losing the benefits of the excellent accessibility those systems afford.

#### (7). Scraper mining.

The choice of an up dip mining method requires that scraping distances be limited to maintain efficiencies.

#### (8). Degree of mechanisation.

The degree of mechanisation has been dealt with in the previous section, in the discussion on trackless methods. The introduction of other forms of new technology, such as hydro-power (water jetting) or backfilling, could provide the necessary impetus to increase panel lengths, back lengths and hence inter-level spacing, without concern for a decrease in overall efficiencies. The use of continuous scrapers allows both raise and inter-level spacing to be increased without adversely affecting the level of productivity.

#### (9). Service shafts.

The concept of service shafts is also a fairly recent innovation. The number of levels served by a deep and busy sub-vertical shaft can be drastically reduced from over 20 to 10 or less. (1500 meter shaft with levels at 70 meter intervals). With less levels to equip and maintain a really efficient track or trackless transport system can be installed between the main shaft and the service shaft.

The latter then distributes the men, material and equipment to the workings via inter-levels spaced 20 to 30 meters apart. Thus good accessibility is provided, while the total amount of development required is not significantly changed.

#### **(10). Geological factors.**

Geological factors can influence the inter-level spacing. Major displacements of the reef by faulting or folding can have this effect. For example at Vaal Reefs, large faulted blocks are serviced by twin haulages, which also serve as intake and return airways.

#### **(11). Direction of mining.**

A change in the direction of mining, from breast to up dip may not seem advisable. However, a smaller inter-level spacing and back length and hence maximum scraping distance, can make this system extremely efficient. (Wes. Rand Cons. utilises both systems - up-dip and breast mining - to suit the circumstances).

#### **(12). Productivity and costs.**

The smaller the amounts and distances that men, material, equipment and rock have to be handled, the more efficient the system generally. This applies particularly to the reef plane. (Beatrix with its short panel lengths and short strike scraping distances to a nearby orepass, illustrates this point and ensures high levels of productivity).

### **5.3.2 THE ANALYSIS OF INTER-LEVEL SPACING.**

The regression analysis for the select group of mines gives the highest value for R squared (0.320) in the category Inter-level spacing vs stope cost/ton. The relationship is an inverse one. This is shown in Figure 5.3.2.2. One would expect that as the ILS increases so access to the working place becomes more difficult, labour productivity should decrease and costs increase. The anomaly must be due to the small number of mines in the sample or because of other over-riding factors.

One would also expect that higher values of R squared would be obtained in the categories of Cost/ton milled, Sq.meter/dev.meter, Sq.meter/stope employee and Tons/stope employee. This is also probably due to the small number in the sample.

# INTERLEVEL SPACING AND PRODUCTIVITY STATISTICS.

INTERLVL COST/TON SQ.MET./ TONS/ SQ.MET./ STO.COST TONS/ DEV.COST TONS/ TONS/  
SPACING, MILL.'S STO.EMP. STO.EMP. DEV.MET./TON (R) DEV.EMP. /TON (R) UDG.EMP. TOT.EMP.

|         |    |        |       |       |       |       |       |       |       |       |
|---------|----|--------|-------|-------|-------|-------|-------|-------|-------|-------|
| ORNFN   | 91 | 152.75 | 13.37 | 48.89 | 20.42 | 31.82 | 57.74 | 41.69 | 27.82 | 22.35 |
| STORIE  | 91 | 145.83 | 11.99 | 47.05 | 19.28 | 37.14 | 78.34 | 51.37 | 30.14 | 23.02 |
| JKEL'K  | 77 | 121.06 | 15    | 51.3  | 20.96 | 26.2  | 68.2  | 30.06 | 21.4  | 15.8  |
| ELKRI   | 72 | 102.02 | 11.99 | 54.24 | 23.43 | 32.05 | 69.85 | 29.25 | 32.55 | 23.97 |
| ACKEN   | 71 | 105.99 | 17.23 | 51.19 | 34.01 | 31.12 | 51.19 | 35.97 |       | 42.87 |
| DOF     | 63 | 176.78 | 7.89  | 52.07 | 14.01 | 58.18 | 39.78 | 57.78 | 23.49 | 19.59 |
| ANON    | 63 | 120.41 | 14.44 | 52.75 | 20.46 | 30.79 | 53.39 | 35.85 | 33.17 | 31.61 |
| ESBRAN  | 63 | 102.01 | 13.2  | 55.53 | 19.00 | 54.85 | 46.9  | 59.21 | 19.13 | 23.51 |
| ROSS    | 51 | 107.03 | 18.46 | 77.85 | 33.44 | 28.05 | 60.55 | 33.83 | 30.55 | 25.31 |
| ITVLEI  | 53 | 127.21 | 6.31  | 20.43 | 17.09 | 14.92 | 55    | 30.08 | 27.61 | 21.48 |
| ESTHOL  | 58 | 7.33   | 7.21  | 53.41 | 22.2  | 63.48 | 33.29 |       | 27.85 | 25.09 |
| ACONS   | 55 | 75.44  | 22.1  | 63.0  | 20.5  | 22.48 | 42.1  | 39.81 |       |       |
| JATRIK  | 60 | 118.33 |       |       | 16.14 | 24.85 |       |       |       |       |
| ESTDEP  | 60 | 126.71 | 11.25 | 43.17 | 14.46 | 44.09 | 78.14 | 28.58 | 25.13 | 19.57 |
| ISTORIE | 48 | 122.03 | 9.42  | 44.14 | 18.36 | 39.53 | 72.67 | 30.56 | 34.37 | 27.77 |
| VALREF  | 47 | 141.47 | 12.28 | 55.3  | 19.5  | 41.74 |       |       | 28.86 | 21.67 |

Interlevel Spacing vs Cost/Ton Milled.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 50.32923 |
| Std Err of Y Est    | 23.03119 |
| R Squared           | 0.09459  |
| No. of Observations | 15       |
| Degrees of Freedom  | 14       |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.020710 |
| Std Err of Coef. | 0.428693 |

Interlevel Spacing vs Sq.Met./Dev.Meter.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 14.77002 |
| Std Err of Y Est    | 8.856164 |
| R Squared           | 0.044419 |
| No. of Observations | 15       |
| Degrees of Freedom  | 14       |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.103626 |
| Std Err of Coef. | 0.128458 |

Interlevel Spacing vs Dev.Cost/Ton.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 50.18075 |
| Std Err of Y Est    | 6.147574 |
| R Squared           | 0.020050 |
| No. of Observations | 13       |
| Degrees of Freedom  | 11       |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.082388 |
| Std Err of Coef. | 0.173578 |

Interlevel Spacing vs Square Met./Slope Emp.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 11.09771 |
| Std Err of Y Est    | 4.500834 |
| R Squared           | 0.007232 |
| No. of Observations | 15       |
| Degrees of Freedom  | 13       |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.025627 |
| Std Err of Coef. | 0.087496 |

Interlevel Spacing vs Slope Cost/Ton.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 54.62918 |
| Std Err of Y Est    | 7.938938 |
| R Squared           | 0.033761 |
| No. of Observations | 19       |
| Degrees of Freedom  | 14       |

|                  |          |
|------------------|----------|
| X Coefficient(s) | -0.09414 |
| Std Err of Coef. | 0.148529 |

Interlevel Spacing vs Tons/Dev.Employee.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 50.54447 |
| Std Err of Y Est    | 5.800740 |
| R Squared           | 0.006491 |
| No. of Observations | 19       |
| Degrees of Freedom  | 11       |

|                  |          |
|------------------|----------|
| X Coefficient(s) | -0.03492 |
| Std Err of Coef. | 0.111818 |

Interlevel Spacing vs Tons/Slope Emp.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 52.25681 |
| Std Err of Y Est    | 14.58386 |
| R Squared           | 0.000110 |
| No. of Observations | 15       |
| Degrees of Freedom  | 13       |

|                  |          |
|------------------|----------|
| X Coefficient(s) | -0.01074 |
| Std Err of Coef. | 0.289516 |

Interlevel Spacing vs Tons/Dev.Emp.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 58.40914 |
| Std Err of Y Est    | 15.27333 |
| R Squared           | 0.008035 |
| No. of Observations | 14       |
| Degrees of Freedom  | 12       |

|                  |          |
|------------------|----------|
| X Coefficient(s) | -0.08598 |
| Std Err of Coef. | 0.818550 |

Interlevel Spacing vs Tons/Total Employee.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 25.21850 |
| Std Err of Y Est    | 8.738601 |
| R Squared           | 0.000243 |
| No. of Observations | 14       |
| Degrees of Freedom  | 12       |

|                  |          |
|------------------|----------|
| X Coefficient(s) | -0.10722 |
| Std Err of Coef. | 0.35736  |

There is no apparent correlation between Interlevel spacing and productivity.

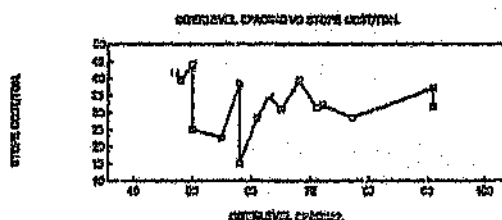
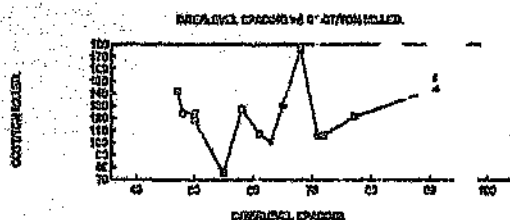


Figure 5.3.2.1

# INTERLEVEL SPACING AND PRODUCTIVITY STATISTICS.

## WEST WITS MINES ONLY

| INE     | INTERLVL<br>SPACING | COST/TON<br>MILL '62 | SQ.MET./<br>STO.EMP. | TONS/<br>STO.EMP. | SQ.MET./<br>DEV.MET. | STO.COST TONS/<br>TON (R) | DEV.COST TONS/<br>TON (R) | TONS/<br>UDG.EMP. | TOT.EMP. |
|---------|---------------------|----------------------|----------------------|-------------------|----------------------|---------------------------|---------------------------|-------------------|----------|
| DORNFN  | 51                  | 152.78               | 18.37                | 48.80             | 20.42                | 81.82                     | 57.74                     | 41.66             | 22.35    |
| ESTDRIE | 51                  | 143.83               | 11.89                | 47.03             | 19.59                | 97.14                     | 79.34                     | 51.37             | 23.02    |
| EELKRL  | 72                  | 165.02               | 11.89                | 54.24             | 28.43                | 32.05                     | 48.87                     | 23.23             | 25.87    |
| COOF    | 69                  | 175.75               | 7.89                 | 33.07             | 14.01                | 89.15                     | 89.70                     | 67.78             | 19.58    |
| BANON   | 65                  | 130.41               | 14.44                | 62.73             | 20.46                | 30.79                     | 52.38                     | 35.38             | 31.81    |
| ESTDEE  | 60                  | 123.71               | 11.05                | 42.17             | 14.48                | 44.09                     | 78.14                     | 28.58             | 19.57    |
| ASTORIE | 45                  | 128.06               | 9.42                 | 44.14             | 18.25                | 39.53                     | 72.37                     | 30.88             | 27.77    |

| Interlevel Spacing vs Cost/Ton Milled.<br>Regression Output:     |          | Interlevel Spacing vs Square Met./Stope Emp.<br>Regression Output: |          | Interlevel Spacing vs Tons/Stope Emp.<br>Regression Output:       |          |
|------------------------------------------------------------------|----------|--------------------------------------------------------------------|----------|-------------------------------------------------------------------|----------|
| Constant                                                         | 100.8239 | Constant                                                           | 8.894677 | Constant                                                          | 48.93160 |
| Std Err of Y Est                                                 | 24.15831 | Std Err of Y Est                                                   | 2.873778 | Std Err of Y Est                                                  | 2.049959 |
| R Squared                                                        | 0.164470 | R Squared                                                          | 0.102205 | R Squared                                                         | 0.008043 |
| No. of Observations                                              | 7        | No. of Observations                                                | 7        | No. of Observations                                               | 7        |
| Degrees of Freedom                                               | 5        | Degrees of Freedom                                                 | 5        | Degrees of Freedom                                                | 5        |
| X Coefficient(s)                                                 | 0.825359 | X Coefficient(s)                                                   | 0.042265 | X Coefficient(s)                                                  | 0.028369 |
| Std Err of Coef.                                                 | 0.540543 | Std Err of Coef.                                                   | 0.056021 | Std Err of Coef.                                                  | 0.21356  |
| Interlevel Spacing vs Sq. Met./Dev. Meter.<br>Regression Output: |          | Interlevel Spacing vs Stope Cost/Ton.<br>Regression Output:        |          | Interlevel Spacing vs Tons/Dev. Emp.<br>Regression Output:        |          |
| Constant                                                         | 12.89452 | Constant                                                           | 47.69817 | Constant                                                          | 74.48755 |
| Std Err of Y Est                                                 | 4.959518 | Std Err of Y Est                                                   | 4.623014 | Std Err of Y Est                                                  | 14.51737 |
| R Squared                                                        | 0.110119 | R Squared                                                          | 0.00023  | R Squared                                                         | 0.033100 |
| No. of Observations                                              | 7        | No. of Observations                                                | 7        | No. of Observations                                               | 7        |
| Degrees of Freedom                                               | 5        | Degrees of Freedom                                                 | 5        | Degrees of Freedom                                                | 5        |
| X Coefficient(s)                                                 | 0.092011 | X Coefficient(s)                                                   | -0.18374 | X Coefficient(s)                                                  | -0.14187 |
| Std Err of Coef.                                                 | 0.118874 | Std Err of Coef.                                                   | 0.108744 | Std Err of Coef.                                                  | 0.342813 |
| Interlevel Spacing vs Dev. Cost/Ton.<br>Regression Output:       |          | Interlevel Spacing vs Tons/UDg. Employees.<br>Regression Output:   |          | Interlevel Spacing vs Tons/Total Employees.<br>Regression Output: |          |
| Constant                                                         | 27.57630 | Constant                                                           | 33.12152 | Constant                                                          | 27.10560 |
| Std Err of Y Est                                                 | 11.18842 | Std Err of Y Est                                                   | 5.962059 | Std Err of Y Est                                                  | 4.800970 |
| R Squared                                                        | 0.044807 | R Squared                                                          | 0.015874 | R Squared                                                         | 0.025458 |
| No. of Observations                                              | 7        | No. of Observations                                                | 7        | No. of Observations                                               | 7        |
| Degrees of Freedom                                               | 5        | Degrees of Freedom                                                 | 5        | Degrees of Freedom                                                | 5        |
| X Coefficient(s)                                                 | 0.127631 | X Coefficient(s)                                                   | -0.05989 | X Coefficient(s)                                                  | -0.04094 |
| Std Err of Coef.                                                 | 0.269600 | Std Err of Coef.                                                   | 0.140705 | Std Err of Coef.                                                  | 0.119303 |

There may be a slight correlation between interlevel spacing and productivity.



Figure 5.3.2.2

One would also expect that higher values of R squared would be obtained in the categories of Cost/ton milled, Sq.meter/dev.meter, Sq.meter/stope employee and Tons/stope employee. This is also probably due to the small number in the sample.

However in the larger sample of the general group, there is also no apparent correlation between inter-level spacing and productivity and costs. (Figure 5.3.2.1.)

Thus one must draw the conclusion that inter-level spacing can have an influence where mines are similar (for example, in the select group) but that other factors will have an over-riding influence, where mines are dissimilar or not contiguous. One must also logically conclude that there should be a direct relationship between ILS and Sq.meter/dev.meter.

### 5.3.3 CROSSCUT AND RAISE SPACING

Where productivity is of a lower order of magnitude, a scattered system of mining is employed and crosscuts and raises are spaced at 180 to 200 meters. This gives a maximum strike scraping distance of 90 to 100 meters, which is the practical limit for a reasonably efficient scraping operation, using ordinary scrapers (as opposed to continuous scrapers). Some mines have crosscuts at 100 to 120 meters apart for the reasons already given. Some mines have a smaller raise spacing but for a different reason. In this case, the main raise serves as a collecting scraper gully for many short, up dip or breast faces.

Conrod has researched the subject of raise spacing for mines using scattered layouts and have concluded that the optimum economic spacing is between 220 and 260 meters (D.R.Lawrence, 1984).

One would expect faster cleaning rates and therefore face advance rates with smaller raise spacings. However, the life of the stope decreases and more development is required. Also the ratio of ledging to straight stoping increases and this tends to reduce the average face advance rate.

This does not apply when more efficient cleaning methods are used to move the broken rock to the centre or dip gullies. This study also showed that costs are highly sensitive to face advance rate, mine call factor and unskilled labour costs. They were less sensitive to equipment costs, skilled labour cost and refrigeration costs. As mentioned previously, mines using longwall mining methods space their crosscuts at 50 to 70 meter intervals.

From the analysis, there appears to be a strong correlation between raise spacing and Sq.meters/dev.meter, as expected, and there also appears to be an inverse relationship with Cost/ton milled for the select group of mines. (Figure 5.3.3.2.)

The correlation is much weaker in the case of the general group where once again other factors have an over-riding influence. (Figure 5.3.3.1.)

The logical conclusion to be drawn therefore is that where mines are operating under otherwise similar conditions that raise or crosscut spacing should have an inverse relationship with labour productivity and cost/ton milled.

#### 5.3.4 NUMBER OF OREPASSES (BOXHOLES).

The subject has been discussed in the section on inter-level spacing under the sub heading of mining method. Providing an orepass per strike gully is a costly business and the cost increases almost exponentially, with an increase in the inter-level spacing. Thus even the richest mines cannot afford this luxury.

The cost of development varies from one mine to another and according to the type of tunnel and the support and equipment installed.

While orepasses do not contain expensive equipment they are difficult, time consuming and expensive to develop.

The regression analysis for the select group shows that there is apparently strong correlation between the number of orepasses and the stope cost/ton and also the tons per underground and total employee. Figure 5.3.4.2. In the former case, the relationship is a direct one while in the latter case the relationship is inverse. As expected there is also an inverse relationship between the number of orepasses and the Sq.meter/dev.meter.

More orepasses require more winch drivers and this may explain the higher stope cost/ton and lower tons/employee. However the square meters and tons per stope employee do not show the same strong correlation although the relationship is still an inverse one.

# RAISE SPACING AND PRODUCTIVITY STATISTICS.

| MILL     | RAISE<br>SPACING | COST/TON<br>MILL \$/TON | TONS/<br>SQ. MET./<br>STO. EMP. | TONS/<br>SQ. MET./<br>STO. EMP. | STO. COST<br>TONS/<br>TON (R) | DEV. COST<br>TONS/<br>TON (R) | TONS/<br>UDG. EMP. | TONS/<br>TOT. EMP. |       |       |
|----------|------------------|-------------------------|---------------------------------|---------------------------------|-------------------------------|-------------------------------|--------------------|--------------------|-------|-------|
| KINROSS  | 180              | 107.09                  | 18.48                           | 77.95                           | 36.44                         | 28.08                         | 60.65              | 38.93              | 30.59 | 25.31 |
| VAALEEF  | 160              | 141.47                  | 12.22                           | 89.9                            | 13.6                          | 41.74                         |                    |                    | 28.36 | 21.87 |
| BRACKEN  | 180              | 105.39                  | 17.75                           | 51.19                           | 34.01                         | 31.12                         | 51.13              | 55.97              |       | 42.57 |
| DEELKPL  | 180              | 105.03                  | 11.59                           | 64.24                           | 29.49                         | 32.05                         | 65.65              | 26.25              | 32.55 | 25.07 |
| GETVLEI  | 190              | 127.21                  | 6.31                            | 20.49                           | 17.09                         | 14.92                         | 63                 | 30.03              | 27.91 | 21.48 |
| WINKELK  | 175              | 121.05                  | 15                              | 61.5                            | 20.94                         | 28.2                          | 69.2               | 30.09              | 21.4  | 16.8  |
| WESTHOL  | 120              | 127.39                  | 7.21                            | 33.41                           | 25.2                          | 39.49                         | 53.29              |                    | 27.85 | 26.03 |
| PRESBRAN | 120              | 100.01                  | 13.2                            | 55.23                           | 19.03                         | 34.65                         | 48.9               | 38.21              | 18.13 | 23.51 |
| WRCONS   | 120              | 75.44                   | 22.1                            | 65.3                            | 29.54                         | 22.48                         | 42.1               | 53.81              |       |       |
| BEATRIK  | 100              | 118.33                  |                                 |                                 | 18.14                         | 24.83                         |                    |                    |       |       |
| DOURNFN  | 60               | 182.75                  | 13.37                           | 48.89                           | 20.42                         | 31.82                         | 57.74              | 41.95              | 27.92 | 22.86 |
| WESTOEF  | 60               | 123.71                  | 11.85                           | 49.17                           | 14.38                         | 44.09                         | 78.14              | 28.56              | 25.13 | 19.57 |
| WIDANON  | 60               | 130.41                  | 14.44                           | 52.75                           | 20.48                         | 30.79                         | 59.36              | 35.35              | 59.17 | 31.61 |
| WESTDRIE | 60               | 143.68                  | 11.63                           | 47.05                           | 18.38                         | 57.14                         | 76.84              | 31.57              | 30.14 | 23.02 |
| EASTDRIE | 60               | 123.03                  | 14.42                           | 44.14                           | 18.59                         | 39.53                         | 72.37              | 30.83              | 34.37 | 27.77 |
| KLOOF    | 60               | 175.79                  | 7.65                            | 79.07                           | 14.01                         | 38.15                         | 39.73              | 57.78              | 23.49 | 19.59 |

| Raise Spacing vs Cost/Ton Milled.<br>Regression Output:   |          |  | Raise Spacing vs Square Met./Stops Emp.<br>Regression Output: |          |  | Raise Spacing vs Tons/Stop Emp.<br>Regression Output:        |          |  |
|-----------------------------------------------------------|----------|--|---------------------------------------------------------------|----------|--|--------------------------------------------------------------|----------|--|
| Constant                                                  | 146.7241 |  | Constant                                                      | 10.83947 |  | Constant                                                     | 45.52089 |  |
| Std Err of Y Est                                          | 21.69998 |  | Std Err of Y Est                                              | 4.391851 |  | Std Err of Y Est                                             | 14.29275 |  |
| R Squared                                                 | 0.189412 |  | R Squared                                                     | 0.054729 |  | R Squared                                                    | 0.038525 |  |
| No. of Observations                                       | 16       |  | No. of Observations                                           | 15       |  | No. of Observations                                          | 15       |  |
| Degrees of Freedom                                        | 14       |  | Degrees of Freedom                                            | 13       |  | Degrees of Freedom                                           | 13       |  |
| X Coefficient(s)                                          | -0.12455 |  | X Coefficient(s)                                              | 0.018465 |  | X Coefficient(s)                                             | 0.050705 |  |
| Std Err of Coef.                                          | 0.10385  |  | Std Err of Coef.                                              | 0.021272 |  | Std Err of Coef.                                             | 0.089228 |  |
| Raise Spacing vs Sq. Met./Dev. Emp.<br>Regression Output: |          |  | Raise Spacing vs Stops Cost/Ton.<br>Regression Output:        |          |  | Raise Spacing vs Tons/Dev. Emp.<br>Regression Output:        |          |  |
| Constant                                                  | 14.11579 |  | Constant                                                      | 59.61228 |  | Constant                                                     | 84.75437 |  |
| Std Err of Y Est                                          | 0.139508 |  | Std Err of Y Est                                              | 7.210481 |  | Std Err of Y Est                                             | 15.28649 |  |
| R Squared                                                 | 0.295975 |  | R Squared                                                     | 0.178107 |  | R Squared                                                    | 0.004321 |  |
| No. of Observations                                       | 16       |  | No. of Observations                                           | 16       |  | No. of Observations                                          | 14       |  |
| Degrees of Freedom                                        | 14       |  | Degrees of Freedom                                            | 14       |  | Degrees of Freedom                                           | 12       |  |
| X Coefficient(s)                                          | 0.031576 |  | X Coefficient(s)                                              | -0.08059 |  | X Coefficient(s)                                             | -0.01772 |  |
| Std Err of Coef.                                          | 0.129312 |  | Std Err of Coef.                                              | 0.034777 |  | Std Err of Coef.                                             | 0.077882 |  |
| Raise Spacing vs Dev. Cost/Ton.<br>Regression Output:     |          |  | Raise Spacing vs Tons/UDg. Emp. vcs.<br>Regression Output:    |          |  | Raise Spacing vs Tons/Total Employees.<br>Regression Output: |          |  |
| Constant                                                  | 41.08604 |  | Constant                                                      | 30.09186 |  | Constant                                                     | 23.10521 |  |
| Std Err of Y Est                                          | 7.789185 |  | Std Err of Y Est                                              | 5.548504 |  | Std Err of Y Est                                             | 6.889655 |  |
| R Squared                                                 | 0.113101 |  | R Squared                                                     | 0.026899 |  | R Squared                                                    | 0.014526 |  |
| No. of Observations                                       | 13       |  | No. of Observations                                           | 13       |  | No. of Observations                                          | 14       |  |
| Degrees of Freedom                                        | 11       |  | Degrees of Freedom                                            | 11       |  | Degrees of Freedom                                           | 12       |  |
| X Coefficient(s)                                          | -0.04889 |  | X Coefficient(s)                                              | -0.01555 |  | X Coefficient(s)                                             | 0.013675 |  |
| Std Err of Coef.                                          | 0.039594 |  | Std Err of Coef.                                              | 0.028204 |  | Std Err of Coef.                                             | 0.032404 |  |

There may be a small correlation between raise spacing and the following factors:-  
Square Meters/Meter Developed, Cost/Ton Milled and Stops Cost on.

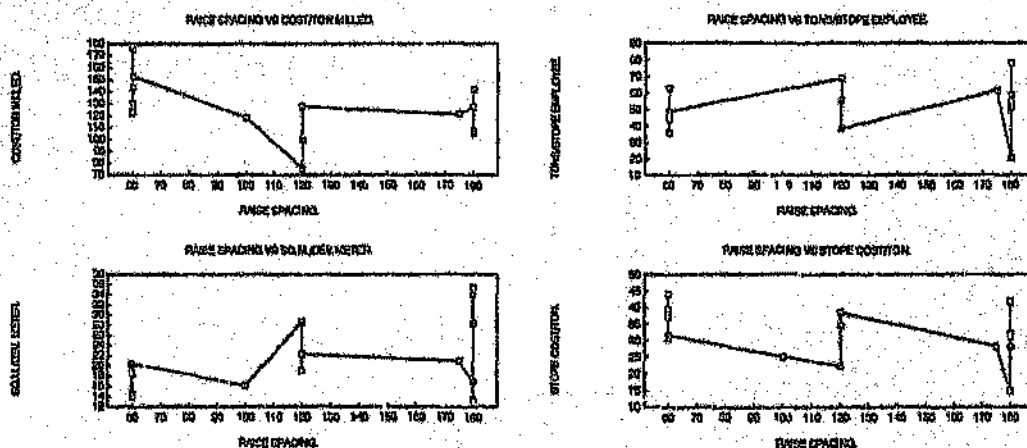


Figure 5.3.3.1

# RAISE SPACING AND PRODUCTIVITY STATISTICS.

WEST WITS MINES ONLY.

| MINE     | RAISE<br>SPACING | COST/TON<br>MILL/59 | SG.MET./<br>STD.EMP. | TONS/<br>STD.EMP. | SG.MET./<br>DEV.MET. | STD.COST TONS/<br>/TON (R). | DEV.COST TONS/<br>DEV.EMP. | TONS/<br>UDG.EMP. | TONS/<br>TOT.EMP. |
|----------|------------------|---------------------|----------------------|-------------------|----------------------|-----------------------------|----------------------------|-------------------|-------------------|
| DEELKYP  | 120              | 103.02              | 11.89                | 84.24             | 26.49                | 32.05                       | 68.85                      | 29.25             | 32.85             |
| DOORNEN  | 60               | 152.78              | 13.57                | 48.89             | 20.42                | 61.82                       | 57.74                      | 41.86             | 27.62             |
| WESTDEEP | 60               | 123.71              | 11.88                | 48.17             | 14.42                | 64.09                       | 78.14                      | 29.58             | 25.13             |
| LIBANON  | 60               | 180.41              | 14.44                | 62.73             | 20.48                | 60.79                       | 59.39                      | 35.35             | 39.17             |
| WESTDRIE | 60               | 143.83              | 11.89                | 47.08             | 18.38                | 37.14                       | 76.34                      | 31.37             | 30.14             |
| EASTDRIE | 60               | 123.09              | 9.42                 | 44.14             | 18.36                | 39.53                       | 72.37                      | 30.99             | 34.37             |
| KLOOF    | 60               | 176.76              | 7.89                 | 36.07             | 14.01                | 39.18                       | 39.78                      | 23.49             | 19.59             |

## Raise Spacing vs Cost/Ton Milled. Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 159.3875 |
| Std Err of Y Est    | 20.42760 |
| R Squared           | 0.342107 |
| No. of Observations | 7        |
| Degrees of Freedom  | 5        |

|                  |          |
|------------------|----------|
| X Coefficient(s) | -0.35048 |
| Std Err of Coef. | 0.189872 |

## Raise Spacing vs Sq.Met./Dev.Meter. Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 12.5575  |
| Std Err of Y Est    | 2.601333 |
| R Squared           | 0.691297 |
| No. of Observations | 7        |
| Degrees of Freedom  | 5        |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.099180 |
| Std Err of Coef. | 0.028105 |

## Raise Spacing vs Dev.Cost/Ton. Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 61.5125  |
| Std Err of Y Est    | 14.62465 |
| R Squared           | 0.018818 |
| No. of Observations | 7        |
| Degrees of Freedom  | 5        |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.040763 |
| Std Err of Coef. | 0.181636 |

## Raise Spacing vs Square Met./Stope Emp. Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 11.12    |
| Std Err of Y Est    | 2.493712 |
| R Squared           | 0.009188 |
| No. of Observations | 7        |
| Degrees of Freedom  | 5        |

|                  |         |
|------------------|---------|
| X Coefficient(s) | 0.0048  |
| Std Err of Coef. | 0.02244 |

## Raise Spacing vs Stope Cost/Ton. Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 39.5625  |
| Std Err of Y Est    | 5.077973 |
| R Squared           | 0.142624 |
| No. of Observations | 7        |
| Degrees of Freedom  | 5        |

|                  |          |
|------------------|----------|
| X Coefficient(s) | -0.04173 |
| Std Err of Coef. | 0.045705 |

## Raise Spacing vs Tons/Jdg.Empl. Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 28.705   |
| Std Err of Y Est    | 5.915500 |
| R Squared           | 0.091185 |
| No. of Observations | 7        |
| Degrees of Freedom  | 5        |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.021361 |
| Std Err of Coef. | 0.053245 |

## Raise Spacing vs Tons/Stope Emp. Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 44.85    |
| Std Err of Y Est    | 5.668608 |
| R Squared           | 0.085294 |
| No. of Observations | 7        |
| Degrees of Freedom  | 5        |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.053277 |
| Std Err of Coef. | 0.078028 |

## Raise Spacing vs Tons/Dev.Empl. Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 61.5125  |
| Std Err of Y Est    | 14.62465 |
| R Squared           | 0.018818 |
| No. of Observations | 7        |
| Degrees of Freedom  | 5        |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.040763 |
| Std Err of Coef. | 0.181636 |

## Raise Spacing vs Tons/Total Employee. Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 22.8925  |
| Std Err of Y Est    | 4.793319 |
| R Squared           | 0.026559 |
| No. of Observations | 7        |
| Degrees of Freedom  | 5        |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.016541 |
| Std Err of Coef. | 0.048144 |

There appears to be a strong correlation between raise spacing and Square Meters/Development Meter and a weaker one compared with Cost/Ton Milled. However there are only a few items in the sample so it may not be really so.

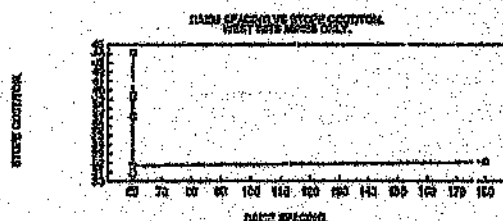
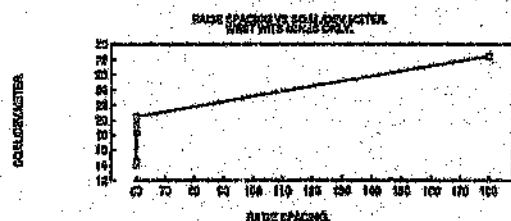
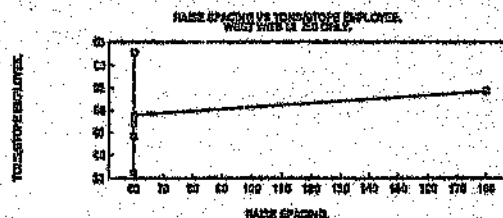
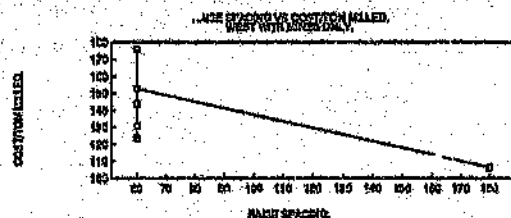


Figure 5.3.2

# NUMBER OF OREPASSES AND PRODUCTIVITY STATISTICS

| MINE       | NUMBER<br>OREPASSES | COST/TON<br>SQ. MET./<br>STO. EMP. | TONS/<br>STO. EMP. | SQ. MET./<br>DEV. MET. | STO. COST TONS/<br>/TON (R) | DEV. COST TONS/<br>DEV. EMP. | TONS/<br>UDG. EMP. | TONS/<br>TOT. EMP. |
|------------|---------------------|------------------------------------|--------------------|------------------------|-----------------------------|------------------------------|--------------------|--------------------|
| BEATRIX    | 8                   | 115.93                             |                    | 18.15                  | 24.85                       |                              |                    |                    |
| WESTDEEP   | 8                   | 123.71                             | 11.58              | 48.17                  | 14.49                       | 44.09                        | 76.14              | 25.58              |
| KINROSS    | 8                   | 107.08                             | 16.48              | 77.93                  | 35.24                       | 20.06                        | 80.85              | 53.88              |
| VAALREEF   | 8                   | 141.47                             | 12.28              | 89.8                   | 13.5                        | 41.74                        |                    | 28.86              |
| PRESBARIAN | 4                   | 109.01                             | 18.2               | 85.88                  | 19.09                       | 64.08                        | 46.8               | 96.21              |
| DEELKRIJL  | 3                   | 106.09                             | 11.63              | 84.24                  | 20.43                       | 82.06                        | 66.86              | 29.26              |
| KLOOF      | 3                   | 175.76                             | 7.89               | 89.07                  | 14.01                       | 89.18                        | 89.78              | 57.78              |
| DOORAK'N   | 3                   | 162.76                             | 13.87              | 48.89                  | 20.42                       | 51.82                        | 87.74              | 41.89              |
| EASTDAIRIE | 3                   | 123.08                             | 9.42               | 44.14                  | 16.28                       | 88.83                        | 72.97              | 30.82              |
| WESTDAIRIE | 3                   | 143.83                             | 11.89              | 47.00                  | 16.28                       | 37.14                        | 76.34              | 31.37              |
| WESTHOLD   | 3                   | 127.89                             | 7.21               | 36.41                  | 22.2                        | 88.46                        | 83.29              | 27.88              |
| LIBANON    | 3                   | 150.41                             | 14.44              | 62.78                  | 20.46                       | 80.79                        | 60.88              | 85.88              |
| WRCONS     | 1                   | 78.44                              | 22.1               | 80.8                   | 28.84                       | 22.46                        | 42.1               | 89.01              |
| GR'NLEI    | 1                   | 127.21                             | 8.31               | 20.43                  | 17.09                       | 14.92                        | 63                 | 30.08              |
| BRACKEN    | 1                   | 106.39                             | 17.75              | 81.16                  | 54.01                       | 51.12                        | 81.19              | 55.97              |
| WINKELK    | 1                   | 121.08                             | 15                 | 81.8                   | 20.84                       | 28.2                         | 86.2               | 30.08              |

| No. of Orepasses vs Cost/Ton Millid.<br>Regression Output:     |          | No. of Orepasses vs Square Meters/Steps Emp<br>Regression Output: |          | No. of Orepasses vs Tons/Steps Employee.<br>Regression Output: |          |
|----------------------------------------------------------------|----------|-------------------------------------------------------------------|----------|----------------------------------------------------------------|----------|
| Constant                                                       | 118.2018 | Constant                                                          | 11.21370 | Constant                                                       | 47.04858 |
| Std Err of Y Est                                               | 24.04937 | Std Err of Y Est                                                  | 4.482073 | Std Err of Y Est                                               | 14.80078 |
| R Squared                                                      | 0.013111 | R Squared                                                         | 0.018489 | R Squared                                                      | 0.011489 |
| No. of Observations                                            | 18       | No. of Observations                                               | 18       | No. of Observations                                            | 18       |
| Degrees of Freedom                                             | 14       | Degrees of Freedom                                                | 19       | Degrees of Freedom                                             | 19       |
| X Coefficient(s)                                               | 1.408989 | X Coefficient(s)                                                  | 0.071089 | X Coefficient(s)                                               | 0.197595 |
| Std Err of Coef.                                               | 3.266714 | Std Err of Coef.                                                  | 0.157095 | Std Err of Coef.                                               | 0.508252 |
| No. of Orepasses vs Sq. Met./Dev. Meter.<br>Regression Output: |          | No. of Orepasses vs Steps Cost/Ton.<br>Regression Output:         |          | No. of Orepasses vs Tons/Dev. Emp.<br>Regression Output:       |          |
| Constant                                                       | 24.88952 | Constant                                                          | 28.58183 | Constant                                                       | 54.74270 |
| Std Err of Y Est                                               | 6.885708 | Std Err of Y Est                                                  | 7.580179 | Std Err of Y Est                                               | 14.72871 |
| R Squared                                                      | 0.089885 | R Squared                                                         | 0.089366 | R Squared                                                      | 0.078083 |
| No. of Observations                                            | 18       | No. of Observations                                               | 18       | No. of Observations                                            | 14       |
| Degrees of Freedom                                             | 14       | Degrees of Freedom                                                | 14       | Degrees of Freedom                                             | 12       |
| X Coefficient(s)                                               | -1.09200 | X Coefficient(s)                                                  | 1.205843 | X Coefficient(s)                                               | 2.935067 |
| Std Err of Coef.                                               | 0.806148 | Std Err of Coef.                                                  | 1.028732 | Std Err of Coef.                                               | 2.953584 |
| No. of Orepasses vs Dev. Cost/Ton.<br>Regression Output:       |          | No. of Orepasses vs Tons/Dev. Employee.<br>Regression Output:     |          | No. of Orepasses vs Tons/Total Employee.<br>Regression Output: |          |
| Constant                                                       | 33.71347 | Constant                                                          | 29.10361 | Constant                                                       | 25.76379 |
| Std Err of Y Est                                               | 8.270945 | Std Err of Y Est                                                  | 5.613305 | Std Err of Y Est                                               | 9.448980 |
| R Squared                                                      | 0.000001 | R Squared                                                         | 0.004018 | R Squared                                                      | 0.085754 |
| No. of Observations                                            | 18       | No. of Observations                                               | 18       | No. of Observations                                            | 14       |
| Degrees of Freedom                                             | 11       | Degrees of Freedom                                                | 11       | Degrees of Freedom                                             | 12       |
| X Coefficient(s)                                               | -0.00787 | X Coefficient(s)                                                  | -0.25382 | X Coefficient(s)                                               | -1.84076 |
| Std Err of Coef.                                               | 1.661876 | Std Err of Coef.                                                  | 1.265231 | Std Err of Coef.                                               | 1.263788 |

There does not appear to be any correlation between No. of Orepasses and Productivity.

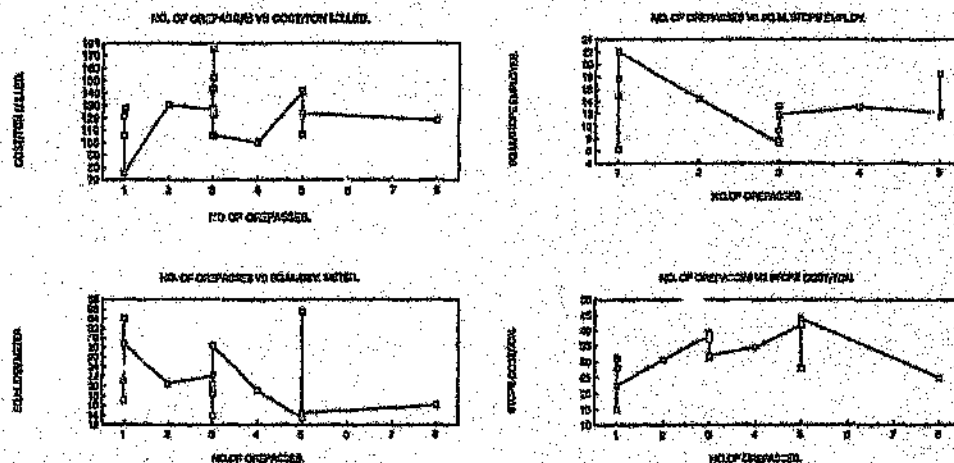


Figure B.3.4.1

# NUMBER OF STOPE OREPASSES AND PRODUCTIVITY STATISTICS

WEST WITS MINES ONLY

| MINE      | NUMBER<br>O/PASSES | COST/TON<br>MILL '89 | SQ.MET/<br>STO.EMP. | TONS/<br>STO.EMP. | SQ.MET/<br>DEV.MET. | STO.COST TONS/<br>/TON (R) | DEV.COST TONS/<br>/TON (R) | UDG.EMP. | TOT.EMP. |
|-----------|--------------------|----------------------|---------------------|-------------------|---------------------|----------------------------|----------------------------|----------|----------|
| WESTDEEF  | 5                  | 123.71               | 11.85               | 45.17             | 14.45               | 44.09                      | 78.14                      | 23.58    | 25.18    |
| DEELKRAAL | 3                  | 103.02               | 11.59               | 54.24             | 23.43               | 32.05                      | 65.85                      | 29.25    | 32.55    |
| KLOOF     | 3                  | 175.78               | 7.68                | 35.07             | 14.01               | 59.16                      | 38.79                      | 57.78    | 23.49    |
| DOORNPIJN | 5                  | 152.78               | 13.37               | 45.59             | 20.42               | 31.32                      | 57.74                      | 41.83    | 27.62    |
| EASTDRIE  | 3                  | 123.08               | 8.42                | 44.14             | 18.93               | 39.53                      | 72.37                      | 30.88    | 34.37    |
| WESTDRIE  | 5                  | 143.83               | 11.69               | 47.03             | 19.33               | 37.14                      | 76.34                      | 31.37    | 30.14    |
| LIBANON   | 2                  | 130.41               | 14.44               | 52.73             | 20.49               | 30.79                      | 59.58                      | 35.35    | 39.17    |

| No. of Orepases vs Cost/Ton Milled.<br>Regression Output:    |          |  | No. of Orepases vs Square Meters/Slope Emp.<br>Regression Output: |          |  | No. of Orepases vs Tons/Slope Employee.<br>Regression Output:  |          |  |
|--------------------------------------------------------------|----------|--|-------------------------------------------------------------------|----------|--|----------------------------------------------------------------|----------|--|
| Constant                                                     | 149.1570 |  | Constant                                                          | 12.93764 |  | Constant                                                       | 58.56294 |  |
| Std Err of Y Est                                             | 24.87327 |  | Std Err of Y Est                                                  | 2.463935 |  | Std Err of Y Est                                               | 8.525483 |  |
| R Squared                                                    | 0.024599 |  | R Squared                                                         | 0.032708 |  | R Squared                                                      | 0.115042 |  |
| No. of Observations                                          | 7        |  | No. of Observations                                               | 7        |  | No. of Observations                                            | 7        |  |
| Degrees of Freedom                                           | 5        |  | Degrees of Freedom                                                | 5        |  | Degrees of Freedom                                             | 5        |  |
| X Coefficient(s)                                             | -4.01505 |  | X Coefficient(s)                                                  | -0.45970 |  | X Coefficient(s)                                               | -3.11911 |  |
| Std Err of Coef.                                             | 11.28361 |  | Std Err of Coef.                                                  | 1.117992 |  | Std Err of Coef.                                               | 3.868828 |  |
| No. of Orepases vs Sq. Met./Day Meter.<br>Regression Output: |          |  | No. of Orepases vs Slope Cost/Ton.<br>Regression Output:          |          |  | No. of Orepases vs Tons/Dev. Emp.<br>Regression Output:        |          |  |
| Constant                                                     | 26.56705 |  | Constant                                                          | 22.72411 |  | Constant                                                       | 43.79411 |  |
| Std Err of Y Est                                             | 4.768773 |  | Std Err of Y Est                                                  | 3.441712 |  | Std Err of Y Est                                               | 13.23538 |  |
| R Squared                                                    | 0.175209 |  | R Squared                                                         | 0.606290 |  | R Squared                                                      | 0.198378 |  |
| No. of Observations                                          | 7        |  | No. of Observations                                               | 7        |  | No. of Observations                                            | 7        |  |
| Degrees of Freedom                                           | 5        |  | Degrees of Freedom                                                | 5        |  | Degrees of Freedom                                             | 5        |  |
| X Coefficient(s)                                             | -2.23588 |  | X Coefficient(s)                                                  | 4.333235 |  | X Coefficient(s)                                               | 6.638235 |  |
| Std Err of Coef.                                             | 2.154249 |  | Std Err of Coef.                                                  | 1.561651 |  | Std Err of Coef.                                               | 6.005455 |  |
| No. of Orepases vs Day Cost/Ton.<br>Regression Output:       |          |  | No. of Orepases vs Tons/UDG. Employees.<br>Regression Output:     |          |  | No. of Orepases vs Tons/Total Employees.<br>Regression Output: |          |  |
| Constant                                                     | 45.87588 |  | Constant                                                          | 42.81705 |  | Constant                                                       | 35.09941 |  |
| Std Err of Y Est                                             | 11.03708 |  | Std Err of Y Est                                                  | 4.555161 |  | Std Err of Y Est                                               | 3.450598 |  |
| R Squared                                                    | 0.087307 |  | R Squared                                                         | 0.423007 |  | R Squared                                                      | 0.487785 |  |
| No. of Observations                                          | 7        |  | No. of Observations                                               | 7        |  | No. of Observations                                            | 7        |  |
| Degrees of Freedom                                           | 5        |  | Degrees of Freedom                                                | 5        |  | Degrees of Freedom                                             | 5        |  |
| X Coefficient(s)                                             | -2.00833 |  | X Coefficient(s)                                                  | -3.98588 |  | X Coefficient(s)                                               | -3.44617 |  |
| Std Err of Coef.                                             | 5.007995 |  | Std Err of Coef.                                                  | 2.071408 |  | Std Err of Coef.                                               | 1.578295 |  |

There appears to be a strong correlation between No. of Orepases and Slope Cost/Ton, Tons/UDG. and Total Employees.

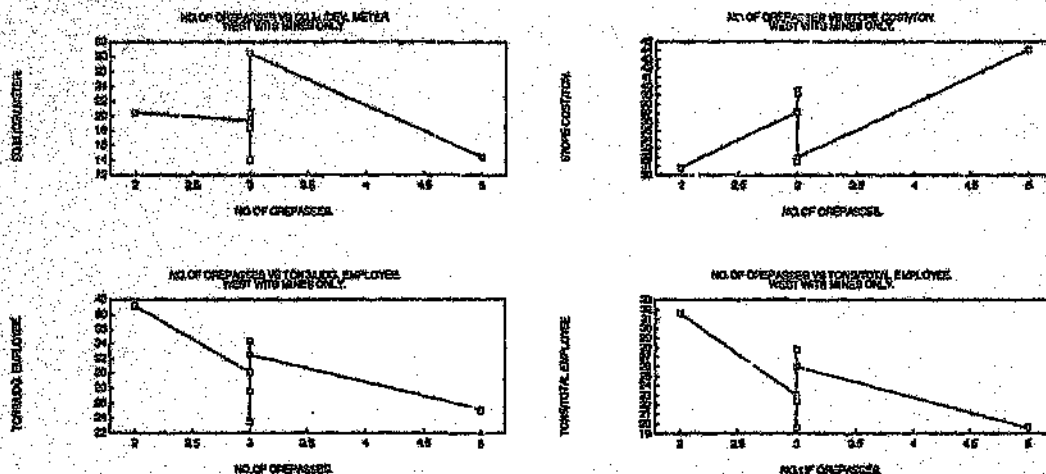


Figure 5.3.4.2

From a logical point of view one would expect productivity and therefore stope cost/ton to improve as the infrastructure is improved, unless the cost of the additional development is also attributed to the total stoping cost (individual accounting systems). This is definitely not the case for the mines in the select group.

There is no apparent correlation between the number of orepasses and labour productivity or costs in the analysis of the general group, although certain mines such as Beatrix do support this theory. This is shown in Figure 5.3.4.1. The conclusion reached is that while one would expect productivity to improve with the provision of additional orepasses there is no statistical evidence to substantiate this.

### 5.3.5 SQUARE METERS/DEVELOPMENT METER.

Figure 5.3.5.2, (select group), shows that there is an apparent correlation between square meters/development meter and cost/ton milled. The relationship, as expected, is an inverse one, as the amount of development increases so should the overall cost. The logic of why there should be a direct relationship with square meters and tons per employee is not obvious. As the ratio of development to stoping decreases so should the number and capacity of the orepasses and labour productivity should decrease (see previous paragraph).

One would also expect the stope cost per ton to vary directly rather than in an inverse manner. The answer probably lies in the small sample size and that the relationship does not exist.

Figure 5.3.5.1. shows the same relationship for square meters and tons per stope employee, for the general group and in other respects as well. It would seem therefore that the answer given in the previous paragraph may be incorrect and that there are other over-riding factors (Eg mining method at West Rand Cons.) which can account for the variation.

The conclusion reached therefore is that square meters/development meter probably has an inverse relationship with cost/ton milled. It would seem logical that overall unit costs should decrease with a decrease in the amount of development.

### 5.4 STOPING LAYOUT.

Under the heading of development layout, factors such as raise spacing and the number of boxholes was discussed as well as the effect they can have on labour productivity and costs. It is necessary to

# SQUARE MET./ DEV.MET. AND PRODUCTIVITY STATISTICS.

| MINE      | SQ.MET./<br>DEV.MET. | COST/TON<br>MILL/89 | SQ.MET./<br>STO.EMP. | TONS/<br>STO.EMP. | STO.COST TON/1<br>/TON (R) | DEV.COST TONS/<br>/TON (R) | TONS/<br>LOG.EMP. | TONS/<br>TOT.EMP. |
|-----------|----------------------|---------------------|----------------------|-------------------|----------------------------|----------------------------|-------------------|-------------------|
| KINROSS   | 35.44                | 107.09              | 18.46                | 77.86             | 28.08                      | 10.85                      | 55.89             | 25.51             |
| BRACKEN   | 34.01                | 105.38              | 17.75                | 51.19             | 31.12                      | 11.19                      | 55.97             | 22.67             |
| WILCOX    | 28.84                | 78.44               | 22.1                 | 56.8              | 22.49                      | 42.1                       | 39.81             |                   |
| DEELKRIJ  | 25.49                | 108.02              | 11.99                | 54.26             | 42.05                      | 16.86                      | 28.25             | 25.97             |
| WESTHOLI  | 22.2                 | 127.33              | 7.21                 | 36.41             | 38.45                      | 13.28                      | 27.29             | 26.03             |
| WINKELK   | 20.84                | 121.06              | 15                   | 61.3              | 28.2                       | 39.2                       | 39.06             | 15.3              |
| STHELEVA  | 20.81                | 146.77              | 8.675                | 34.038            | 32.43                      | 10.33                      | 50.33             |                   |
| LEANNON   | 20.46                | 130.41              | 14.44                | 62.73             | 30.78                      | 15.39                      | 35.35             | 31.61             |
| DOORNFN   | 20.42                | 132.78              | 13.37                | 48.89             | 31.62                      | 17.74                      | 41.88             | 22.39             |
| WESTORIE  | 19.36                | 143.68              | 11.63                | 47.08             | 37.14                      | 19.34                      | 31.87             | 23.02             |
| PRESSBARI | 19.00                | 100.01              | 13.2                 | 55.63             | 34.05                      | 48.0                       | 39.21             | 23.51             |
| EASTORIE  | 18.39                | 138.08              | 9.42                 | 44.14             | 39.83                      | 18.37                      | 30.69             | 27.77             |
| GRITALE   | 17.09                | 127.21              | 9.31                 | 20.43             | 14.82                      | 69                         | 30.19             | 21.46             |
| BEATRICK  | 16.14                | 110.33              |                      |                   | 24.85                      |                            |                   |                   |
| WESTDEEP  | 14.88                | 123.71              | 11.86                | 48.17             | 44.08                      | 16.14                      | 28.58             | 15.57             |
| KLOOF     | 14.01                | 175.79              | 7.69                 | 34.07             | 39.19                      | 10.78                      | 57.78             | 19.59             |
| WALDEEP   | 13.5                 | 131.47              | 12.22                | 58.8              | 41.74                      |                            | 28.88             | 21.67             |
| STILFONT  |                      | 73.39               |                      |                   |                            |                            |                   |                   |
| LESLIE    |                      | 110.71              |                      |                   |                            |                            |                   |                   |
| BLANDED   |                      | 197.85              | 10.28                | 86.74             |                            |                            | 28.08             | 21.84             |

| Square Meters/Dev. Meter vs Cost/Ton Milled.<br>Regression Output: |          | Sq. Meters/Dev. Meter vs Sq. Meters/Stone Empl.<br>Regression Output: |          | Square Meters/Dev. Meter vs Tons/Stone Empl.<br>Regression Output: |          |
|--------------------------------------------------------------------|----------|-----------------------------------------------------------------------|----------|--------------------------------------------------------------------|----------|
| Constant                                                           | 170.7010 | Constant                                                              | 3.147544 | Constant                                                           | 28.28916 |
| Std Err of Y Est                                                   | 19.23950 | Std Err of Y Est                                                      | 3.542852 | Std Err of Y Est                                                   | 12.62712 |
| R Squared                                                          | 0.362185 | R Squared                                                             | 0.444425 | R Squared                                                          | 0.269131 |
| No. of Observations                                                | 17       | No. of Observations                                                   | 16       | No. of Observations                                                | 18       |
| Degrees of Freedom                                                 | 16       | Degrees of Freedom                                                    | 14       | Degrees of Freedom                                                 | 14       |
| X Coefficient(s)                                                   | -2.18877 | X Coefficient(s)                                                      | 0.434895 | X Coefficient(s)                                                   | 1.114499 |
| Std Err of Coef.                                                   | 0.781831 | Std Err of Coef.                                                      | 0.121946 | Std Err of Coef.                                                   | 0.490854 |
| Square Meters/Dev. Meter vs Slope Cost/Ton.<br>Regression Output:  |          | Square Meters/Dev. Meter vs Tons/Dev. Empl.<br>Regression Output:     |          |                                                                    |          |
| Constant                                                           | 49.45392 | Constant                                                              | 66.93688 |                                                                    |          |
| Std Err of Y Est                                                   | 7.012035 | Std Err of Y Est                                                      | 16.87583 |                                                                    |          |
| R Squared                                                          | 0.177960 | R Squared                                                             | 0.012901 |                                                                    |          |
| No. of Observations                                                | 16       | No. of Observations                                                   | 15       |                                                                    |          |
| Degrees of Freedom                                                 | 14       | Degrees of Freedom                                                    | 13       |                                                                    |          |
| X Coefficient(s)                                                   | -0.47454 | X Coefficient(s)                                                      | -0.28898 |                                                                    |          |
| Std Err of Coef.                                                   | 0.272580 | Std Err of Coef.                                                      | 0.698922 |                                                                    |          |
| Square Meters/Dev. Meter vs Dev. Cost/Ton.<br>Regression Output:   |          | Square Meters/Dev. Meter vs Tons/Total Empl.<br>Regression Output:    |          |                                                                    |          |
| Constant                                                           | 41.79133 | Constant                                                              | 12.49341 |                                                                    |          |
| Std Err of Y Est                                                   | 8.747553 | Std Err of Y Est                                                      | 5.32781  |                                                                    |          |
| R Squared                                                          | 0.032134 | R Squared                                                             | 0.375030 |                                                                    |          |
| No. of Observations                                                | 14       | No. of Observations                                                   | 14       |                                                                    |          |
| Degrees of Freedom                                                 | 12       | Degrees of Freedom                                                    | 12       |                                                                    |          |
| X Coefficient(s)                                                   | -0.22733 | X Coefficient(s)                                                      | 0.578694 |                                                                    |          |
| Std Err of Coef.                                                   | 0.389155 | Std Err of Coef.                                                      | 0.215852 |                                                                    |          |

There appears to be some correlation between Square Meters/Dev. Meter and the following:  
Cost/Ton Milled, Square Meters and Tons/Stone Employee and Tons/Total Employee.

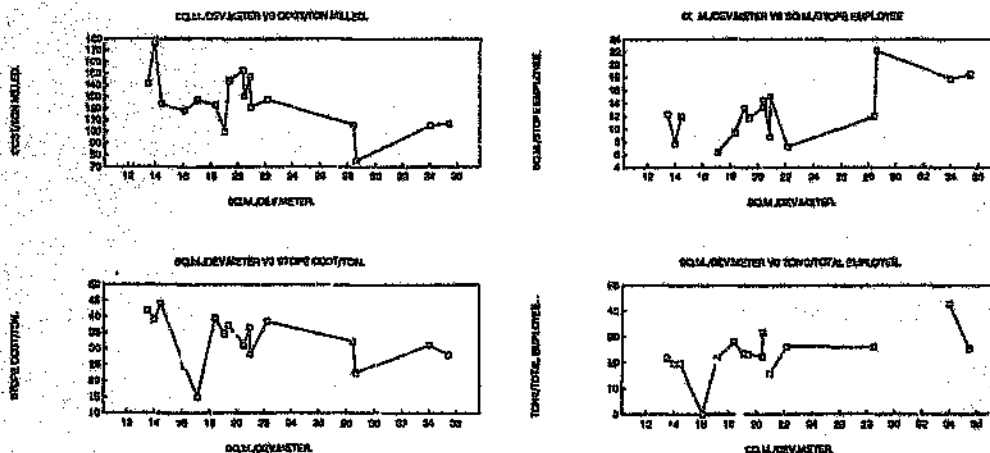


Figure 5.3.5.1

# SQUARE MET. PER DEV. MET. AND PRODUCTIVITY STATISTICS. WEST WITS MINES ONLY.

| MINE     | SQ.MET./<br>DEV.MET. | COST/TON<br>MILL'89 | SQ.MET./<br>STO.EMP. | TONS/<br>STO.EMP. | STD.COST<br>TONS/<br>DEVEMP. | DEV.COST<br>TONS/<br>UDG.EMP. | TONS/<br>TOT.EMP. |
|----------|----------------------|---------------------|----------------------|-------------------|------------------------------|-------------------------------|-------------------|
| DEELKRL  | 28.43                | 103.02              | 11.99                | 54.24             | 32.05                        | 68.65                         | 25.97             |
| LIBANCN  | 20.46                | 120.41              | 14.44                | 62.73             | 30.79                        | 59.38                         | 31.81             |
| DOORNFN  | 20.42                | 152.78              | 13.37                | 48.85             | 31.62                        | 57.74                         | 22.85             |
| WESTDRIE | 19.38                | 143.68              | 11.68                | 47.09             | 57.14                        | 76.34                         | 23.02             |
| EASTDRIE | 16.36                | 123.05              | 9.42                 | 44.14             | 39.53                        | 72.37                         | 27.77             |
| WESTDEEP | 14.48                | 123.71              | 11.85                | 48.17             | 44.09                        | 78.14                         | 19.57             |
| KLOOF    | 14.01                | 175.76              | 7.85                 | 35.07             | 39.18                        | 39.78                         | 19.59             |

| Square Meters/Dev.Meter vs Cost/Ton Milled.<br>Regression Output: |          | Sq.Meter/Dev.Meter vs Sq.Meters/Stoppe Empl.<br>Regression Output: |          | Square Meters/Dev.Meter vs Tons/Stoppe Empl.<br>Regression Output: |          |
|-------------------------------------------------------------------|----------|--------------------------------------------------------------------|----------|--------------------------------------------------------------------|----------|
| Constant                                                          | 182.8185 | Constant                                                           | 7.228895 | Constant                                                           | 29.04043 |
| Std Err of Y Est                                                  | 20.05588 | Std Err of Y Est                                                   | 2.221675 | Std Err of Y Est                                                   | 7.316036 |
| R Squared                                                         | 0.355564 | R Squared                                                          | 0.218571 | R Squared                                                          | 0.348648 |
| No. of Observations                                               | 7        | No. of Observations                                                | 7        | No. of Observations                                                | 7        |
| Degrees of Freedom                                                | 5        | Degrees of Freedom                                                 | 5        | Degrees of Freedom                                                 | 5        |
| X Coefficient(s)                                                  | -2.89932 | X Coefficient(s)                                                   | 0.220348 | X Coefficient(s)                                                   | 1.018573 |
| Std Err of Coef.                                                  | 7934     | Std Err of Coef.                                                   | 0.188097 | Std Err of Coef.                                                   | 0.822617 |

| Square Meters/Dev.Meter vs Stoppe Cost/Ton.<br>Regression Output: |          | Square Meters/Dev.Meter vs Tons/Dev.Empl.<br>Regression Output: |          |
|-------------------------------------------------------------------|----------|-----------------------------------------------------------------|----------|
| Constant                                                          | 51.24087 | Constant                                                        | 52.8091  |
| Std Err of Y Est                                                  | 3.705417 | Std Err of Y Est                                                | 14.40982 |
| R Squared                                                         | 0.543389 | R Squared                                                       | 0.047433 |
| No. of Observations                                               | 7        | No. of Observations                                             | 7        |
| Degrees of Freedom                                                | 5        | Degrees of Freedom                                              | 5        |
| X Coefficient(s)                                                  | -0.76953 | X Coefficient(s)                                                | 0.811886 |
| Std Err of Coef.                                                  | 0.315471 | Std Err of Coef.                                                | 1.226488 |

| Square Meters/Dev.Meter vs Dev.Cost/Ton.<br>Regression Output: |          | Square Meters/Dev.Meter vs Tons/UDg.Empl.<br>Regression Output: |          | Square Meters/Dev.Meter vs Tons/Total Empl.<br>Regression Output: |          |
|----------------------------------------------------------------|----------|-----------------------------------------------------------------|----------|-------------------------------------------------------------------|----------|
| Constant                                                       | 84.82432 | Constant                                                        | 18.44295 | Constant                                                          | 15.02138 |
| Std Err of Y Est                                               | 10.27926 | Std Err of Y Est                                                | 5.066725 | Std Err of Y Est                                                  | 4.165992 |
| R Squared                                                      | 0.19099  | R Squared                                                       | 0.289257 | R Squared                                                         | 0.268701 |
| No. of Observations                                            | 7        | No. of Observations                                             | 7        | No. of Observations                                               | 7        |
| Degrees of Freedom                                             | 5        | Degrees of Freedom                                              | 5        | Degrees of Freedom                                                | 5        |
| X Coefficient(s)                                               | -0.95056 | X Coefficient(s)                                                | 0.615191 | X Coefficient(s)                                                  | 0.477644 |
| Std Err of Coef.                                               | 0.874917 | Std Err of Coef.                                                | 0.431253 | Std Err of Coef.                                                  | 0.354562 |

There appears to be some correlation between Square Meters/Dev.Meter and the following:  
Cost/Ton Milled, Square Meters and Tons/Stoppe Employee and Tons/Total Employee.

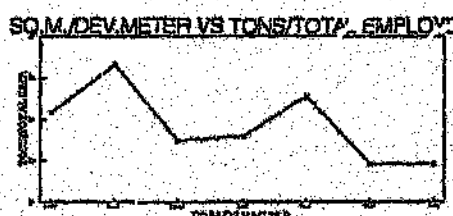
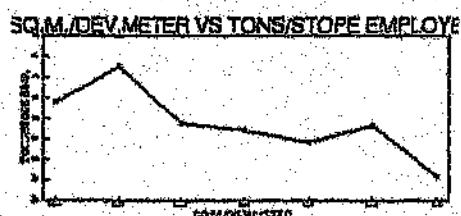
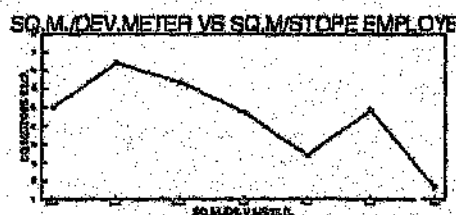
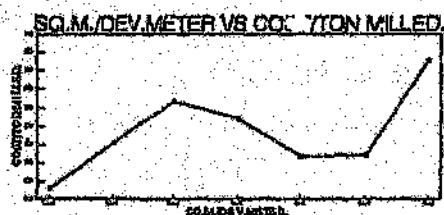


TABLE 5.3.5.2

consider two other factors related to stope layouts, namely back-length and panel length.

The stoping layouts for the mines covered by the survey, are shown in Table 3.3, and in the appendix.

#### **5.4.1 BACK-LENGTH.**

The back-length is the length of the stope face between the main levels or inter-levels of the mine. This is obviously a function of inter-level spacing and the dip of the reef (or the apparent dip, where stope faces are mined off true dip). An analysis of the back lengths in use shows a variation from a maximum of 280 meters to a minimum of 127. Further analysis reveals that the mines with the steeper dipping reefs tend to have shorter backs than the mines with the flatter dips.

Access for men, material and equipment is usually hampered by the conditions encountered on the reef plane. These are: rough, sloping and slippery footwalls or ladderways, insufficient headroom, confined spaces and a hot and humid environment. These conditions plus the fact that the movement of these items (men etc), is usually against a counter flow of rock moving from the face towards the centre gully and orepasses, further hampers progress. The degree of difficulty is directly proportional to the distance travelled. The distance travelled, is the sum of the distances traversed, on the dip of the reef plus the distance traversed on strike. In other words, down the centre gully, along the strike gully and down the face. The maximum distance for any given working place, is from the top or bottom entrance of the stope to a point on the face, midway between the top and the bottom of the stope. This distance can only be limited by, reducing the inter-level distance (and hence the back length) or reducing the distance mined on strike (crosscut or raise spacing).

The degree of difficulty is also proportional to the dip. Steeply dipping workings are obviously more difficult to traverse than flat ones. By the same token, narrow stopes are more difficult than wide ones.

Thus mines exhibiting the foregoing characteristics, will benefit more by reducing back length and maximum strike distances, than those which do not. In the deep level mines where strike stability pillars are used the back length is a function of the number of inter-levels between the pillars.

Figure 5.4.1.2, shows that there is an apparent correlation between the back-length and labour productivity in the select group of mines.

The relationship is an inverse one for underground and total employees (productivity should improve as there is better access). This is what one would expect, however the relationship does not extend to the tons/stope employee. One must conclude on the evidence available that there is no real correlation and that backlength is not an important factor.

There is apparently no correlation between back-length and productivity in the case of the general group (Figure 5.4.1.1).

Once again the only conclusion one can reach is that there should be an improvement in labour productivity with a smaller back-length, as access should improve.

### 5.4.2 PANEL LENGTH

Mention was made previously that the most difficult part of the stope to traverse is on the stope face. The amount of travel on the face, can be limited by reducing the panel length. This has the added benefit of improving the face cleaning times. The disadvantages of this are: more capital equipment and possibly orepasses are required as well as more waste cutting in the form of strike gullies. This increases the amount of waste dilution of the ore to the mill.

The subject of optimum economic panel length has also been researched by Comro (D.A. Immelman, 1983). The conclusion reached was that shorter panels were seldom better than longer ones.

Those mines using so called trackless mining methods (TM3), have in certain cases increased the panel length (thus reducing the amount of dilution), in the knowledge that the improved cleaning facility in the strike roadways (L.H.D.'s) and improved access for men, material and equipment, more than compensates for the increase in panel length.

Figure 5.4.2.2. shows that there is an apparent correlation between panel length and cost/ton milled (inverse relationship), for the select group. This is what one would expect. However, this relationship is not reflected in the stoping cost/ton and one must conclude that there is no real relationship. There is also an apparent correlation between panel length and Tons/dev.emp. and Dev. Cost/ton. These seem to fly in the face of expected logic and are probably due to the smallness of the sample.

Figure 5.4.2.1. shows a correlation between panel length and square meters/stope emp. The relationship is an inverse one as can logically be expected (longer panels - more "lost blasts"). The correlation is weaker for tons/stope employee. However mines with short panels (West Rand Cons. and the Evander mines) definitely have higher stope labour productivities. There is no logical explanation

# BACKLENGTH AND PRODUCTIVITY STATISTICS.

| MINE     | BACK LENGTH | COST/TON MILL/30 | SQ.MET./ TONS/ STC.EMP. | TONS/ STC.EMP. | SQ.MET./ DEV.MET. | STC.COST TONS/ (TON R) | DEV.COST TONS/ (TON R) | UDG.EMP. | TOT.EMP. |
|----------|-------------|------------------|-------------------------|----------------|-------------------|------------------------|------------------------|----------|----------|
| BEATRICK | 260         | 118.33           |                         |                | 16.14             | 26.25                  |                        |          |          |
| GRIVLEY  | 253         | 127.21           | 6.31                    | 20.45          | 17.33             | 14.92                  | 65                     | 50.08    | 27.01    |
| WESTDRIE | 240         | 143.83           | 11.63                   | 47.05          | 19.33             | 37.14                  | 78.34                  | 31.37    | 30.14    |
| WESTDELF | 240         | 129.71           | 11.63                   | 48.17          | 14.43             | 44.09                  | 78.14                  | 28.58    | 28.13    |
| KINROSS  | 240         | 107.08           | 10.40                   | 77.25          | 35.44             | 22.02                  | 60.55                  | 35.93    | 30.50    |
| WESTHOLL | 224         | 127.83           | 7.21                    | 36.41          | 22.2              | 35.45                  | 63.25                  | 27.88    | 27.88    |
| DOORNIN  | 224         | 152.79           | 13.97                   | 48.85          | 20.48             | 51.82                  | 87.74                  | 41.69    | 27.02    |
| VAALERS  | 175         | 141.47           | 12.22                   | 58.6           | 19.5              | 41.71                  | 68.55                  | 29.55    | 27.88    |
| DELRIFT  | 170         | 103.02           | 11.63                   | 54.24          | 25.43             | 32.05                  | 68.55                  | 29.55    | 32.53    |
| WINDOLK  | 159         | 121.05           | 13                      | 51.3           | 20.64             | 28.2                   | 69.2                   | 30.04    | 21.4     |
| PHESERAN | 140         | 100.01           | 13.2                    | 55.53          | 19.03             | 34.65                  | 49                     | 39.21    | 15.13    |
| KLOOF    | 133         | 175.70           | 7.93                    | 23.07          | 14.01             | 39.10                  | 33.73                  | 57.78    | 23.46    |
| EASTDRIE | 132         | 123.05           | 8.42                    | 44.14          | 18.33             | 39.53                  | 72.87                  | 30.25    | 24.57    |
| WILCOXS  | 100         | 76.44            | 32.1                    | 55.8           | 20.64             | 22.83                  | 42.1                   | 39.81    |          |
| BRACKEN  | 127         | 109.83           | 17.75                   | 51.18          | 54.01             | 51.12                  | 51.18                  | 55.57    | 42.07    |
| LISANON  | 105         | 130.41           | 14.44                   | 62.73          | 20.46             | 30.79                  | 59.30                  | 35.39    | 39.17    |

|                                                       |          |  |                                                         |          |  |                                                         |          |  |
|-------------------------------------------------------|----------|--|---------------------------------------------------------|----------|--|---------------------------------------------------------|----------|--|
| Backlength vs Cost/Ton Milled.<br>Regression Output   |          |  | Backlength vs Square Met./Step Em.<br>Regression Output |          |  | Backlength vs Tons/Step Em.<br>Regression Output        |          |  |
| Constant                                              | 113.1833 |  | Constant                                                | 11.21370 |  | Constant                                                | 14.41078 |  |
| Std Err of Y Est                                      | 23.81645 |  | Std Err of Y Est                                        | 4.462073 |  | Std Err of Y Est                                        | 0.011469 |  |
| R Squared                                             | 0.031407 |  | R Squared                                               | 0.018483 |  | R Squared                                               | 0.011469 |  |
| No. of Observations                                   | 16       |  | No. of Observations                                     | 15       |  | No. of Observations                                     | 15       |  |
| Degrees of Freedom                                    | 14       |  | Degrees of Freedom                                      | 13       |  | Degrees of Freedom                                      | 13       |  |
| X Coefficient(s)                                      | 0.480029 |  | X Coefficient(s)                                        | 0.071053 |  | X Coefficient(s)                                        | 0.167365 |  |
| Std Err of Coef.                                      | 0.712458 |  | Std Err of Coef.                                        | 0.157029 |  | Std Err of Coef.                                        | 0.505258 |  |
| Backlength vs Sq.Met./Dev.Meter.<br>Regression Output |          |  | Backlength vs Steps Cost/Ton.<br>Regression Output      |          |  | Backlength vs Tons/Dev.Em.<br>Regression Output         |          |  |
| Constant                                              | 19.11595 |  | Constant                                                | 27.40987 |  | Constant                                                | 78.02263 |  |
| Std Err of Y Est                                      | 6.881056 |  | Std Err of Y Est                                        | 7.634427 |  | Std Err of Y Est                                        | 4.43776  |  |
| R Squared                                             | 0.017809 |  | R Squared                                               | 0.065613 |  | R Squared                                               | 0.111813 |  |
| No. of Observations                                   | 16       |  | No. of Observations                                     | 16       |  | No. of Observations                                     | 14       |  |
| Degrees of Freedom                                    | 14       |  | Degrees of Freedom                                      | 14       |  | Degrees of Freedom                                      | 12       |  |
| X Coefficient(s)                                      | 14       |  | X Coefficient(s)                                        | 0.228748 |  | X Coefficient(s)                                        | -0.64895 |  |
| Std Err of Coef.                                      | 11       |  | Std Err of Coef.                                        | 0.229847 |  | Std Err of Coef.                                        | 0.628807 |  |
| Backlength vs Dev.Cost/Ton.<br>Regression Output      |          |  | Backlength vs Tons/Dev.Em.<br>Regression Output         |          |  | Backlength vs Tons/Total Employee.<br>Regression Output |          |  |
| Constant                                              | 29.91902 |  | Constant                                                | 29.67192 |  | Constant                                                | 16.01865 |  |
| Std Err of Y Est                                      | 7.879102 |  | Std Err of Y Est                                        | 5.888543 |  | Std Err of Y Est                                        | 6.188387 |  |
| R Squared                                             | 0.058927 |  | R Squared                                               | 0.008269 |  | R Squared                                               | 0.182863 |  |
| No. of Observations                                   | 16       |  | No. of Observations                                     | 19       |  | No. of Observations                                     | 14       |  |
| Degrees of Freedom                                    | 11       |  | Degrees of Freedom                                      | 11       |  | Degrees of Freedom                                      | 12       |  |
| X Coefficient(s)                                      | 0.278811 |  | X Coefficient(s)                                        | 0.071851 |  | X Coefficient(s)                                        | 0.344551 |  |
| Std Err of Coef.                                      | 0.809112 |  | Std Err of Coef.                                        | 0.223351 |  | Std Err of Coef.                                        | 0.223516 |  |

There does not appear to be any correlation between Backlength and Productivity.

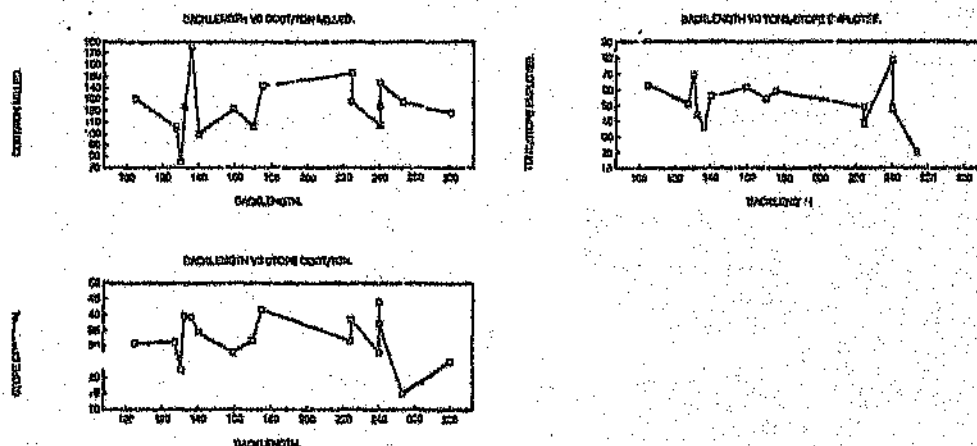


Figure 5.4.1.1

# BACKLENGTH AND PRODUCTIVITY STATISTICS.

WEST WITS MINES ONLY.

| MINE     | BACK LENGTH | COST/TON SQ. MET./ MILL. '88 | TONS/ STG. EMP. | TONS/ STG. EMP. | SQ. MET./ DEV. MET. | STG. COST TONS/ (TON (R). | DEV. COST TONS/ DEV. EMP. | TONS/ (TON (R). | UDG. EMP. | TOT. EMP. |
|----------|-------------|------------------------------|-----------------|-----------------|---------------------|---------------------------|---------------------------|-----------------|-----------|-----------|
| WESTORE  | 250         | 143.88                       | 11.86           | 47.03           | 19.08               | 37.14                     | 78.34                     | 31.37           | 80.14     | 83.02     |
| WESTDEEP | 240         | 125.71                       | 11.08           | 48.17           | 14.40               | 44.65                     | 78.14                     | 28.56           | 25.13     | 19.57     |
| DOORNFN  | 224         | 182.70                       | 13.87           | 40.09           | 20.42               | 31.03                     | 57.74                     | 41.88           | 27.52     | 22.86     |
| DESKRL   | 170         | 100.02                       | 11.59           | 54.24           | 20.43               | 32.08                     | 60.55                     | 25.25           | 32.55     | 25.07     |
| ILLOOF   | 138         | 175.73                       | 7.65            | 26.07           | 14.01               | 25.16                     | 39.70                     | 57.78           | 23.49     | 19.59     |
| EASTDRG  | 138         | 123.03                       | 8.42            | 44.14           | 19.36               | 30.63                     | 72.37                     | 30.89           | 34.57     | 27.77     |
| LIGANON  | 105         | 130.41                       | 14.44           | 62.73           | 20.40               | 30.79                     | 69.38                     | 35.35           | 39.11     | 31.61     |

| Backlength vs Cost/Ton Mined.      |          |  | Backlength vs Square Met./Stope Emp. |          |  | Backlength vs Tonn./Stope Emp.      |          |  |
|------------------------------------|----------|--|--------------------------------------|----------|--|-------------------------------------|----------|--|
| Regression Output:                 |          |  | Regression Output:                   |          |  | Regression Output:                  |          |  |
| Constant                           | 135.8304 |  | Constant                             | 10.02907 |  | Constant                            | 58.98304 |  |
| Std Err of Y Est                   | 25.10453 |  | Std Err of Y Est                     | 2.453353 |  | Std Err of Y Est                    | 0.944344 |  |
| R Squared                          | 0.000078 |  | R Squared                            | 0.040988 |  | R Squared                           | 0.026177 |  |
| No. of Observations                | 7        |  | No. of Observations                  | 7        |  | No. of Observations                 | 7        |  |
| Degrees of Freedom                 | 5        |  | Degrees of Freedom                   | 5        |  | Degrees of Freedom                  | 5        |  |
| X Coefficient(s)                   | 0.003471 |  | X Coefficient(s)                     | 0.056212 |  | X Coefficient(s)                    | -0.02374 |  |
| Std Err of Coef.                   | 0.182937 |  | Std Err of Coef.                     | 0.017792 |  | Std Err of Coef.                    | 0.084750 |  |
| Backlength vs Sq. Met./Dev. Meter. |          |  | Backlength vs Stope Cost/Ton.        |          |  | Backlength vs Tonn./Dev. Emp.       |          |  |
| Regression Output:                 |          |  | Regression Output:                   |          |  | Regression Output:                  |          |  |
| Constant                           | 20.02301 |  | Constant                             | 51.60051 |  | Constant                            | 43.33042 |  |
| Std Err of Y Est                   | 5.235769 |  | Std Err of Y Est                     | 5.254069 |  | Std Err of Y Est                    | 12.77699 |  |
| R Squared                          | 0.007018 |  | R Squared                            | 0.082451 |  | R Squared                           | 0.286357 |  |
| No. of Observations                | 7        |  | No. of Observations                  | 7        |  | No. of Observations                 | 7        |  |
| Degrees of Freedom                 | 5        |  | Degrees of Freedom                   | 5        |  | Degrees of Freedom                  | 5        |  |
| X Coefficient(s)                   | -0.09712 |  | X Coefficient(s)                     | 0.025498 |  | X Coefficient(s)                    | 0.118718 |  |
| Std Err of Coef.                   | 0.037897 |  | Std Err of Coef.                     | 0.036040 |  | Std Err of Coef.                    | 0.092320 |  |
| Backlength vs Dev. Cost/Ton.       |          |  | Backlength vs Tonn./Udg. Employee.   |          |  | Backlength vs Tonn./Total Employee. |          |  |
| Regression Output:                 |          |  | Regression Output:                   |          |  | Regression Output:                  |          |  |
| Constant                           | 46.40048 |  | Constant                             | 39.88248 |  | Constant                            | 33.33866 |  |
| Std Err of Y Est                   | 10.89200 |  | Std Err of Y Est                     | 5.020093 |  | Std Err of Y Est                    | 3.710137 |  |
| R Squared                          | 0.081803 |  | R Squared                            | 0.302279 |  | R Squared                           | 0.417286 |  |
| No. of Observations                | 7        |  | No. of Observations                  | 7        |  | No. of Observations                 | 7        |  |
| Degrees of Freedom                 | 5        |  | Degrees of Freedom                   | 5        |  | Degrees of Freedom                  | 5        |  |
| X Coefficient(s)                   | -0.05001 |  | X Coefficient(s)                     | -0.05349 |  | X Coefficient(s)                    | -0.05080 |  |
| Std Err of Coef.                   | 0.073359 |  | Std Err of Coef.                     | 0.036346 |  | Std Err of Coef.                    | 0.026881 |  |

There appears to be some correlation between Backlength and Tonn./Dev., Udg. and Total Employee.

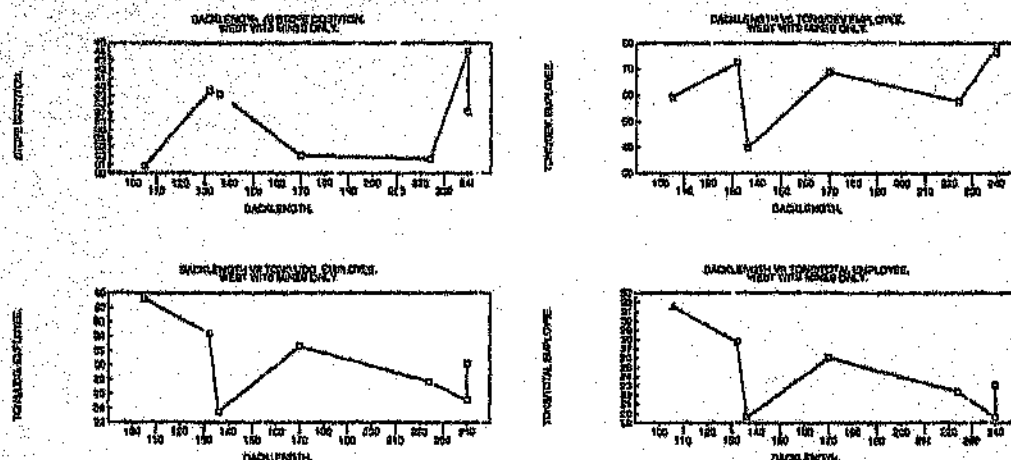


Figure 8.4.1.2

# PANEL LENGTH AND PRODUCTIVITY STATISTICS.

| MINE     | PANEL LENGTH | CUST/TON | TON/ SQ.MET. | TONS/ STC.EMP. | TONS/ STC.EMP. | TONS/ STC.EMP. | TONS/ STC.EMP. | TONS/ STC.EMP. | TONS/ STC.EMP. | TONS/ STC.EMP. |
|----------|--------------|----------|--------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|          |              |          |              |                |                |                |                |                |                |                |
| WESTDEEP | 40           | 124.71   | 11.09        | 46.17          | 14.46          | 44.09          | 70.14          | 26.58          | 25.19          | 19.57          |
| WESTHOLD | 37           | 127.39   | 7.21         | 56.41          | 22.2           | 33.45          | 83.29          | 27.88          | 28.03          |                |
| FRESHER  | 35           | 100.01   | 15.2         | 55.63          | 19.03          | 34.05          | 45.3           | 39.21          | 19.13          | 23.31          |
| LEBANON  | 39           | 130.41   | 14.46        | 62.74          | 20.49          | 40.78          | 59.35          | 35.35          | 35.17          | 31.31          |
| VAALREEF | 35           | 141.47   | 12.28        | 66.6           | 18.6           | 41.74          |                |                | 26.88          | 21.87          |
| DEBURA   | 34           | 103.02   | 11.69        | 54.24          | 20.43          | 32.05          | 69.05          | 29.25          | 32.55          | 26.07          |
| EASTDRIE | 33           | 123.03   | 9.42         | 44.14          | 18.63          | 39.53          | 72.57          | 30.96          | 34.67          | 27.77          |
| WESTDRIE | 30           | 142.89   | 11.09        | 47.63          | 18.38          | 37.14          | 78.54          | 31.37          | 30.14          | 23.02          |
| BEATON   | 30           | 113.33   |              |                | 18.14          | 24.95          |                |                |                |                |
| GETVUSH  | 28           | 127.81   | 8.41         | 30.13          | 17.09          | 14.82          | 63             | 30.05          | 27.61          | 21.36          |
| DOONFIN  | 28           | 122.74   | 13.57        | 46.89          | 20.42          | 31.82          | 57.74          | 41.67          | 27.62          | 22.98          |
| REDF     | 27           | 176.70   | 7.63         | 32.07          | 14.01          | 53.18          | 59.78          | 57.78          | 23.49          | 16.99          |
| KALROSE  | 24           | 187.03   | 18.48        | 77.93          | 35.44          | 23.03          | 60.65          | 33.93          | 30.83          | 23.31          |
| WINDYHAT | 21           | 121.63   | 13           | 31.2           | 20.54          | 23.2           | 62.2           | 33.05          | 21.4           | 15.3           |
| BRACKEN  | 18           | 109.39   | 12.78        | 51.19          | 31.01          | 31.12          | 51.19          | 35.87          |                | 42.67          |
| WILCONS  | 8            | 75.45    | 22.1         | 66.3           | 23.94          | 22.48          | 42.1           | 39.31          |                |                |

| Panel length vs Cost/Ton Mined.<br>Regression Output:    |          |  | Panel length vs Square Met./Steps Emp.<br>Regression Output: |          |  | Panel length vs Tons/Steps Emp.<br>Regression Output:       |          |  |
|----------------------------------------------------------|----------|--|--------------------------------------------------------------|----------|--|-------------------------------------------------------------|----------|--|
| Constant                                                 | 88.82098 |  | Constant                                                     | 21.89664 |  | Constant                                                    | 83.89446 |  |
| Std. Err. of Y Est                                       | 22.29320 |  | Std. Err. of Y Est                                           | 3.280648 |  | Std. Err. of Y Est                                          | 13.81714 |  |
| R Squared                                                | 0.183932 |  | R Squared                                                    | 0.469268 |  | R Squared                                                   | 0.102481 |  |
| No. of Observations                                      | 19       |  | No. of Observations                                          | 15       |  | No. of Observations                                         | 15       |  |
| Degrees of Freedom                                       | 14       |  | Degrees of Freedom                                           | 13       |  | Degrees of Freedom                                          | 13       |  |
| X Coefficient(s)                                         | 0.532833 |  | X Coefficient(s)                                             | -0.31188 |  | X Coefficient(s)                                            | -0.47072 |  |
| Std. Err. of Coef.                                       | 0.421952 |  | Std. Err. of Coef.                                           | 0.592020 |  | Std. Err. of Coef.                                          | 0.366361 |  |
| Panel length vs Sq.Met./Dev.Meter.<br>Regression Output: |          |  | Panel length vs Steps Cost/Ton.<br>Regression Output:        |          |  | Panel length vs Tons/Dev.Emp.<br>Regression Output:         |          |  |
| Constant                                                 | 84.08519 |  | Constant                                                     | 20.55923 |  | Constant                                                    | 36.76619 |  |
| Std. Err. of Y Est                                       | 8.578583 |  | Std. Err. of Y Est                                           | 6.830074 |  | Std. Err. of Y Est                                          | 12.58282 |  |
| R Squared                                                | 0.369204 |  | R Squared                                                    | 0.240573 |  | R Squared                                                   | 0.324335 |  |
| No. of Observations                                      | 19       |  | No. of Observations                                          | 19       |  | No. of Observations                                         | 14       |  |
| Degrees of Freedom                                       | 14       |  | Degrees of Freedom                                           | 14       |  | Degrees of Freedom                                          | 12       |  |
| X Coefficient(s)                                         | -0.44894 |  | X Coefficient(s)                                             | 0.407675 |  | X Coefficient(s)                                            | 0.281634 |  |
| Std. Err. of Coef.                                       | 0.183820 |  | Std. Err. of Coef.                                           | 0.183569 |  | Std. Err. of Coef.                                          | 0.356002 |  |
| Panel length vs Dev.Cost/Ton.<br>Regression Output:      |          |  | Panel length vs Tons/Udg.Employees.<br>Regression Output:    |          |  | Panel length vs Tons/Total Employees.<br>Regression Output: |          |  |
| Constant                                                 | 40.16127 |  | Constant                                                     | 21.15401 |  | Constant                                                    | 33.75289 |  |
| Std. Err. of Y Est                                       | 6.098433 |  | Std. Err. of Y Est                                           | 5.442804 |  | Std. Err. of Y Est                                          | 8.215553 |  |
| R Squared                                                | 0.041030 |  | R Squared                                                    | 0.063587 |  | R Squared                                                   | 0.149421 |  |
| No. of Observations                                      | 13       |  | No. of Observations                                          | 13       |  | No. of Observations                                         | 14       |  |
| Degrees of Freedom                                       | 11       |  | Degrees of Freedom                                           | 11       |  | Degrees of Freedom                                          | 12       |  |
| X Coefficient(s)                                         | -0.16484 |  | X Coefficient(s)                                             | 0.228910 |  | X Coefficient(s)                                            | -0.20400 |  |
| Std. Err. of Coef.                                       | 0.238899 |  | Std. Err. of Coef.                                           | 0.284859 |  | Std. Err. of Coef.                                          | 0.209381 |  |

There seems to be a correlation between Panel length and the following:-  
Square Meters/Steps Employee; Square meters/Dev. Meter; Steps Cost/Ton; Tons/Dev.Employees.

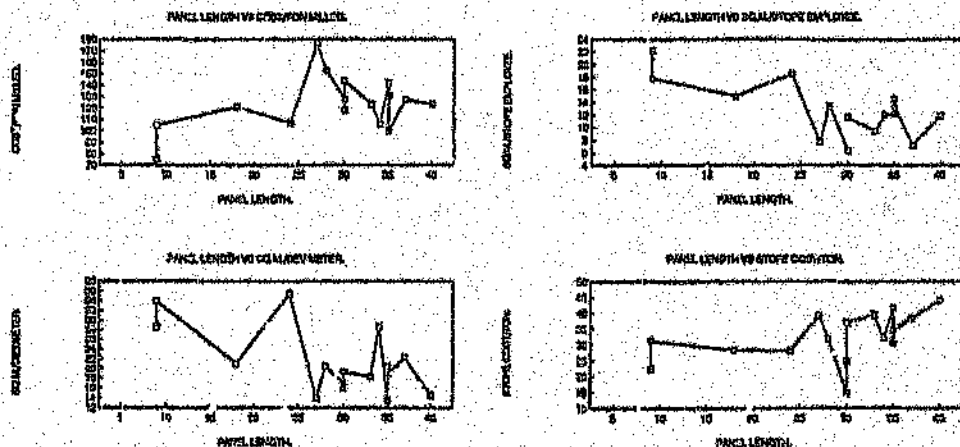


Figure 5.4.1

# PANEL LENGTH AND PRODUCTIVITY STATISTICS.

WEST WITS MINES ONLY.

| MINES    | PANEL  | COST/TON | SQ.MET./ | TONS/    | SQ.MET./ | STO.COST | TONS/    | DEV.COST | TONS/    | TONS/    |
|----------|--------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|          | LENGTH | MILL '88 | STO.EMP. | STO.EMP. | DEV.MET. | /TON (R) | DEV.EMP. | /TON (R) | UDG.EMP. | TOT.EMP. |
| WESTDEEP | 40     | 123.71   | 11.65    | 43.17    | 14.43    | 44.09    | 78.14    | 28.58    | 28.13    | 18.37    |
| LEBANON  | 88     | 180.41   | 14.44    | 62.78    | 20.48    | 80.79    | 59.89    | 95.35    | 39.17    | 31.61    |
| DEELKRIJ | 34     | 116.02   | 11.98    | 54.84    | 28.43    | 32.09    | 98.95    | 29.25    | 32.95    | 23.97    |
| EASTORIE | 33     | 123.03   | 9.42     | 44.14    | 18.38    | 59.53    | 72.37    | 30.93    | 34.37    | 27.77    |
| WESTDRIE | 50     | 143.23   | 11.89    | 47.09    | 19.39    | 57.14    | 78.34    | 31.37    | 30.14    | 23.02    |
| DOORNHOF | 28     | 182.76   | 13.37    | 49.89    | 20.42    | 31.82    | 57.74    | 41.88    | 27.82    | 22.35    |
| KLOOF    | 27     | 175.70   | 7.88     | 36.07    | 14.01    | 39.18    | 39.79    | 57.78    | 23.49    | 19.59    |

| Panel length vs Cost/Ton Milled.<br>Regression Output:   |          |  | Panel length vs Square Met./Stope Emp.<br>Regression Output: |          |  | Panel length vs Tons/Stope Emp.<br>Regression Output:       |          |  |
|----------------------------------------------------------|----------|--|--------------------------------------------------------------|----------|--|-------------------------------------------------------------|----------|--|
| Constant                                                 | 282.0878 |  | Constant                                                     | 5.702810 |  | Constant                                                    | 19.50044 |  |
| Std Err of Y Est                                         | 16.41535 |  | Std Err of Y Est                                             | 2.345393 |  | Std Err of Y Est                                            | 7.995202 |  |
| R Squared                                                | 0.578178 |  | R Squared                                                    | 0.125841 |  | R Squared                                                   | 0.241231 |  |
| No. of Observations                                      | 7        |  | No. of Observations                                          | 7        |  | No. of Observations                                         | 7        |  |
| Degrees of Freedom                                       | 5        |  | Degrees of Freedom                                           | 5        |  | Degrees of Freedom                                          | 5        |  |
| X Coefficient(s)                                         | -3.57183 |  | X Coefficient(s)                                             | 0.178844 |  | X Coefficient(s)                                            | 0.902278 |  |
| Std Err of Coef.                                         | 1.467918 |  | Std Err of Coef.                                             | 0.212579 |  | Std Err of Coef.                                            | 0.715836 |  |
| Panel length vs Sq.Met./Dev.Major.<br>Regression Output: |          |  | Panel length vs Stope Cost/Ton.<br>Regression Output:        |          |  | Panel length vs Tons/Dev.Emp.<br>Regression Output:         |          |  |
| Constant                                                 | 10.31825 |  | Constant                                                     | 24.87791 |  | Constant                                                    | 1.581115 |  |
| Std Err of Y Est                                         | 9.251852 |  | Std Err of Y Est                                             | 5.200307 |  | Std Err of Y Est                                            | 11.21727 |  |
| R Squared                                                | 0.000909 |  | R Squared                                                    | 0.101134 |  | R Squared                                                   | 0.422784 |  |
| No. of Observations                                      | 7        |  | No. of Observations                                          | 7        |  | No. of Observations                                         | 7        |  |
| Degrees of Freedom                                       | 5        |  | Degrees of Freedom                                           | 5        |  | Degrees of Freedom                                          | 5        |  |
| X Coefficient(s)                                         | 0.032184 |  | X Coefficient(s)                                             | 0.383544 |  | X Coefficient(s)                                            | 1.945892 |  |
| Std Err of Coef.                                         | 0.478098 |  | Std Err of Coef.                                             | 0.471365 |  | Std Err of Coef.                                            | 1.016755 |  |
| Panel length vs Dev.Cost/Ton.<br>Regression Output:      |          |  | Panel length vs Tons/UDg.Employees.<br>Regression Output:    |          |  | Panel length vs Tons/Total Employees.<br>Regression Output: |          |  |
| Constant                                                 | 80.61215 |  | Constant                                                     | 20.02823 |  | Constant                                                    | 17.63127 |  |
| Std Err of Y Est                                         | 7.918944 |  | Std Err of Y Est                                             | 8.801035 |  | Std Err of Y Est                                            | 4.757354 |  |
| R Squared                                                | 0.520469 |  | R Squared                                                    | 0.068218 |  | R Squared                                                   | 0.043080 |  |
| No. of Observations                                      | 7        |  | No. of Observations                                          | 7        |  | No. of Observations                                         | 7        |  |
| Degrees of Freedom                                       | 5        |  | Degrees of Freedom                                           | 5        |  | Degrees of Freedom                                          | 5        |  |
| X Coefficient(s)                                         | -1.07107 |  | X Coefficient(s)                                             | 0.318380 |  | X Coefficient(s)                                            | 0.204812 |  |
| Std Err of Coef.                                         | 0.717336 |  | Std Err of Coef.                                             | 0.528317 |  | Std Err of Coef.                                            | 0.431214 |  |

There appears to be a correlation between Panel length and Cost/Ton Milled, Tons/Dev.Employee and Development Cost/Ton. However, there are only a few items and so the results are questionable.

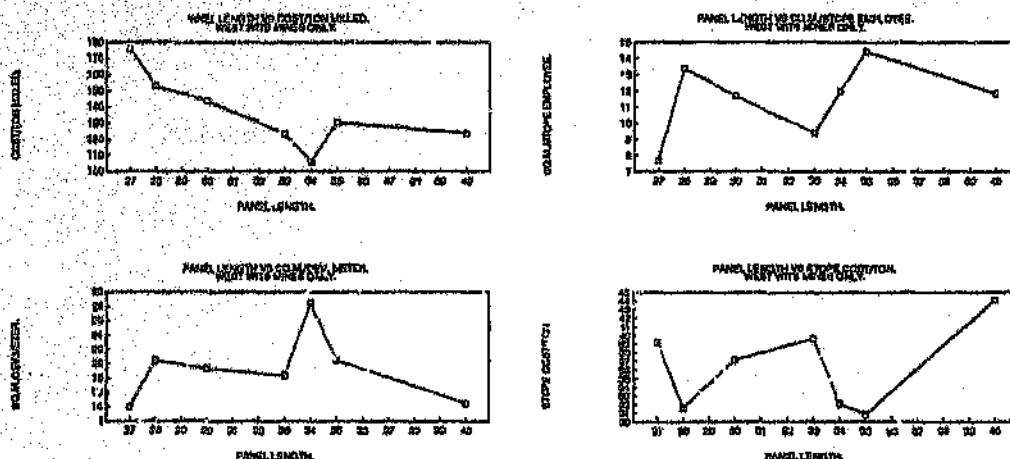


Figure 5.4.2.1

For the other apparent correlations.

The conclusion drawn is that an increase in panel length does not materially affect productivity. On the other hand, Comra has demonstrated that a decrease in panel length will lead to a decrease in overall productivity (revenue), unless labour productivity improves substantially and the hoisting and milling rates can be increased (D.A. Immelman, 1983).

### 5.4.3 THE RATIO OF STOPE TONS/TOTAL TONS.

This ratio (like the previous one - square meters/development meter) is an important parameter as far as labour productivity and costs is concerned. Labour productivity is likely to increase as this ratio increases and costs are likely to come down (development is usually more costly than stoping). It is also an indicator of the efficiency of the mining method and layouts used. The higher the ratio the better the overall productivity, (most of the effort is concentrated in the revenue producing areas).

Figure 5.4.3.2. shows that the ratio appears to vary directly with square met./stope emp., stope, underground and total tons per employee and inversely with the stope cost per ton, for the select group. There is no apparent correlation with cost per ton milled (a logical explanation is difficult). Probably the sample is too small and/or there is in fact no relationship, or other factors have an over-riding influence.

Figure 5.4.3.1. (general group), does appear to have a correlation between stope tons/total tons and cost/ton milled, albeit slight. The other apparent correlations are the same as the select group.

In conclusion therefore, one can say that the more tunnels which are developed the higher the costs will be and the lower the labour productivity although many mine managers believe the contrary is true.

It may also be true that those mines which concentrate their efforts in increasing the ratio of stope tons/total tons do so out of necessity (to concentrate their resources in the revenue producing areas) and will therefore also get the best production out of their labour at the lowest cost.

# STOPE TONS/TOTAL TONS AND PRODUCTIVITY STATISTICS

| MINE      | STO.TONS           | COST/TON | SQ.MET./ | TONS/    | SQ.MET./ | STO.COST TONS/ | DEV.COST TONS/ | TONS/             |
|-----------|--------------------|----------|----------|----------|----------|----------------|----------------|-------------------|
|           | /TOT.TONS MILL '88 | STO.EMP. | STO.EMP. | DEV.MET. | /TON (R) | DEVEMP.        | /TON (R)       | UDJ.EMP. TOT.EMP. |
| WACOONS   | 0.887              | 75.44    | 22.1     | 68.6     | 23.64    | 22.46          | 42.1           | 69.31             |
| BRACKEN   | 0.970              | 105.99   | 17.78    | 31.15    | 34.01    | 31.12          | 51.19          | 35.87             |
| KINROSS   | 0.815              | 107.02   | 18.48    | 77.89    | 35.44    | 28.09          | 60.85          | 33.89             |
| PRESSMAN  | 0.812              | 100.01   | 13.2     | 53.93    | 19.09    | 34.65          | 48.5           | 36.21             |
| STHELENA  | 0.808              | 146.77   | 9.876    | 34.033   | 20.91    | 36.43          | 30.35          | 50.28             |
| LIBANON   | 0.801              | 130.41   | 14.44    | 82.73    | 20.48    | 30.78          | 35.35          | 39.17             |
| ERTVLSI   | 0.793              | 127.21   | 6.31     | 20.43    | 17.06    | 14.02          | 53             | 50.09             |
| DEERHILL  | 0.779              | 106.02   | 11.98    | 54.24    | 26.43    | 32.05          | 68.05          | 28.25             |
| DOONFIN   | 0.754              | 152.75   | 19.37    | 48.99    | 26.43    | 31.92          | 57.74          | 41.85             |
| WES/DONIS | 0.752              | 143.23   | 11.88    | 47.85    | 18.26    | 37.14          | 79.34          | 31.37             |
| WINKEL    | 0.749              | 121.05   | 15       | 61.3     | 20.54    | 26.2           | 66.2           | 30.06             |
| EASTDRIE  | 0.736              | 129.05   | 8.82     | 44.14    | 15.38    | 38.53          | 72.37          | 30.58             |
| KLOOF     | 0.721              | 176.73   | 7.69     | 56.07    | 14.01    | 35.18          | 39.78          | 57.78             |
| WESTHOLD  | 0.716              | 127.33   | 7.21     | 39.41    | 25.2     | 34.46          | 59.29          | 27.58             |
| WESTCOOP  | 0.695              | 123.71   | 11.95    | 59.17    | 19.46    | 44.09          | 78.14          | 25.58             |

| Stope Tons/Total Tons vs Cost/Ton Milled.   |          |  | Stope Tons/Total Tons vs Square Met./Stope Emp. |          |  | Stope Tons/Total Tons vs Tons/Stope Emp. |          |  |
|---------------------------------------------|----------|--|-------------------------------------------------|----------|--|------------------------------------------|----------|--|
| Regression Output:                          |          |  | Regression Output:                              |          |  | Regression Output:                       |          |  |
| Constant                                    | 273.6923 |  | Constant                                        | -25.6275 |  | Constant                                 | -23.5857 |  |
| Std Err of Y Est                            | 21.50733 |  | Std Err of Y Est                                | 3.581308 |  | Std Err of Y Est                         | 14.00515 |  |
| R Squared                                   | 0.243189 |  | R Squared                                       | 0.414180 |  | R Squared                                | 0.144489 |  |
| No. of Observations                         | 16       |  | No. of Observations                             | 15       |  | No. of Observations                      | 15       |  |
| Degrees of Freedom                          | 14       |  | Degrees of Freedom                              | 13       |  | Degrees of Freedom                       | 13       |  |
| X Coefficient(s)                            | -194.307 |  | X Coefficient(s)                                | 49.23218 |  | X Coefficient(s)                         | 94.91508 |  |
| Std Err of Coef.                            | 81.75739 |  | Std Err of Coef.                                | 16.23956 |  | Std Err of Coef.                         | 63.65061 |  |
| Stope Tons/Total Tons vs Sq.Met./Dev.Meter. |          |  | Stope Tons/Total Tons vs Stope Cost/Ton.        |          |  | Stope Tons/Total Tons vs Tons/Dev.EMP.   |          |  |
| Regression Output:                          |          |  | Regression Output:                              |          |  | Regression Output:                       |          |  |
| Constant                                    | -37.2571 |  | Constant                                        | 94.63318 |  | Constant                                 | 188.1120 |  |
| Std Err of Y Est                            | 4.265735 |  | Std Err of Y Est                                | 5.995020 |  | Std Err of Y Est                         | 13.86102 |  |
| R Squared                                   | 0.478258 |  | R Squared                                       | 0.404582 |  | R Squared                                | 0.341822 |  |
| No. of Observations                         | 15       |  | No. of Observations                             | 18       |  | No. of Observations                      | 15       |  |
| Degrees of Freedom                          | 13       |  | Degrees of Freedom                              | 13       |  | Degrees of Freedom                       | 13       |  |
| X Coefficient(s)                            | 76.57833 |  | X Coefficient(s)                                | -79.6778 |  | X Coefficient(s)                         | -184.189 |  |
| Std Err of Coef.                            | 22.18350 |  | Std Err of Coef.                                | 26.87586 |  | Std Err of Coef.                         | 63.19353 |  |
| Stope Tons/Total Tons vs Dev.Cost/Ton.      |          |  | Stope Tons/Total Tons vs Tons/Udg.Employees.    |          |  | Stope Tons/Total Tons vs Tons/Total Emp. |          |  |
| Regression Output:                          |          |  | Regression Output:                              |          |  | Regression Output:                       |          |  |
| Constant                                    | 24.87029 |  | Constant                                        | -5.35502 |  | Constant                                 | -2.24786 |  |
| Std Err of Y Est                            | 8.643953 |  | Std Err of Y Est                                | 0.918813 |  | Std Err of Y Est                         | 3.326487 |  |
| R Squared                                   | 0.010707 |  | R Squared                                       | 0.243127 |  | R Squared                                | 0.193227 |  |
| No. of Observations                         | 14       |  | No. of Observations                             | 12       |  | No. of Observations                      | 12       |  |
| Degrees of Freedom                          | 12       |  | Degrees of Freedom                              | 10       |  | Degrees of Freedom                       | 10       |  |
| X Coefficient(s)                            | 19.18221 |  | X Coefficient(s)                                | 48.26208 |  | X Coefficient(s)                         | 34.62536 |  |
| Std Err of Coef.                            | 42.12766 |  | Std Err of Coef.                                | 25.48347 |  | Std Err of Coef.                         | 22.37357 |  |

There appears to be a fairly good correlation between Stope Tons/Total Tons and the following:-  
 Sq.Meters/Dev.Meter (expected); Tons/Total Employees; Tons/Dev.Employees; Sq.Met./Stope Emp ;Stope Cost/Ton; Cost/Ton Milled.

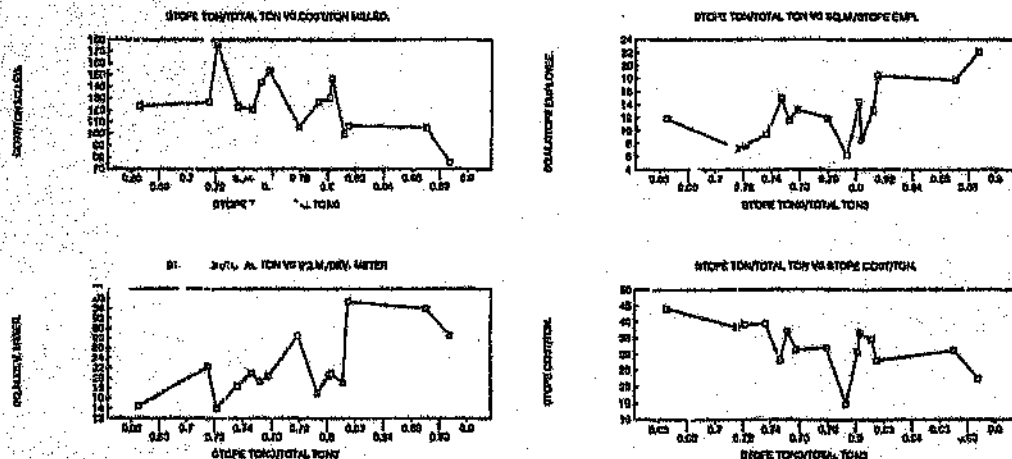


Figure 5.4.3.1

# PANEL LENGTH AND PRODUCTIVITY STATISTICS.

WEST WITS MINES ONLY.

| MINE      | PANEL LENGTH | COST/TON SQ.MET./ MILL'S | TONS/ STO.EMP. | SQ.MET./ DEV.MET. | STO.COST TONS/ /TON (R) | DEV.COST TONS/ DEV.EMP. /TON (R) | TONS/ UDG.EMP. | TOT.EMP. |       |       |
|-----------|--------------|--------------------------|----------------|-------------------|-------------------------|----------------------------------|----------------|----------|-------|-------|
| WESTDEEP  | 40           | 128.71                   | 11.88          | 43.17             | 14.48                   | 44.08                            | 78.14          | 28.58    | 28.13 | 18.97 |
| LEANON    | 36           | 180.41                   | 14.44          | 62.78             | 20.43                   | 50.78                            | 59.30          | 35.36    | 38.17 | 31.81 |
| DEELKRIJL | 34           | 110.02                   | 11.88          | 54.24             | 28.43                   | 32.05                            | 58.05          | 28.25    | 32.55 | 25.07 |
| EASTORIE  | 33           | 123.03                   | 9.42           | 44.14             | 15.36                   | 39.53                            | 12.37          | 30.88    | 34.97 | 27.77 |
| WESTORIE  | 50           | 145.23                   | 11.88          | 47.05             | 18.39                   | 37.14                            | 76.34          | 31.37    | 30.14 | 23.02 |
| DOORNFN   | 28           | 192.78                   | 13.37          | 48.58             | 20.42                   | 31.62                            | 67.74          | 41.88    | 27.82 | 22.35 |
| KLOOF     | 27           | 175.70                   | 7.66           | 36.07             | 14.01                   | 39.18                            | 35.78          | 57.75    | 22.49 | 19.58 |

| Panel length vs Cost/Ton Mined.    |          |  | Panel length vs Square Met./Stope Emp. |          |  | Panel length vs Tons/Stope Emp.      |          |  |
|------------------------------------|----------|--|----------------------------------------|----------|--|--------------------------------------|----------|--|
| Regression Output:                 |          |  | Regression Output:                     |          |  | Regression Output:                   |          |  |
| Constant                           | 202.0578 |  | Constant                               | 5.702810 |  | Constant                             | 19.50044 |  |
| Std Err of Y Est                   | 18.41539 |  | Std Err of Y Est                       | 2.348263 |  | Std Err of Y Est                     | 7.895202 |  |
| R Squared                          | 0.575178 |  | R Squared                              | 0.125941 |  | R Squared                            | 0.241231 |  |
| No. of Observations                | 7        |  | No. of Observations                    | 7        |  | No. of Observations                  | 7        |  |
| Degrees of Freedom                 | 5        |  | Degrees of Freedom                     | 5        |  | Degrees of Freedom                   | 5        |  |
| X Coefficient(s)                   | -3.87153 |  | X Coefficient(s)                       | 0.178544 |  | X Coefficient(s)                     | 0.902276 |  |
| Std Err of Coef.                   | 1.467918 |  | Std Err of Coef.                       | 0.212579 |  | Std Err of Coef.                     | 0.718886 |  |
| Panel length vs Sq.Met./Dev.Miner. |          |  | Panel length vs Stope Obs/Ton.         |          |  | Panel length vs Tons/Dev.Emp.        |          |  |
| Regression Output:                 |          |  | Regression Output:                     |          |  | Regression Output:                   |          |  |
| Constant                           | 10.31823 |  | Constant                               | 24.87791 |  | Constant                             | 1.581115 |  |
| Std Err of Y Est                   | 5.251892 |  | Std Err of Y Est                       | 5.200300 |  | Std Err of Y Est                     | 11.21727 |  |
| R Squared                          | 0.000908 |  | R Squared                              | 0.101134 |  | R Squared                            | 0.422784 |  |
| No. of Observations                | 7        |  | No. of Observations                    | 7        |  | No. of Observations                  | 7        |  |
| Degrees of Freedom                 | 5        |  | Degrees of Freedom                     | 5        |  | Degrees of Freedom                   | 5        |  |
| X Coefficient(s)                   | 0.032184 |  | X Coefficient(s)                       | 0.353544 |  | X Coefficient(s)                     | 1.945992 |  |
| Std Err of Coef.                   | 0.470036 |  | Std Err of Coef.                       | 0.471305 |  | Std Err of Coef.                     | 1.016755 |  |
| Panel length vs Dev.Cost/Ton.      |          |  | Panel length vs Tons/Dev.Employee.     |          |  | Panel length vs Tons/Total Employee. |          |  |
| Regression Output:                 |          |  | Regression Output:                     |          |  | Regression Output:                   |          |  |
| Constant                           | 90.81215 |  | Constant                               | 20.02923 |  | Constant                             | 17.63527 |  |
| Std Err of Y Est                   | 7.818344 |  | Std Err of Y Est                       | 5.801035 |  | Std Err of Y Est                     | 4.757364 |  |
| R Squared                          | 0.520468 |  | R Squared                              | 0.068215 |  | R Squared                            | 0.043080 |  |
| No. of Observations                | 7        |  | No. of Observations                    | 7        |  | No. of Observations                  | 7        |  |
| Degrees of Freedom                 | 5        |  | Degrees of Freedom                     | 5        |  | Degrees of Freedom                   | 5        |  |
| X Coefficient(s)                   | -1.87107 |  | X Coefficient(s)                       | 0.318380 |  | X Coefficient(s)                     | 0.204612 |  |
| Std Err of Coef.                   | 0.717335 |  | Std Err of Coef.                       | 0.525817 |  | Std Err of Coef.                     | 0.431214 |  |

There appears to be a correlation between Panel length and Cost/Ton Mined, Tons/Dev.Employee and Development Cost/Ton. However, there are only a few items and so the results are questionable.

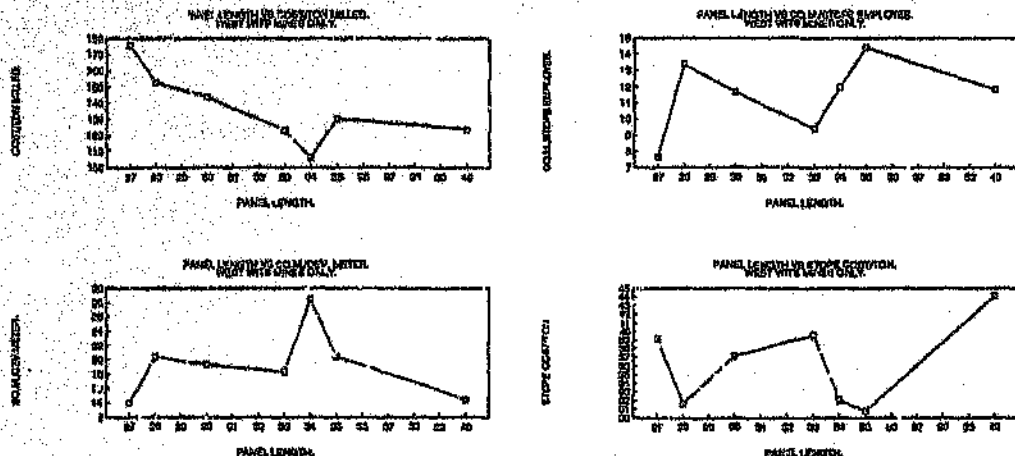


Figure 5.4.2.2

## 5.5 EFFECTIVE SHIFT TIME

Consider the formula:  $\text{Production} = \text{production rate} * \text{effective working time}$ . The available time for production workers is laid down by legislation and negotiation, between employers and employees associations and can be regarded as fixed, for the purpose of this discussion. The available time is made up of effective shift time (working time) and travelling time. The point of this preamble is this; one cannot say that because the production/productivity is better, that one mining layout (mine "A"), is better than another (mine "B"), without considering the effective shift time.

No information was obtained from the mines in this respect. There can be little doubt however, that productivity and costs will improve in direct relationship to the length of the effective shift time. Mines like West Rand Cons., Beatrix and the Evander mines substantiate this.

## 5.6 PRODUCTION RATE AND LABOUR PRODUCTIVITY.

Production rate is the second part of the formula and it is affected by many factors, both physical and human. Let us now consider some of these.

### MANAGEMENT PHILOSOPHY AND POLICY.

The policy may be to maximise productivity of the skilled workers. For example, after a bout of wage negotiations, including productivity bargaining, management will attempt to recoup some of the additional expenditure on wages, by reducing staff.

After a disruptive strike, management may decide to mechanise as many of the operations as possible, thus increasing the output per employee and reducing the potential for future disruption of production.

Even without these particular incentives, management is always striving to improve productivity and reduce costs.

The decision to reduce the number of stopers for example, may bring about a change in the mining method, concentrated mining, double shift stoping, maximum face advance, smaller inter-level spacing and raise spacing.

One mine, not included in this survey, is experimenting with a sixteen man mechanised section, which will be capable of producing 35000 tons of ore per month.

A more likely management philosophy, would be to optimise the operation by putting together the most cost effective mixture of skilled and unskilled labour, material and equipment, not to mention working environment.

Once again no information is available from the mines on this rather nebulous aspect. However low grade mines generally operate at higher levels of labour productivity and lower costs out of necessity and it would seem likely that the Managements on those mines would place a higher emphasis on these aspects.

In recent times, much has been spoken and written about new approaches by Management to improve the levels of productivity on their mines. In many instances however they have been more like "a return to basics" (that is, the principles and practices, which have been developed over the years, to effectively manage and control complex mining operations).

Many of these principles were lost sight of, because of the high gold price (in Rand terms) and high profit margins. Filling the mills with sub-economic ore was acceptable as unit costs came down (benefits of scale of operations) and profits rose marginally.

At present there is a concerted effort to mine only that portion of the orebody which is above the economic pay-limit even if this results in a reduction in the milling rate and an increase in the unit costs.

Management has also made great strides in reducing those items which contribute most to operating costs, namely labour and stores.

## STOPING WIDTH

An increase in the stoping width above 1.5 meters, usually adversely affects the output, in square meters per employee. On the other hand, the tons per employee may continue to rise.

Above 1.8 meters, even the tons per employee may decline. This is caused by difficulties in supporting the roof (a larger, more dense pack and carrying out operations above ones head).

It is difficult to mine efficiently in narrow flat dipping stopes (less than 1 meter). As the width increases so operations become easier even though more support is required.

Figure 5.6.2.2 shows how productivity and costs vary with decreasing stoping widths on the select group of mines.

As expected, there is an inverse relationship between stope width and square meters per stope

employee. On the other hand there may be a direct relationship between the stoping width and tons/underground and total employee. In both cases the logic expressed in the first paragraph of this section would appear to be substantiated.

The same correlation appears to hold for the general group (Figure 5.6.2.1.) as far as square meters per stope employee is concerned. In addition there is a direct relationship between stope width and stope cost per ton. This would also appear to support the logic.

One can conclude therefore that square meters per stope employee will vary inversely with the stope width, which should vary directly with the cost per square meter.

With a higher stope width one may be tempted to increase the amount of development (square meters/ton developed). This indeed, appears to be the case.

### MINING METHOD

Although the mining methods for the various mines were studied, this was done mainly from the viewpoint of the stoping and development layout rather than the effectiveness of the method.

The reasons for this were as follows:-

- \*most of the mines employed face and strike scraper cleaning methods
- \*the mines in the select group were all involved in longwall mining.

On the other hand, mining methods such as TM3 do have a profound effect on labour productivity and costs. Making use of gravity assist for example, or full or semi shrinkage methods, or "throw blasting" (with short up-dip or breast faces), can greatly improve productivity and production rate. Thus the analysis was performed in terms of the layout rather than small differences in method and has been discussed elsewhere in the report.

### ROCK ENGINEERING CONSIDERATIONS.

Events such as pressure bursts, falls of ground, rock scaling and fretting are all due to high stress levels and usually result in additional material having to be handled or re-development having to be done. This obviously affects productivity adversely. The aspect of extra and denser support has already been dealt with.

Other measures such as caving, backfilling and the use of stability pillars will affect productivity either beneficially or adversely.

Once again this topic was not considered as an item for direct comparison but rather in terms of the

# STOPE WIDTH AND PRODUCTIVITY STATISTICS

| MINE       | STOPE WIDTH RANGE |           | COST/TON SQ. MET./ TONS/ |           | SQ. MET./ |           | STO COST TONS/ |           | DEV. COST TONS/ |           | TONS/     |           |
|------------|-------------------|-----------|--------------------------|-----------|-----------|-----------|----------------|-----------|-----------------|-----------|-----------|-----------|
|            |                   |           | MILL. '83                | STO. EMP. | STO. EMP. | DEV. MET. | TOL. (R)       | DEV. EMP. | TOL. (R)        | DEV. EMP. | TOL. EMP. | TOL. EMP. |
| EASTDRIE   | 1.61              | 1.61-1.70 | 123.08                   | 8.42      | 44.14     | 16.36     | 69.83          | 72.37     | 50.68           | 64.37     | 27.77     |           |
| WESTHOLD   | 1.57              | 1.51-1.50 | 127.83                   | 7.21      | 38.41     | 22.2      | 85.45          | 89.28     | 49.28           | 27.86     | 26.88     |           |
| PRESSMAN   | 1.616             | 1.51-1.60 | 100.01                   | 19.2      | 57.83     | 19.08     | 34.65          | 48.8      | 99.21           | 19.18     | 23.51     |           |
| ILDOOF     | 1.61              | 1.51-1.60 | 175.78                   | 7.63      | 55.07     | 14.01     | 39.18          | 63.78     | 57.78           | 28.48     | 19.29     |           |
| LIBANON    | 1.49              | 1.41-1.50 | 150.41                   | 14.44     | 62.73     | 20.48     | 50.78          | 68.23     | 33.58           | 58.17     | 31.81     |           |
| DEBELKAL   | 1.48              | 1.41-1.50 | 103.02                   | 11.99     | 54.84     | 28.48     | 98.05          | 63.86     | 29.25           | 32.53     | 25.67     |           |
| STHELENA   | 1.43              | 1.41-1.50 | 140.77                   | 8.75      | 34.08     | 20.91     | 35.43          | 50.65     | 50.23           |           |           |           |
| VALAREEF   | 1.33              | 1.31-1.40 | 141.87                   | 12.22     | 58.5      | 13.5      | 41.74          |           |                 | 28.88     | 21.87     |           |
| WESTDRIE   | 1.31              | 1.31-1.40 | 143.89                   | 11.59     | 47.09     | 18.33     | 97.14          | 79.34     | 31.37           | 60.14     | 23.02     |           |
| WESTDEEP   | 1.25              | 1.21-1.30 | 123.71                   | 11.85     | 49.17     | 14.43     | 44.08          | 78.14     | 29.68           | 26.13     | 19.57     |           |
| CL. RNP. N | 1.16              | 1.11-1.20 | 129.78                   | 13.57     | 48.89     | 20.42     | 31.32          | 57.74     | 41.68           | 27.82     | 22.95     |           |
| WINKA. K   | 1.18              | 1.11-1.20 | 121.05                   | 15        | 61.3      | 20.94     | 25.2           | 88.2      | 30.08           | 21.4      | 15.8      |           |
| WACONS     | 1.12              | 1.11-1.20 | 75.44                    | 22.1      | 68.8      | 23.84     | 22.48          | 42.1      | 58.81           |           |           |           |
| KUROSS     | 1.11              | 1.11-1.20 | 107.03                   | 19.45     | 77.85     | 35.44     | 28.08          | 60.65     | 33.93           | 30.58     | 25.51     |           |
| BRALDEN    | 1.05              | 1.01-1.10 | 105.29                   | 17.75     | 51.19     | 34.01     | 31.12          | 51.19     | 35.87           |           | 42.87     |           |
| GPTYLEI    | 1.01              | 1.01-1.10 | 127.21                   | 8.31      | 20.48     | 17.09     | 14.83          | 53        | 80.08           | 27.81     | 21.48     |           |

|                                                                |  |          |                                                                   |  |          |                                                           |  |          |
|----------------------------------------------------------------|--|----------|-------------------------------------------------------------------|--|----------|-----------------------------------------------------------|--|----------|
| Slope Width vs Cost/Ton Mill.<br>Regression Output:            |  |          | Slope Width vs Square Meters/Stopa Employee<br>Regression Output: |  |          | Slope Width vs Tons/Stopa Employee.<br>Regression Output: |  |          |
| Constant                                                       |  | 80.88849 | Constant                                                          |  | 26.62339 | Constant                                                  |  | 67.02578 |
| Std Err of Y Est                                               |  | 22.52405 | Std Err of Y Est                                                  |  | 3.508257 | Std Err of Y Est                                          |  | 14.83792 |
| R Squared                                                      |  | 0.007688 | R Squared                                                         |  | 0.240805 | R Squared                                                 |  | 0.831277 |
| No. of Observations                                            |  | 16       | No. of Observations                                               |  | 16       | No. of Observations                                       |  | 16       |
| Degrees of Freedom                                             |  | 16       | Degrees of Freedom                                                |  | 14       | Degrees of Freedom                                        |  | 14       |
| X Coefficient(s)                                               |  | 83.25740 | X Coefficient(s)                                                  |  | -10.5773 | X Coefficient(s)                                          |  | -12.5700 |
| Std Err of Coef.                                               |  | 28.53982 | Std Err of Coef.                                                  |  | 6.027702 | Std Err of Coef.                                          |  | 15.63348 |
| Slope Width vs Square Meters/Dev. Meter.<br>Regression Output: |  |          | Slope Width vs Stopa Cost/Ton.<br>Regression Output:              |  |          | Slope Width vs Tons/Dev. Employee.<br>Regression Output:  |  |          |
| Constant                                                       |  | 38.68781 | Constant                                                          |  | 8.421869 | Constant                                                  |  | 41.47580 |
| Std Err of Y Est                                               |  | 8.248988 | Std Err of Y Est                                                  |  | 6.328484 | Std Err of Y Est                                          |  | 18.92851 |
| R Squared                                                      |  | 0.182223 | R Squared                                                         |  | 0.333580 | R Squared                                                 |  | 0.018273 |
| No. of Observations                                            |  | 17       | No. of Observations                                               |  | 17       | No. of Observations                                       |  | 15       |
| Degrees of Freedom                                             |  | 15       | Degrees of Freedom                                                |  | 15       | Degrees of Freedom                                        |  | 13       |
| X Coefficient(s)                                               |  | -15.1029 | X Coefficient(s)                                                  |  | 22.14253 | X Coefficient(s)                                          |  | 10.71888 |
| Std Err of Coef.                                               |  | 7.280890 | Std Err of Coef.                                                  |  | 8.078117 | Std Err of Coef.                                          |  | 21.77580 |
| Slope Width vs Dev. Cost/Ton.<br>Regression Output:            |  |          | Slope Width vs Tons/ Sq. Employee.<br>Regression Output:          |  |          | Slope Width vs Tons/Total Employee.<br>Regression Output: |  |          |
| Constant                                                       |  | 21.43050 | Constant                                                          |  | 20.48749 | Constant                                                  |  | 25.11548 |
| Std Err of Y Est                                               |  | 8.534508 | Std Err of Y Est                                                  |  | 5.493658 | Std Err of Y Est                                          |  | 6.789148 |
| R Squared                                                      |  | 0.079489 | R Squared                                                         |  | 0.046042 | R Squared                                                 |  | 0.000081 |
| No. of Observations                                            |  | 14       | No. of Observations                                               |  | 13       | No. of Observations                                       |  | 14       |
| Degrees of Freedom                                             |  | 12       | Degrees of Freedom                                                |  | 11       | Degrees of Freedom                                        |  | 12       |
| X Coefficient(s)                                               |  | 11.80498 | X Coefficient(s)                                                  |  | 5.816425 | X Coefficient(s)                                          |  | -0.28311 |
| Std Err of Coef.                                               |  | 11.87851 | Std Err of Coef.                                                  |  | 7.982808 | Std Err of Coef.                                          |  | 9.084041 |

There appears to be some correlation between Slope Width and Square Meters/Stopa Employee, Square meters per development meter and Slope Cost/Ton.

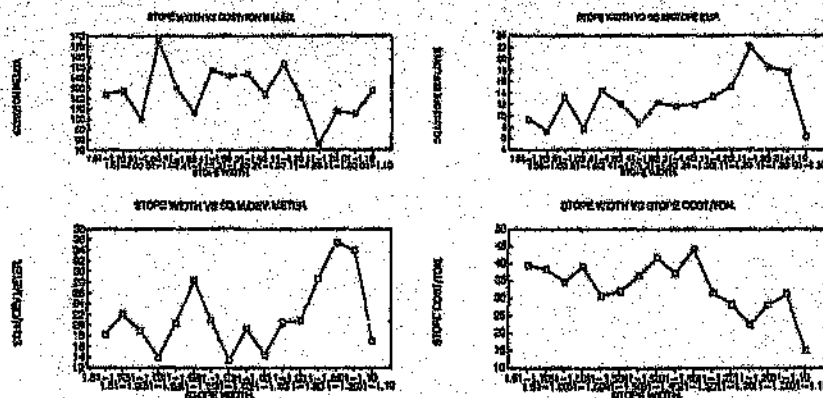


Figure 3.3.2.1

# STOPE WIDTH AND PRODUCTIVITY STATISTICS.

WEST WITS MINES ONLY.

| MINE       | STOPE WIDTH | COST/TON SQ.MET./ MILL '89 | TONS/ STO.EMP. | TONS/ STO.EMP. | SQ.MET./ DEV.MET. | STO.COST TONS/ (TON #) | DEV.COST TONS/ DEV.EMP. | TONS/ (TON #) | UDG.EMP. | TOT.EMP. |
|------------|-------------|----------------------------|----------------|----------------|-------------------|------------------------|-------------------------|---------------|----------|----------|
| EASTDRIE   | 1.61-1.70   | 123.08                     | 9.42           | 44.14          | 18.33             | 59.83                  | 2.87                    | 50.58         | 94.87    | 27.77    |
| KLOOF      | 1.51-1.60   | 173.78                     | 7.69           | 65.07          | 14.01             | 58.18                  | 39.78                   | 57.78         | 28.49    | 19.88    |
| LIBANON    | 1.41-1.50   | 180.41                     | 14.44          | 52.78          | 20.49             | 30.78                  | 59.58                   | 33.05         | 39.17    | 31.81    |
| DEELKRIJL  | 1.41-1.50   | 175.02                     | 11.73          | 54.24          | 23.33             | 62.03                  | 69.65                   | 24.25         | 32.55    | 25.87    |
| WESTDRIE   | 1.31-1.40   | 173.89                     | 11.69          | 47.08          | 19.33             | 97.14                  | 76.94                   | 31.57         | 50.14    | 23.02    |
| WESTDEEM   | 1.21-1.30   | 123.71                     | 11.85          | 48.17          | 14.45             | 44.08                  | 78.14                   | 28.58         | 25.13    | 18.57    |
| DOORAKHILL | 1.11-1.20   | 152.78                     | 13.37          | 48.45          | 20.42             | 31.82                  | 57.74                   | 41.68         | 27.62    | 22.35    |

|                                                       |          |                                                         |          |                                                      |          |
|-------------------------------------------------------|----------|---------------------------------------------------------|----------|------------------------------------------------------|----------|
| Stope width vs Cost/ton milled.<br>Regression Output: |          | Stope width vs Sq.Met./Stope emp.<br>Regression Output: |          | Stope width vs Tons/Stope emp.<br>Regression Output: |          |
| Constant                                              | 126.6067 | Constant                                                | 21.03450 | Constant                                             | 53.73246 |
| Std Err of Y Est                                      | 24.71754 | Std Err of Y Est                                        | 2.185170 | Std Err of Y Est                                     | 9.041245 |
| R Squared                                             | 0.028593 | R Squared                                               | 0.289202 | R Squared                                            | 0.004863 |
| No. of Observations                                   | 7        | No. of Observations                                     | 7        | No. of Observations                                  | 7        |
| Degrees of Freedom                                    | 5        | Degrees of Freedom                                      | 5        | Degrees of Freedom                                   | 5        |
| X Coefficient(s)                                      | -22.9874 | X Coefficient(s)                                        | -8.82939 | X Coefficient(s)                                     | -3.55802 |
| Std Err of Coef.                                      | 61.68763 | Std Err of Coef.                                        | 5.446901 | Std Err of Coef.                                     | 22.53680 |

|                                                         |          |                                                      |          |                                                    |          |
|---------------------------------------------------------|----------|------------------------------------------------------|----------|----------------------------------------------------|----------|
| Stope width vs Sq.met./Dev.meter.<br>Regression Output: |          | Stope width vs Stope cost/ton.<br>Regression Output: |          | Stope width vs Tons/Dev.emp.<br>Regression Output: |          |
| Constant                                                | 16.86413 | Constant                                             | 34.85878 | Constant                                           | 87.98348 |
| Std Err of Y Est                                        | 6.242742 | Std Err of Y Est                                     | 5.481743 | Std Err of Y Est                                   | 14.45770 |
| R Squared                                               | 0.004373 | R Squared                                            | 0.001207 | R Squared                                          | 0.041091 |
| No. of Observations                                     | 7        | No. of Observations                                  | 7        | No. of Observations                                | 7        |
| Degrees of Freedom                                      | 5        | Degrees of Freedom                                   | 5        | Degrees of Freedom                                 | 5        |
| X Coefficient(s)                                        | 1.936712 | X Coefficient(s)                                     | 1.062222 | X Coefficient(s)                                   | -18.6814 |
| Std Err of Coef.                                        | 13.03840 | Std Err of Coef.                                     | 13.68415 | Std Err of Coef.                                   | 38.03824 |

|                                                        |          |                                                       |          |                                                        |          |
|--------------------------------------------------------|----------|-------------------------------------------------------|----------|--------------------------------------------------------|----------|
| Stope width vs Stope cost / ton.<br>Regression Output: |          | Stope width vs Tons / udc. emp.<br>Regression Output: |          | Stope width vs Tons / total emp.<br>Regression Output: |          |
| Constant                                               | 27.78623 | Constant                                              | 0.351629 | Constant                                               | 4.473584 |
| Std Err of Y Est                                       | 11.37421 | Std Err of Y Est                                      | 5.324819 | Std Err of Y Est                                       | 4.145071 |
| R Squared                                              | 0.009458 | R Squared                                             | 0.215003 | R Squared                                              | 0.273189 |
| No. of Observations                                    | 7        | No. of Observations                                   | 7        | No. of Observations                                    | 7        |
| Degrees of Freedom                                     | 5        | Degrees of Freedom                                    | 5        | Degrees of Freedom                                     | 5        |
| X Coefficient(s)                                       | 8.184922 | X Coefficient(s)                                      | 15.53257 | X Coefficient(s)                                       | 14.15820 |
| Std Err of Coef.                                       | 26.35215 | Std Err of Coef.                                      | 13.27299 | Std Err of Coef.                                       | 10.33477 |

There appears to be a correlation between Stope Width and Sq.Meters/StopeEmployees, Tons/Udc.Employee and Tons/Total Employee.

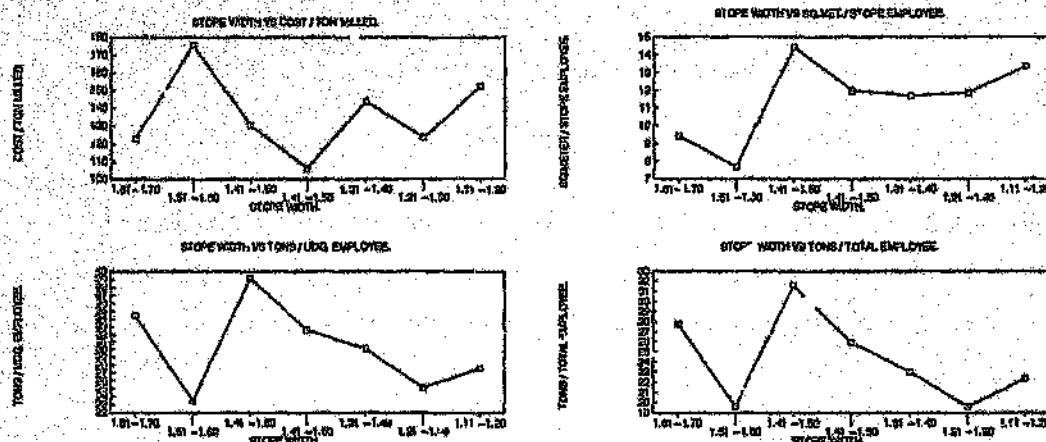


Figure 5.6.2.2

effects on development and stoping layouts and the effect of depth and environmental conditions. There can be little doubt that mines such as Western Deep Levels are adversely affected by rock pressure, seismic events and heat.

#### DEGREE OF MECHANISATION.

The use of mechanical loaders (L.H.D.'s), drill rigs (hydraulic drills and Stomacs), utility vehicles (men and material transport) can markedly improve the output per person.

The synergistic effect of combining different forms of technology has also been investigated (R.P.H. Willis, 1989). He showed that the use of hydro-powered equipment, backfill and trackless mining (TM3) together in a single mining system, could significantly affect working cost, capital cost and revenue.

These factors were not taken into consideration for comparison purposes because the mines are very similar in their application of new systems and methods. Future studies may well take into account the degree to which backfilling, hydro-power and non-explosive rock breaking technologies are applied.

#### GEOLOGICAL FACTORS.

The presence of faults and dykes, which displace the reef or bury it under naturally inept rock material, in the immediate hanging or footwall, can be a major factor to improve productivity.

A mine such as Vaal Reefs, which is plagued by faulting, will have higher output per productivities than other mines which do not have the same adverse conditions, all other things being equal. No cognizance was taken of this factor for the purpose of the comparisons in this survey. Instead, it may have been catered for indirectly in the development layouts, where for example, the square meters/development meter are the lowest of all the mines.

#### UNDERGROUND SORTING OF WASTE ROCK.

The sorting (separating) of the waste rock, preferably as close to the source as possible, has tremendous cost benefits. This is documented in various Comro reports (A.L. Hinde etc, 1985/1986). These include mining, transport, hoisting, crushing, milling, filtration, extraction and tailings disposal costs.

## SERVICES.

The nature of the power and water service supply systems can materially benefit production efforts. The newer technologies, such as hydro-power, provide attractive alternatives to electricity and compressed air. The high pressure water can also be used to assist cleaning (water jetting).

The logistics problems associated with the provision of men, material and equipment into a conventional mine, (against a counter flow of rock) have been dealt with. The provision of better material handling facilities, such as overhead monorope or monorail systems or (in the case of trackless mining) utility vehicles can overcome these problems.

The provision of separate travelling ways for men and material can materially assist efforts to improve productivity. The use of backfill can have a major impact on productivity. These aspects were not analysed because the information was not obtained.

## EDUCATION TRAINING AND MOTIVATION.

By improving the skill and motivation of the supervisors and workers major improvements can be achieved. The payment of adequate and well structured incentive bonuses can be a powerful stimulant to the work-force. One must use the foregoing, to temper the conclusions drawn, when comparing the productivity statistics of the different mines, in terms of the differences in the stoping and development layouts only. These aspects were not analysed because of lack of information.

## EXTERNAL FACTORS WHICH AFFECT PRODUCTIVITY.

These include government intervention and taxation, union activity, head office and industry contributions, socio-political pressures, environmental obligations, which list is not necessarily comprehensive.

Capital expenditure, such as that required to open up a new extension to the mine or increase the rate of production, can also affect the profits of the mine and therefore its productivity.

## DEPTH OF MINING OPERATIONS.

The greater the depth of mining the higher the cost and the lower the labour productivity. This would seem logical due to the more complex infrastructure and the more adverse the working conditions (temperature and pressure). However, environmental conditions can be artificially improved and rock pressure effects can be ameliorated by good rock engineering practices.

Figure 5.6.11.2. shows the relationship between depth and productivity and costs for the select group of mines. There is an apparent correlation (inverse relationship) between depth of workings and tons/underground and total employee. In terms of the foregoing argument, one can accept that this is logical. There is also apparently, an inverse relationship between depth and square meter-/development meter. This is also logical, as inter-level spacing may have to be reduced to accommodate stability pillars (Eg Kloof and Western Deep Levels).

There is also a fairly good correlation between depth and stope cost/ton and cost/ton milled in the case of the general group, which also seems perfectly logical (Figure 5.6.11.1.).

One can conclude therefore that with increasing depth of workings, costs will increase and labour productivities will decline.

#### THE DIP OF THE REEF

Where the dip of the reef exceeds the angle of repose, the broken ore moves under the force of gravity. This should lead to possible savings in labour (Eg winch drivers). On the other hand, certain jobs become more difficult (Eg development of steep raises, support of stopes).

Figure 5.6.12.2. for the select group indicates a direct relationship between the dip of the reef and tons/employee. This would appear to corroborate the logic of the preceding paragraph. There is also an indirect relationship with stope cost/ton, which is also logical. However the size of the sample is small and the results are by no means conclusive.

On the other hand, Libanon is the only mine where the average dip exceeds the angle of repose of broken rock and it has better labour efficiencies and lower costs than similar mines.

Figure 5.6.12.1. for the general group shows no apparent correlation between the dip of the reef and productivity and costs.

Another explanation is that there is only a small percentage of mines in the sample where the dip of

# DEPTH AND PRODUCTIVITY STATISTICS.

| MINE      | MID - FT. |        | CC JT./TON | SQ.FT./ TONS/ |          | SQ.MET./ | STO.COST TONS/ | DEV.COST TONS/ |           | TONS/ |          |
|-----------|-----------|--------|------------|---------------|----------|----------|----------------|----------------|-----------|-------|----------|
|           | DEPTH.    | DEPTH. |            | STO.EMP.      | STO.EMP. |          |                | DEV.NET.       | /TON (R). |       | DEV.EMP. |
| WESTDEEP  | 2617      | 2655   | 125.71     | 11.85         | 48.17    | 14.48    | 44.08          | 75.14          | 28.58     | 28.13 | 19.57    |
| DOORNEN   | 2594      | 2575   | 182.79     | 18.97         | 46.86    | 20.42    | 31.92          | 57.74          | 41.08     | 27.32 | 22.55    |
| KLOOF     | 2335      | 2375   | 175.78     | 7.99          | 36.07    | 14.01    | 35.18          | 55.78          | 57.78     | 25.48 | 18.68    |
| DEELKRIJL | 2068      | 2125   | 108.02     | 11.55         | 35.23    | 20.43    | 32.05          | 55.55          | 25.25     | 22.55 | 25.57    |
| EASTORIE  | 2050      | 2125   | 125.00     | 9.42          | 44.14    | 18.35    | 39.55          | 73.57          | 50.99     | 34.97 | 27.77    |
| ELANDSD   | 2031      | 2125   | 137.55     | 10.26         | 55.74    |          |                |                |           | 25.05 | 21.54    |
| VAALRSEF  | 1855      | 1875   | 141.47     | 12.22         | 50.8     | 15.5     | 41.74          |                |           | 25.55 | 21.57    |
| LIBANON   | 1515      | 1575   | 130.41     | 14.44         | 52.75    | 20.45    | 30.75          | 59.55          | 35.55     | 39.17 | 31.01    |
| PRESBRAN  | 1574      | 1625   | 100.01     | 12.2          | 55.53    | 19.03    | 34.68          | 45.5           | 59.21     | 19.13 | 23.51    |
| KINROSS   | 1535      | 1625   | 107.00     | 10.48         | 77.55    | 35.44    | 25.05          | 60.65          | 35.33     | 30.59 | 25.51    |
| WESTORIE  | 1485      | 1575   | 143.03     | 11.53         | 47.05    | 18.55    | 37.14          | 75.34          | 51.57     | 30.14 | 23.02    |
| STHELENA  | 1385      | 1575   | 146.77     | 0.575         | 54.55    | 25.51    | 55.43          | 50.53          | 50.25     |       |          |
| WESTHOLD  | 1305      | 1375   | 127.33     | 7.21          | 35.41    | 22.2     | 39.45          | 53.25          |           | 27.33 | 25.03    |
| WINKELK   | 1121      | 1125   | 121.05     | 15            | 51.3     | 20.54    | 25.2           | 65.2           | 50.05     | 21.4  | 15.5     |
| BEATRIX   | 787       | 875    | 115.33     |               |          | 15.14    | 24.83          |                |           |       |          |
| GR-TLEI   | 522       | 585    | 127.21     | 5.31          | 20.43    | 17.05    | 14.32          | 55             | 50.05     | 27.51 | 21.55    |
| BRACKEN   | 522       | 525    | 155.59     | 17.75         | 51.15    | 54.01    | 51.12          | 51.15          | 35.57     |       | 42.57    |
| WROGNS    | 404       | 375    | 75.44      | 22.1          | 55.5     | 25.54    | 22.48          | 42.1           | 33.51     |       |          |

|                                    |  |           |                                       |  |          |                              |  |          |
|------------------------------------|--|-----------|---------------------------------------|--|----------|------------------------------|--|----------|
| Depth vs Cost/Ton milled.          |  |           | Depth vs Square meters/Stop Employee. |  |          | Depth vs Tons/Stop Employee. |  |          |
| Regression Output:                 |  |           | Regression Output:                    |  |          | Regression Output:           |  |          |
| Constant                           |  | 50.04150  | Constant                              |  | 19.09932 | Constant                     |  | 49.54455 |
| Std Err of Y Est                   |  | 21.02590  | Std Err of Y Est                      |  | 4.108934 | Std Err of Y Est             |  | 14.58592 |
| R Squared                          |  | 0.512115  | R Squared                             |  | 0.116838 | R Squared                    |  | 0.001857 |
| No. of Observations                |  | 20        | No. of Observations                   |  | 17       | No. of Observations          |  | 17       |
| Degrees of Freedom                 |  | 16        | Degrees of Freedom                    |  | 15       | Degrees of Freedom           |  | 15       |
| X Coefficient(s)                   |  | 0.021507  | X Coefficient(s)                      |  | -0.00226 | X Coefficient(s)             |  | 0.001005 |
| Std Err of Coef.                   |  | 0.007825  | Std Err of Coef.                      |  | 0.001510 | Std Err of Coef.             |  | 0.005587 |
| Depth vs Square meters/Dev. meter. |  |           | Depth vs Stop Cost/Ton.               |  |          | Depth vs Tons/Dev. Employee. |  |          |
| Regression Output:                 |  |           | Regression Output:                    |  |          | Regression Output:           |  |          |
| Constant                           |  | 27.23555  | Constant                              |  | 25.10355 | Constant                     |  | 52.51555 |
| Std Err of Y Est                   |  | 5.275305  | Std Err of Y Est                      |  | 5.415912 | Std Err of Y Est             |  | 15.78544 |
| R Squared                          |  | 0.144504  | R Squared                             |  | 0.511867 | R Squared                    |  | 0.040001 |
| No. of Observations                |  | 17        | No. of Observations                   |  | 17       | No. of Observations          |  | 15       |
| Degrees of Freedom                 |  | 15        | Degrees of Freedom                    |  | 15       | Degrees of Freedom           |  | 13       |
| X Coefficient(s)                   |  | -0.000561 | X Coefficient(s)                      |  | 0.008181 | X Coefficient(s)             |  | 0.004951 |
| Std Err of Coef.                   |  | 0.002392  | Std Err of Coef.                      |  | 0.002054 | Std Err of Coef.             |  | 0.006721 |
| Depth vs Dev. Cost/Ton.            |  |           | Depth vs Tons/Log Employee.           |  |          | Depth vs Tons/Tot. Employee. |  |          |
| Regression Output:                 |  |           | Regression Output:                    |  |          | Regression Output:           |  |          |
| Constant                           |  | 54.48224  | Constant                              |  | 25.51355 | Constant                     |  | 51.15051 |
| Std Err of Y Est                   |  | 5.632103  | Std Err of Y Est                      |  | 5.395579 | Std Err of Y Est             |  | 5.055352 |
| R Squared                          |  | 0.013333  | R Squared                             |  | 0.009154 | R Squared                    |  | 0.137571 |
| No. of Observations                |  | 14        | No. of Observations                   |  | 14       | No. of Observations          |  | 15       |
| Degrees of Freedom                 |  | 12        | Degrees of Freedom                    |  | 12       | Degrees of Freedom           |  | 13       |
| X Coefficient(s)                   |  | 0.001435  | X Coefficient(s)                      |  | 0.000516 | X Coefficient(s)             |  | -0.00335 |
| Std Err of Coef.                   |  | 0.003559  | Std Err of Coef.                      |  | 0.002757 | Std Err of Coef.             |  | 0.002594 |

There appears to be a fairly strong correlation between Depth and Stop Cost/Ton.  
There appears to be a weaker correlation between Depth and Cost/Ton Milled.

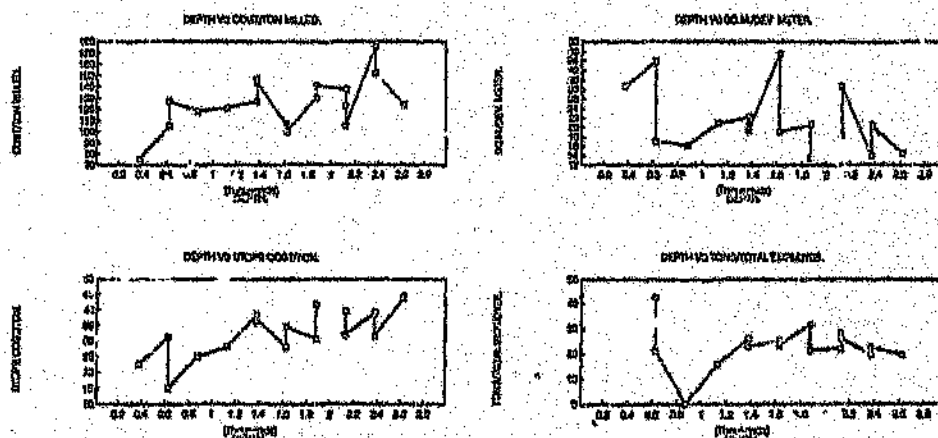


Figure 5.9.11.1

# DEPTH AND PRODUCTIVITY STATISTICS.

WEST WITS MINES ONLY.

MID-PT.

MINE DEPTH. DEPTH COST/T SQ.MET./ TONS/ SQ.MET./ STO.COST/TONS/ DEV.COST TONS/ TONS/  
RANGE MILL '89 STO.EMP. STO.EMP. DEV.MET./ TON (R). DEV.EMP./ TON (R). UDG.EMP. TOT.EMP.

|           |      |      |        |       |       |       |       |       |       |       |       |
|-----------|------|------|--------|-------|-------|-------|-------|-------|-------|-------|-------|
| WESTDEEP  | 2817 | 2525 | 123.71 | 11.85 | 48.17 | 14.48 | 44.09 | 78.14 | 29.58 | 25.19 | 19.57 |
| DOORNFIN  | 2384 | 2375 | 152.70 | 13.37 | 43.89 | 20.42 | 51.62 | 57.74 | 41.66 | 27.62 | 22.66 |
| KLOOF     | 2835 | 2375 | 175.78 | 7.63  | 38.07 | 14.01 | 39.18 | 58.78 | 57.78 | 28.48 | 19.89 |
| DEELKRIJL | 2088 | 2125 | 106.02 | 11.99 | 34.24 | 28.43 | 32.03 | 63.86 | 29.25 | 32.55 | 25.67 |
| EASTDRIE  | 2088 | 2125 | 123.08 | 9.42  | 44.14 | 18.38 | 39.53 | 72.37 | 30.93 | 34.87 | 27.77 |
| ELANDSD   | 2051 | 2125 | 137.65 | 10.23 | 69.74 |       |       |       |       | 26.08 | 21.84 |
| LIBANON   | 1816 | 1875 | 180.51 | 14.44 | 62.78 | 20.48 | 50.79 | 59.39 | 35.35 | 39.17 | 31.61 |
| WESTDRIE  | 1439 | 1375 | 143.83 | 11.69 | 47.08 | 19.35 | 37.14 | 78.34 | 51.67 | 30.14 | 23.02 |

Depth vs Cost/Ton milled.

Regression Output:

|                     |         |
|---------------------|---------|
| Constant            | 123.654 |
| Std. Err. of Y Est  | 22.8763 |
| R Squared           | 0.01028 |
| No. of Observations | 8       |
| Degrees of Freedom  | 6       |

|                    |        |
|--------------------|--------|
| X Coefficient(s)   | 0.0061 |
| Std. Err. of Coef. | 0.0247 |

Depth vs Square meters/Dev.meter.

Regression Output:

|                     |         |
|---------------------|---------|
| Constant            | 28.9474 |
| Std. Err. of Y Est  | 4.20908 |
| R Squared           | 0.12705 |
| No. of Observations | 7       |
| Degrees of Freedom  | 5       |

|                    |        |
|--------------------|--------|
| X Coefficient(s)   | -0.004 |
| Std. Err. of Coef. | 0.0053 |

Depth vs Dev. Cost/Ton.

Regression Output:

|                     |         |
|---------------------|---------|
| Constant            | 21.5038 |
| Std. Err. of Y Est  | 11.0404 |
| R Squared           | 0.08879 |
| No. of Observations | 7       |
| Degrees of Freedom  | 5       |

|                    |        |
|--------------------|--------|
| X Coefficient(s)   | 0.0071 |
| Std. Err. of Coef. | 0.0119 |

Depth vs Square meters/Stop Employees.

Regression Output:

|                     |         |
|---------------------|---------|
| Constant            | 13.8059 |
| Std. Err. of Y Est  | 2.29280 |
| R Squared           | 0.08592 |
| No. of Observations | 8       |
| Degrees of Freedom  | 6       |

|                    |         |
|--------------------|---------|
| X Coefficient(s)   | -0.0011 |
| Std. Err. of Coef. | 0.00247 |

Depth vs Stop Cost/Ton.

Regression Output:

|                     |         |
|---------------------|---------|
| Constant            | 25.5033 |
| Std. Err. of Y Est  | 5.05982 |
| R Squared           | 0.14904 |
| No. of Observations | 7       |
| Degrees of Freedom  | 5       |

|                    |         |
|--------------------|---------|
| X Coefficient(s)   | 0.00512 |
| Std. Err. of Coef. | 0.00547 |

Depth vs Tons/Dev. Employees.

Regression Output:

|                     |         |
|---------------------|---------|
| Constant            | 49.2316 |
| Std. Err. of Y Est  | 4.73765 |
| R Squared           | 0.37858 |
| No. of Observations | 7       |
| Degrees of Freedom  | 5       |

|                    |         |
|--------------------|---------|
| X Coefficient(s)   | -0.0089 |
| Std. Err. of Coef. | 0.00519 |

Depth vs Stop Employees.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 89.02108 |
| Std. Err. of Y Est  | 10.79483 |
| R Squared           | 0.080144 |
| No. of Observations | 8        |
| Degrees of Freedom  | 6        |

|                    |          |
|--------------------|----------|
| X Coefficient(s)   | -0.00848 |
| Std. Err. of Coef. | 0.011685 |

Depth vs Tons/Dev. Employees.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 81.39545 |
| Std. Err. of Y Est  | 14.59889 |
| R Squared           | 0.048976 |
| No. of Observations | 7        |
| Degrees of Freedom  | 5        |

|                    |          |
|--------------------|----------|
| X Coefficient(s)   | -0.00750 |
| Std. Err. of Coef. | 0.015592 |

Depth vs Tons/Tot. Employees.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 88.02040 |
| Std. Err. of Y Est  | 4.053957 |
| R Squared           | 0.505153 |
| No. of Observations | 7        |
| Degrees of Freedom  | 5        |

|                    |          |
|--------------------|----------|
| X Coefficient(s)   | -0.00550 |
| Std. Err. of Coef. | 0.004369 |

There appears to be a weak correlation between Depth and Tons/Dev. Employees and per Total Employees.

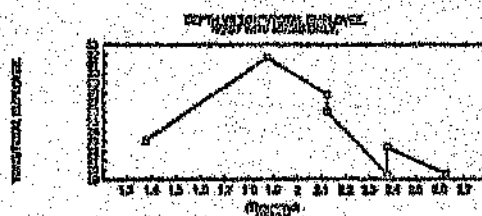
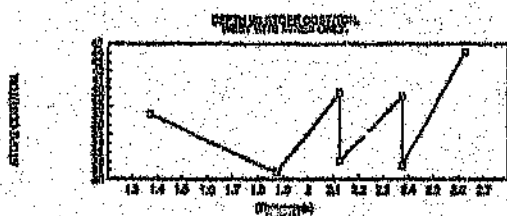
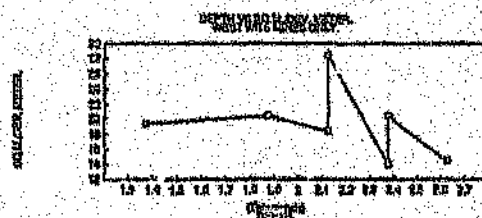
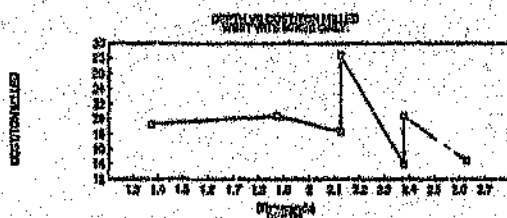


Figure 5.6.11.2

# REEF DIP AND PRODUCTIVITY STATISTICS.

| MINE      | DIP OF REEF. | COST/TON MILL. '99 | SQ. MET./STO. EMP. | TONS/STO. EMP. | SQ. MET./DEV. MET. | STO. COST TONS/TON (R). | DEV. COST TONS/TON (R). | UDG. EMP. | TONS/STO. EMP. |
|-----------|--------------|--------------------|--------------------|----------------|--------------------|-------------------------|-------------------------|-----------|----------------|
| LIBANON   | 33           | 130.41             | 14.44              | 62.73          | 20.46              | 30.79                   | 59.38                   | 35.35     | 59.17          |
| BRACKEN   | 34           | 108.39             | 17.75              | 61.18          | 34.01              | 31.12                   | 51.18                   | 35.37     | 48.67          |
| KLOOF     | 30           | 175.78             | 7.69               | 86.07          | 14.01              | 98.18                   | 39.78                   | 57.78     | 29.46          |
| WINKELK   | 29           | 121.05             | 15                 | 61.3           | 20.84              | 39.2                    | 56.2                    | 30.08     | 21.4           |
| FRESBRAN  | 27           | 100.01             | 13.2               | 55.93          | 19.08              | 34.85                   | 49.9                    | 59.21     | 18.13          |
| DEELKRIJL | 25           | 102.02             | 11.88              | 54.24          | 29.43              | 82.06                   | 88.68                   | 29.25     | 32.55          |
| DOORNIN   | 24           | 152.78             | 13.57              | 48.89          | 20.42              | 31.93                   | 57.74                   | 41.86     | 27.62          |
| EASTONIE  | 22           | 123.03             | 9.42               | 44.14          | 16.50              | 39.53                   | 72.37                   | 30.98     | 94.37          |
| WESTONIE  | 22           | 143.83             | 11.89              | 47.08          | 19.55              | 37.14                   | 78.33                   | 31.37     | 30.14          |
| WESTDEEF  | 21           | 123.71             | 11.85              | 48.17          | 14.48              | 44.09                   | 76.14                   | 28.55     | 35.15          |
| WROONG    | 18           | 78.44              | 22.1               | 58.8           | 28.64              | 22.46                   | 42.1                    | 38.81     |                |
| WESTHOLL  | 15           | 127.33             | 7.21               | 58.41          | 22.2               | 38.45                   | 93.29                   | 27.88     | 28.69          |
| KINROSS   | 15           | 107.05             | 18.49              | 77.55          | 35.44              | 28.09                   | 60.55                   | 33.93     | 30.59          |
| VAALREEF  | 15           | 141.47             | 12.22              | 56.8           | 13.8               | 41.74                   |                         | 28.88     | 31.87          |
| GRIVLEI   | 13           | 127.21             | 8.31               | 20.43          | 17.05              | 14.92                   | 63                      | 92.08     | 27.61          |
| BEATRIX   | 5            | 118.33             |                    |                | 16.14              | 24.59                   |                         |           | 21.48          |

| Dip of Reef vs Cost/Ton Milled.<br>Regression Output:     |          | Dip of Reef vs Square Met./Stope Emp.<br>Regression Output: |          | Dip of Reef vs Tons/Stope Emp.<br>Regression Output:      |          |
|-----------------------------------------------------------|----------|-------------------------------------------------------------|----------|-----------------------------------------------------------|----------|
| Constant                                                  | 113.1806 | Constant                                                    | 11.21370 | Constant                                                  | 47.04936 |
| Std Err of Y Est                                          | 23.81845 | Std Err of Y Est                                            | 4.482073 | Std Err of Y Est                                          | 14.60078 |
| R Squared                                                 | 0.051407 | R Squared                                                   | 0.015493 | R Squared                                                 | 0.011490 |
| No. of Observations                                       | 18       | No. of Observations                                         | 18       | No. of Observations                                       | 18       |
| Degrees of Freedom                                        | 14       | Degrees of Freedom                                          | 13       | Degrees of Freedom                                        | 13       |
| X Coefficient(s)                                          | 0.480328 | X Coefficient(s)                                            | 0.071056 | X Coefficient(s)                                          | 0.187388 |
| Std Err of Coef.                                          | 0.712459 | Std Err of Coef.                                            | 0.157096 | Std Err of Coef.                                          | 0.508232 |
| Dip of Reef vs Sq. Met./Dev. Meter.<br>Regression Output: |          | Dip of Reef vs Stope Cost/Ton.<br>Regression Output:        |          | Dip of Reef vs Tons/Dev. Emp.<br>Regression Output:       |          |
| Constant                                                  | 19.11385 | Constant                                                    | 27.40937 | Constant                                                  | 78.82533 |
| Std Err of Y Est                                          | 9.981099 | Std Err of Y Est                                            | 7.824427 | Std Err of Y Est                                          | 14.45778 |
| R Squared                                                 | 0.017809 | R Squared                                                   | 0.086313 | R Squared                                                 | 0.111813 |
| No. of Observations                                       | 18       | No. of Observations                                         | 18       | No. of Observations                                       | 14       |
| Degrees of Freedom                                        | 14       | Degrees of Freedom                                          | 14       | Degrees of Freedom                                        | 12       |
| X Coefficient(s)                                          | 0.104904 | X Coefficient(s)                                            | 0.226745 | X Coefficient(s)                                          | -0.84985 |
| Std Err of Coef.                                          | 0.208211 | Std Err of Coef.                                            | 0.239347 | Std Err of Coef.                                          | 0.528907 |
| Dip of Reef vs Dev. Cost/Ton.<br>Regression Output:       |          | Dip of Reef vs Tons/UDg. Employee.<br>Regression Output:    |          | Dip of Reef vs Tons/Total Employee.<br>Regression Output: |          |
| Constant                                                  | 25.91302 | Constant                                                    | 28.87102 | Constant                                                  | 18.91846 |
| Std Err of Y Est                                          | 7.979103 | Std Err of Y Est                                            | 5.598543 | Std Err of Y Est                                          | 8.188097 |
| R Squared                                                 | 0.069327 | R Squared                                                   | 0.089269 | R Squared                                                 | 0.182863 |
| No. of Observations                                       | 18       | No. of Observations                                         | 13       | No. of Observations                                       | 14       |
| Degrees of Freedom                                        | 11       | Degrees of Freedom                                          | 11       | Degrees of Freedom                                        | 12       |
| X Coefficient(s)                                          | 0.278311 | X Coefficient(s)                                            | 0.071851 | X Coefficient(s)                                          | 0.344591 |
| Std Err of Coef.                                          | 0.308112 | Std Err of Coef.                                            | 0.223351 | Std Err of Coef.                                          | 0.225916 |

There does not appear to be any correlation between Dip of Reef and Productivity.

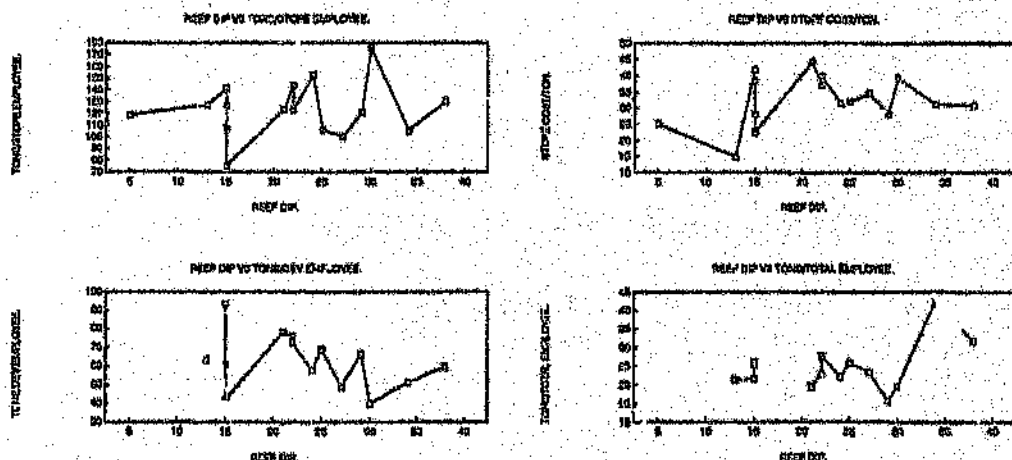


Figure 5.6.12.1

# REEF DIP AND PRODUCTIVITY STATISTICS

WEST WITS MINES ONLY.

| MINE     | DIP OF REEF, | COST/TON SQ.MET./ MILL'39 | TONS/ STO.EMP. | SQ.MET./ DEV.MET. | STO.COST TONS/ TON (R) | DEV.COST TONS/ TON (R) | UDG.EMP. | TOT.EMP. |       |       |
|----------|--------------|---------------------------|----------------|-------------------|------------------------|------------------------|----------|----------|-------|-------|
| LIBANON  | 38           | 136.51                    | 14.44          | 82.73             | 50.48                  | 50.78                  | 58.39    | 35.95    | 38.17 | 31.31 |
| WLOOF    | 30           | 175.73                    | 7.69           | 36.07             | 14.01                  | 59.10                  | 56.78    | 37.78    | 23.49 | 19.50 |
| DEELKRI  | 25           | 106.02                    | 11.88          | 34.24             | 25.43                  | 32.05                  | 68.85    | 29.23    | 32.55 | 25.07 |
| DOORFEN  | 44           | 152.78                    | 13.37          | 40.89             | 20.62                  | 31.82                  | 57.74    | 41.86    | 27.92 | 22.35 |
| EASTBRIE | 22           | 123.03                    | 8.32           | 44.14             | 18.38                  | 69.53                  | 72.37    | 30.36    | 54.37 | 27.77 |
| WESTBRIE | 23           | 143.83                    | 11.88          | 47.08             | 18.38                  | 37.14                  | 78.34    | 31.37    | 30.14 | 23.03 |
| WESTBROF | 25           | 123.21                    | 11.85          | 40.17             | 14.45                  | 44.08                  | 73.14    | 28.58    | 25.13 | 19.57 |

| Dip of Reef vs Cost/Ton Millid.<br>Regression Output:     |          | Dip of Reef vs Square Met./Stope Emp.<br>Regression Output: |          | Dip of Reef vs Tons/Stope Emp.<br>Regression Output:       |          |
|-----------------------------------------------------------|----------|-------------------------------------------------------------|----------|------------------------------------------------------------|----------|
| Constant                                                  | 115.5741 | Constant                                                    | 8.880785 | Constant                                                   | 4.6375   |
| Std Err of Y Est                                          | 24.88129 | Std Err of Y Est                                            | 2.419744 | Std Err of Y Est                                           | 0.041841 |
| R Squared                                                 | 0.041177 | R Squared                                                   | 0.007094 | R Squared                                                  | 0.212784 |
| No. of Observations                                       | 7        | No. of Observations                                         | 7        | No. of Observations                                        | 7        |
| Degrees of Freedom                                        | 5        | Degrees of Freedom                                          | 5        | Degrees of Freedom                                         | 5        |
| X Coefficient(s)                                          | 0.786991 | X Coefficient(s)                                            | 0.087397 | X Coefficient(s)                                           | 0.627432 |
| Std Err of Coef.                                          | 1.858158 | Std Err of Coef.                                            | 0.162332 | Std Err of Coef.                                           | 0.536738 |
| Dip of Reef vs Sq. Met./Dev. Meter.<br>Regression Output: |          | Dip of Reef vs Stope Cost/Ton.<br>Regression Output:        |          | Dip of Reef vs Tons/Dev. Emp.<br>Regression Output:        |          |
| Constant                                                  | 10.30477 | Constant                                                    | 47.61186 | Constant                                                   | 99.85029 |
| Std Err of Y Est                                          | 5.247273 | Std Err of Y Est                                            | 4.693159 | Std Err of Y Est                                           | 11.74208 |
| R Squared                                                 | 0.002389 | R Squared                                                   | 0.377233 | R Squared                                                  | 0.367453 |
| No. of Observations                                       | 7        | No. of Observations                                         | 7        | No. of Observations                                        | 7        |
| Degrees of Freedom                                        | 5        | Degrees of Freedom                                          | 5        | Degrees of Freedom                                         | 5        |
| X Coefficient(s)                                          | 0.046585 | X Coefficient(s)                                            | -0.45342 | X Coefficient(s)                                           | -1.34319 |
| Std Err of Coef.                                          | 0.392174 | Std Err of Coef.                                            | 0.312570 | Std Err of Coef.                                           | 0.785077 |
| Dip of Reef vs Dev. Cost/Ton.<br>Regression Output:       |          | Dip of Reef vs Tons/Dev. Employee.<br>Regression Output:    |          | Dip of Reef vs Tons/Total Employees.<br>Regression Output: |          |
| Constant                                                  | 16.79178 | Constant                                                    | 19.51118 | Constant                                                   | 14.18949 |
| Std Err of Y Est                                          | 10.49738 | Std Err of Y Est                                            | 5.328904 | Std Err of Y Est                                           | 4.121698 |
| R Squared                                                 | 0.156287 | R Squared                                                   | 0.219509 | R Squared                                                  | 0.281719 |
| No. of Observations                                       | 7        | No. of Observations                                         | 7        | No. of Observations                                        | 7        |
| Degrees of Freedom                                        | 5        | Degrees of Freedom                                          | 5        | Degrees of Freedom                                         | 5        |
| X Coefficient(s)                                          | 0.678383 | X Coefficient(s)                                            | 0.416754 | X Coefficient(s)                                           | 0.387387 |
| Std Err of Coef.                                          | 0.704538 | Std Err of Coef.                                            | 0.357719 | Std Err of Coef.                                           | 0.276929 |

There appears to be some correlation between Dip of Reef and Tons/Employee and also Stope Cost/Ton.

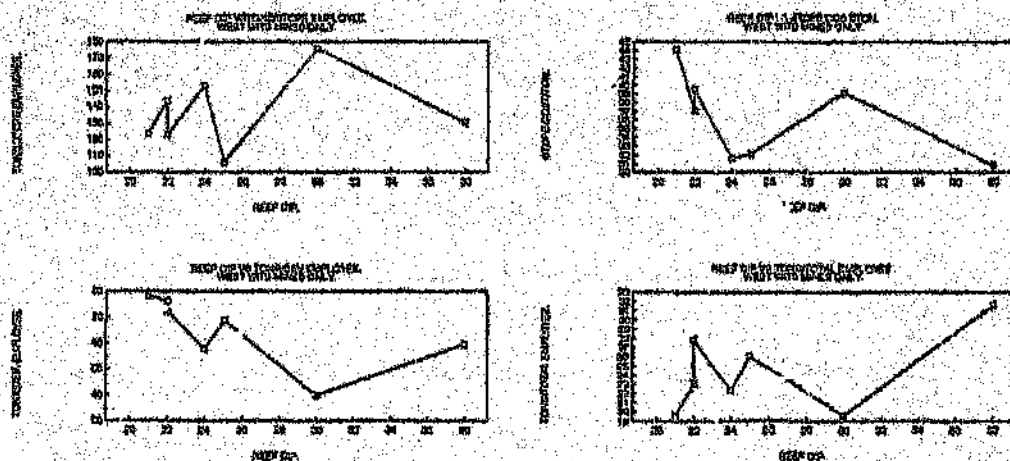


Figure 5.6.12.2

the reef exceeds the angle of repose of broken ore. The conclusion to be reached therefore, is that there is no real evidence to support the theory that steeply dipping reefs are more easily or cheaply mined or vice versa.

### THE GRADE OF THE ORE

A mine which is struggling to survive is unlikely to waste money on non-essential items. It may even go so far as to reduce the amount of development it is currently undertaking, in the hope that it can catch up when the price of its product improves.

The net result is that such a mine employs only sufficient labour to keep the production going at the desired level and purchases only the minimum of equipment, preferring to salvage as much as possible from those workings which are not required immediately. A higher grade mine on the other hand would rather spend money ahead of time if this can lead to future or long term savings. It may also increase the amount of development to improve access to the workings (ie less square meters/development meter).

One would therefore expect lower labour productivity and higher unit costs on high grade mines, all other things being equal.

Figure 5.6.13.2. shows that for the select group, there is in fact a strong inverse correlation between grade of ore and square meters and tons per employee. There is also a fairly good direct relationship between grade and costs (per ton milled, stope cost/ton, dev.cost/ton).

There is also apparently an inverse relationship with square meters/development meter. Figure 5.6.13.1. confirms these relationships for a general group of mines. The general conclusion therefore is that the higher the grade of ore mined the higher the unit costs will be and the lower the level of labour productivity.

### ENVIRONMENTAL CONDITIONS.

The use of ice and chilled water, to cool the environment can vastly improve human performances, in those areas with high virgin rock and wet bulb temperatures. With increasing depth of workings and also a change from one mining district to another, there can be an appreciable increase in the Virgin Rock Temperature. This increase together with varying degrees of humidity, can adversely affect labour productivity. The remedy is to increase the flow of air or to cool it down, both of

# GRADE OF ORL AND PRODUCTIVITY STATISTICS.

| MINE      | GRADE  | COST/TON | SQ.MET./<br>MILL. '89 | TONS/<br>STO.EMP. | STO.COST TONS/<br>DEV.MET. | TON (R) | DEV.COST TONS/<br>DEV.EMP. | TON (R) | UDG.EMP. | TONS/<br>TOT.EMP. |
|-----------|--------|----------|-----------------------|-------------------|----------------------------|---------|----------------------------|---------|----------|-------------------|
| KLOOF     | 12.800 | 175.78   | 7.69                  | 39.07             | 14.01                      | 35.18   | 39.74                      | 57.78   | 23.49    | 18.59             |
| WESTDRIE  | 10.200 | 143.89   | 11.69                 | 47.08             | 19.38                      | 37.14   | 79.34                      | 31.37   | 30.14    | 23.02             |
| EASTORIE  | 9.580  | 123.08   | 9.82                  | 44.14             | 18.38                      | 39.83   | 72.37                      | 30.58   | 34.37    | 27.77             |
| VAALREEF  | 5.920  | 141.47   | 12.22                 | 56.8              | 13.5                       | 41.74   |                            |         | 28.89    | 21.37             |
| ELANDSD   | 8.760  | 137.65   | 10.28                 | 66.74             |                            |         |                            |         | 26.09    | 21.54             |
| WESTDEEP  | 6.310  | 128.71   | 11.85                 | 48.17             | 14.48                      | 44.09   | 78.14                      | 28.51   | 25.13    | 18.57             |
| BEATRIX   | 6.000  | 118.33   |                       |                   | 18.14                      | 21.86   |                            |         |          |                   |
| DEELKRIJL | 5.900  | 109.02   | 11.89                 | 54.24             | 28.43                      | 32.05   | 68.85                      | 28.28   | 32.59    | 25.87             |
| KINROSS   | 5.700  | 107.09   | 18.48                 | 77.85             | 35.44                      | 29.03   | 60.65                      | 43.93   | 30.50    | 23.31             |
| WINKEL'K  | 5.800  | 121.05   | 18                    | 61.3              | 20.94                      | 28.2    | 68.2                       | 30.03   | 21.4     | 15.8              |
| STHELENA  | 5.310  | 148.77   | 9.975                 | 34.033            | 20.81                      | 30.48   | 30.30                      | 50.23   |          |                   |
| DOORN'N   | 5.040  | 182.78   | 13.37                 | 49.89             | 20.42                      | 31.62   | 57.74                      | 41.59   | 27.82    | 22.36             |
| WEST'OLD  | 4.870  | 127.33   | 7.21                  | 38.41             | 22.2                       | 38.48   | 63.29                      |         | 27.85    | 29.09             |
| LISANON   | 4.600  | 160.41   | 14.44                 | 62.73             | 20.45                      | 30.78   | 55.38                      | 35.35   | 39.17    | 31.81             |
| LESLIE    | 4.010  | 110.71   |                       |                   |                            |         |                            |         |          |                   |
| PRESBRAN  | 3.960  | 100.01   | 13.2                  | 55.88             | 18.08                      | 34.65   | 48.9                       | 39.21   | 19.19    | 23.51             |
| GR'TVLEI  | 3.950  | 127.21   | 9.31                  | 20.43             | 17.08                      | 14.92   | 63                         | 30.08   | 27.61    | 21.48             |
| BRACKEN   | 3.480  | 105.39   | 17.76                 | 51.19             | 34.01                      | 31.12   | 51.19                      | 35.97   |          | 42.87             |
| WROONS    | 2.600  | 75.44    | 22.1                  | 68.8              | 28.64                      | 22.48   | 42.1                       | 39.81   |          |                   |
| STILFONT  | 2.370  | 73.59    |                       |                   |                            |         |                            |         |          |                   |

Grade vs Cost/Ton Milled.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 80.89381 |
| Std Err of Y Est    | 17.16107 |
| R Squared           | 0.541928 |
| No. of Observations | 20       |
| Degrees of Freedom  | 18       |

X Coefficient(s)

Std Err of Coef.

7.271295

1.578696

Grade vs Square Met./Stope Emp.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 16.80438 |
| Std Err of Y Est    | 5.915854 |
| R Squared           | 0.197707 |
| No. of Observations | 17       |
| Degrees of Freedom  | 15       |

X Coefficient(s)

Std Err of Coef.

-0.74140

0.385828

Grade vs Tons/Stope Emp.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 58.62700 |
| Std Err of Y Est    | 14.89171 |
| R Squared           | 0.049902 |
| No. of Observations | 17       |
| Degrees of Freedom  | 15       |

X Coefficient(s)

Std Err of Coef.

-1.17817

1.443880

Grade vs Sq.Met./Dev.Meter.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 28.63570 |
| Std Err of Y Est    | 8.097933 |
| R Squared           | 0.218334 |
| No. of Observations | 16       |
| Degrees of Freedom  | 14       |

X Coefficient(s)

Std Err of Coef.

-1.17365

0.602339

Grade vs Stope Cost/Ton.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 23.99125 |
| Std Err of Y Est    | 6.514128 |
| R Squared           | 0.290563 |
| No. of Observations | 16       |
| Degrees of Freedom  | 14       |

X Coefficient(s)

Std Err of Coef.

1.540791

0.643447

Grade vs Tons/Dev.EMP.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 58.28631 |
| Std Err of Y Est    | 17.08143 |
| R Squared           | 0.003989 |
| No. of Observations | 16       |
| Degrees of Freedom  | 15       |

X Coefficient(s)

Std Err of Coef.

0.384736

1.891024

Grade vs Dev.Cost/Ton.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 80.84208 |
| Std Err of Y Est    | 8.442144 |
| R Squared           | 0.089538 |
| No. of Observations | 14       |
| Degrees of Freedom  | 12       |

X Coefficient(s)

Std Err of Coef.

0.867770

0.844893

Grade vs Tons/Udg.EMP.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 23.53583 |
| Std Err of Y Est    | 5.418296 |
| R Squared           | 0.000861 |
| No. of Observations | 14       |
| Degrees of Freedom  | 12       |

X Coefficient(s)

Std Err of Coef.

-0.08058

0.599224

Grade vs Tons/Total Emp.

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | 30.32386 |
| Std Err of Y Est    | 6.055634 |
| R Squared           | 0.136838 |
| No. of Observations | 16       |
| Degrees of Freedom  | 13       |

X Coefficient(s)

Std Err of Coef.

-0.92177

0.698050

There appears to be a fairly good correlation between Grade and Cost/Ton Milled.

There may be a weak correlation between Grade and Sq.Meters/Stope Employees and /Meter Dev.and Stope Cost/Ton

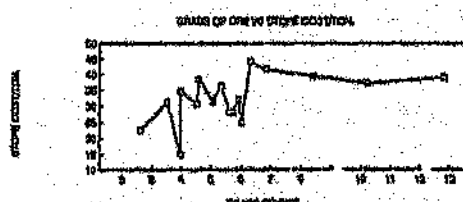
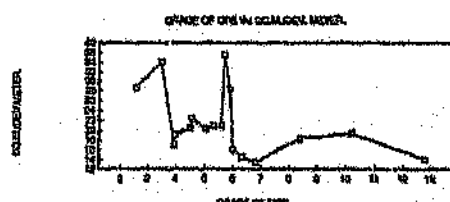
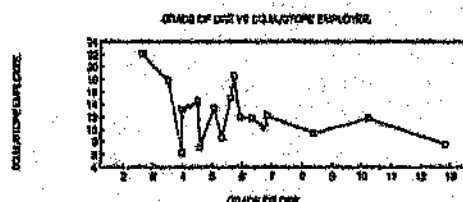
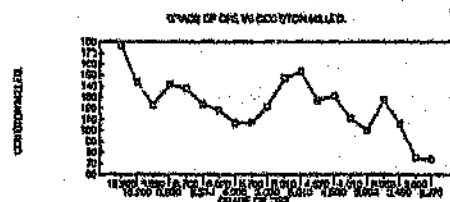


Figure 5.9.13.1

# REEF DIP AND PRODUCTIVITY STATISTICS

| MINE      | DIP OF REEF | COST/TON MILL '89 | SQ.MET./STO.EMP. | TONS/STO.EMP. | SQ.MET./DEV.MET. | STO.COST TONS/ (TON (R). | DEV.COST TONS/ (TON (R). | UDG.EMP. | TOT.EMP. |
|-----------|-------------|-------------------|------------------|---------------|------------------|--------------------------|--------------------------|----------|----------|
| LIBANON   | 38          | 130.41            | 14.44            | 62.78         | 20.46            | 30.78                    | 58.38                    | 35.35    | 31.17    |
| BRACKEN   | 34          | 105.39            | 17.76            | 61.19         | 34.01            | 31.12                    | 51.13                    | 35.87    | 42.67    |
| KLOOF     | 30          | 175.78            | 7.89             | 33.07         | 14.01            | 38.18                    | 38.78                    | 57.79    | 23.46    |
| WINKEL 'K | 29          | 121.05            | 15               | 61.5          | 20.84            | 29.2                     | 60.2                     | 60.08    | 21.4     |
| RESBRAN   | 27          | 100.01            | 13.2             | 63.63         | 18.08            | 34.65                    | 48.0                     | 39.21    | 15.13    |
| DEELIGT   | 25          | 106.02            | 11.88            | 54.24         | 23.43            | 32.05                    | 66.65                    | 26.25    | 32.55    |
| DOORNH'N  | 24          | 152.78            | 18.57            | 48.65         | 30.42            | 31.62                    | 37.74                    | 41.66    | 27.62    |
| EASTONIE  | 22          | 123.03            | 8.42             | 44.14         | 16.30            | 39.53                    | 72.37                    | 30.98    | 54.37    |
| WESTDRIE  | 22          | 143.85            | 11.89            | 47.08         | 19.88            | 37.14                    | 78.34                    | 31.37    | 30.14    |
| WESTDEEF  | 21          | 125.71            | 11.85            | 49.17         | 14.48            | 44.09                    | 78.14                    | 23.55    | 35.12    |
| WRCONS    | 15          | 75.44             | 22.1             | 68.8          | 28.84            | 22.48                    | 42.1                     | 36.81    |          |
| WESTHOL   | 15          | 127.93            | 7.21             | 38.41         | 22.2             | 53.45                    | 55.28                    | 27.86    | 25.09    |
| JOHROSS   | 18          | 107.05            | 18.48            | 77.85         | 35.44            | 28.00                    | 60.65                    | 33.83    | 30.35    |
| VAALREEF  | 15          | 141.47            | 12.22            | 56.8          | 13.6             | 41.74                    |                          | 28.88    | 31.57    |
| GR'TVLEI  | 19          | 127.21            | 8.31             | 20.43         | 17.03            | 14.92                    | 63                       | 35.08    | 27.61    |
| BEATRIX   | 6           | 118.33            |                  |               | 16.14            | 24.85                    |                          |          | 21.46    |

| Dip of Reef vs Cost/Ton Milled.<br>Regression Output:   |          | Dip of Reef vs Square Met./Stope Emp.<br>Regression Output: |          | Dip of Reef vs Tons/Stope Emp.<br>Regression Output:       |          |
|---------------------------------------------------------|----------|-------------------------------------------------------------|----------|------------------------------------------------------------|----------|
| Constant                                                | 113.1806 | Constant                                                    | 11.21370 | Constant                                                   | 47.04936 |
| Std Err of Y Est                                        | 23.81045 | Std Err of Y Est                                            | 4.482073 | Std Err of Y Est                                           | 14.60076 |
| R Squared                                               | 0.031407 | R Squared                                                   | 0.015493 | R Squared                                                  | 0.011499 |
| No. of Observations                                     | 18       | No. of Observations                                         | 18       | No. of Observations                                        | 18       |
| Degrees of Freedom                                      | 14       | Degrees of Freedom                                          | 13       | Degrees of Freedom                                         | 13       |
| X Coefficient(s)                                        | 0.480028 | X Coefficient(s)                                            | 0.071056 | X Coefficient(s)                                           | 0.187365 |
| Std Err of Coef.                                        | 0.712458 | Std Err of Coef.                                            | 0.157096 | Std Err of Coef.                                           | 0.306232 |
| Dip of Reef vs Sq.Met./Dev.Mater.<br>Regression Output: |          | Dip of Reef vs Stope Cost/Ton.<br>Regression Output:        |          | Dip of Reef vs Tons/Dev.EMP.<br>Regression Output:         |          |
| Constant                                                | 19.11395 | Constant                                                    | 27.40967 | Constant                                                   | 76.02253 |
| Std Err of Y Est                                        | 9.981088 | Std Err of Y Est                                            | 7.82427  | Std Err of Y Est                                           | 14.43778 |
| R Squared                                               | 0.017809 | R Squared                                                   | 0.066813 | R Squared                                                  | 0.111813 |
| No. of Observations                                     | 16       | No. of Observations                                         | 16       | No. of Observations                                        | 14       |
| Degrees of Freedom                                      | 14       | Degrees of Freedom                                          | 14       | Degrees of Freedom                                         | 12       |
| X Coefficient(s)                                        | 0.104904 | X Coefficient(s)                                            | 0.229745 | X Coefficient(s)                                           | -0.64985 |
| Std Err of Coef.                                        | 0.208211 | Std Err of Coef.                                            | 0.220647 | Std Err of Coef.                                           | 0.528907 |
| Dip of Reef vs Dev.Cost/Ton.<br>Regression Output:      |          | Dip of Reef vs Tons/Udg.EMPLOYEES.<br>Regression Output:    |          | Dip of Reef vs Tons/Total EMPLOYEES.<br>Regression Output: |          |
| Constant                                                | 28.91302 | Constant                                                    | 25.67162 | Constant                                                   | 10.01995 |
| Std Err of Y Est                                        | 7.975103 | Std Err of Y Est                                            | 5.568543 | Std Err of Y Est                                           | 8.168067 |
| R Squared                                               | 0.089327 | R Squared                                                   | 0.009259 | R Squared                                                  | 0.182363 |
| No. of Observations                                     | 13       | No. of Observations                                         | 13       | No. of Observations                                        | 14       |
| Degrees of Freedom                                      | 11       | Degrees of Freedom                                          | 11       | Degrees of Freedom                                         | 12       |
| X Coefficient(s)                                        | 0.278311 | X Coefficient(s)                                            | 0.071851 | X Coefficient(s)                                           | 0.344551 |
| Std Err of Coef.                                        | 0.308112 | Std Err of Coef.                                            | 0.223351 | Std Err of Coef.                                           | 0.226316 |

There does not appear to be any correlation between Dip of Reef and Productivity.

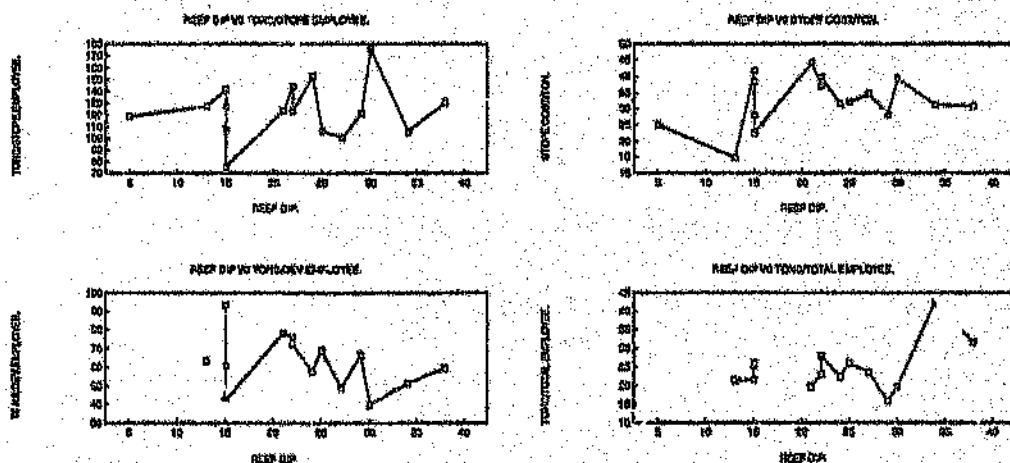


Figure 5.8.12.1

which are expensive. One would expect therefore, to see a decrease in productivity and an increase in costs with increasing virgin rock temperatures, wet bulb and a decrease in wet kata readings. The effect of an increase in face velocities is likely to be less evident.

#### Virgin rock temperature.

Figure 5.6.14.1.2. (for the select group) shows that there is an apparent correlation between the VRT and the tons per employee. As expected, the relationship is an inverse one. There is also apparently, an inverse relationship between VRT and square meters/development meter. Hotter mines require more complex development layouts, to re-condition the air.

Figure 5.6.14.1.1 (the general group) shows a fairly good correlation between the VRT and the costs. As expected, the relationship is a direct one.

The general conclusion therefore, is that labour productivity will go down and costs will go up with an increase in VRT.

The same conclusions were drawn regarding "Depth of workings" (section 5.6.11.). It would seem logical however that the main or basic causes for lower productivities and higher costs is not depth per se, but the effects of increased depth, namely increased heat, pressure and travelling times. The same conclusions were drawn earlier regarding "Age of mine" (section 5.1).

#### Wet bulb temperatures.

Figure 5.6.14.2.2. (select group) indicates that there is a fairly good direct relationship between wet bulb and the stope cost/ton. There is an inverse relationship between the temperatures and the labour productivity in the stopes.

The conclusion reached therefore is that with an increase in the wet bulb temperature, one would expect a decrease in productivity and an increase in costs.

Figure 5.6.14.2.1. (general group) seems to support this view.

#### Wet Kata readings.

One would expect a direct relationship between Wet Kata readings and labour productivities and an inverse one with costs.

# VIRGIN ROCK TEMPERATURE AND PRODUCTIVITY STATISTICS.

| MINE      | VIRGIN<br>ROCK TEM | COST/TON<br>MILL. °99 | SQ. MET./<br>STO. EMP. | TONS/<br>STO. EMP. | SQ. MET./<br>DEV. MET. | STO. COST TONS/<br>TON (R) | DEV. COST TONS/<br>TON (R) | DEV. COST TONS/<br>TON (R) | TONS/<br>DEV. EMP. | TONS/<br>TOT. EMP. |
|-----------|--------------------|-----------------------|------------------------|--------------------|------------------------|----------------------------|----------------------------|----------------------------|--------------------|--------------------|
| DOORWIN   | 48.1               | 152.78                | 13.37                  | 46.88              | 20.42                  | 51.5                       | 57.74                      | 41.66                      | 27.62              | 22.35              |
| WESTDEEF  | 44.6               | 123.71                | 11.85                  | 48.17              | 14.48                  | 44.08                      | 78.14                      | 28.58                      | 25.18              | 14.57              |
| KLOOF     | 44                 | 175.78                | 7.89                   | 38.07              | 14.01                  | 38.18                      | 38.78                      | 57.78                      | 23.48              | 19.59              |
| STHELENA  | 43.1               | 148.77                | 8.75                   | 34.03              | 20.81                  | 33.43                      | 30.83                      | 50.23                      |                    |                    |
| PRESBRAN  | 42.5               | 100.01                | 18.2                   | 55.63              | 18.08                  | 34.65                      | 48.3                       | 33.21                      | 10.18              | 28.51              |
| KINROSS   | 41.6               | 107.08                | 15.48                  | 77.95              | 38.44                  | 26.08                      | 60.05                      | 33.93                      | 30.58              | 25.31              |
| VAALEEF   | 41.6               | 141.47                | 12.22                  | 58.8               | 13.5                   | 41.74                      |                            |                            | 28.88              | 21.87              |
| EASTDRIE  | 39.2               | 123.08                | 8.42                   | 44.14              | 18.38                  | 39.53                      | 72.37                      | 30.88                      | 34.37              | 27.77              |
| WESTDRIE  | 39.1               | 127.03                | 7.21                   | 38.41              | 22.5                   | 36.45                      | 93.28                      |                            | 27.53              | 28.03              |
| ELANDSTON | 38                 | 187.65                | 10.28                  | 65.74              |                        |                            |                            |                            | 28.08              | 21.84              |
| DELMARL   | 37.8               | 108.02                | 11.89                  | 51.24              | 28.43                  | 32.05                      | 65.55                      | 29.25                      | 32.55              | 25.97              |
| LIBANON   | 36.2               | 150.41                | 14.44                  | 82.73              | 20.45                  | 30.78                      | 58.38                      | 35.38                      | 39.17              | 31.81              |
| WESTDRIE  | 35                 | 143.88                | 11.08                  | 47.08              | 18.38                  | 37.14                      | 18.34                      | 31.37                      | 30.14              | 23.02              |
| BEATRICK  | 34.8               | 116.93                |                        |                    | 18.14                  | 24.92                      |                            |                            |                    |                    |
| WINKELK   | 34.2               | 121.05                | 15                     | 61.3               | 20.84                  | 28.2                       | 63.2                       | 30.06                      | 21.4               | 15.8               |
| STILFOOT  | 34.2               | 73.59                 |                        |                    |                        |                            |                            |                            |                    |                    |
| LESLIE    | 30.9               | 110.71                |                        |                    |                        |                            |                            |                            |                    |                    |
| BRACKEN   | 28                 | 105.88                | 17.75                  | 51.18              | 34.01                  | 31.12                      | 51.18                      | 35.97                      |                    | 42.87              |
| GRITVLEI  | 28                 | 127.21                | 6.51                   | 20.48              | 17.08                  | 14.82                      | 63                         | 30.08                      | 27.81              | 21.48              |
| WIRONS    | 18                 | 75.44                 | 22.1                   | 63.8               | 28.04                  | 22.48                      | 42.1                       | 39.81                      |                    |                    |

|                                                        |          |  |                                                           |          |  |                                                   |          |  |
|--------------------------------------------------------|----------|--|-----------------------------------------------------------|----------|--|---------------------------------------------------|----------|--|
| VRT vs Cost/Ton milled.<br>Regression Output:          |          |  | VRT vs Square meters/Stop Employee.<br>Regression Output: |          |  | VRT vs Tons/Stop Employee.<br>Regression Output:  |          |  |
| Constant                                               | 51.94982 |  | Constant                                                  | 20.88394 |  | Constant                                          | 53.56891 |  |
| Std Err of Y Est                                       | 21.07111 |  | Std Err of Y Est                                          | 3.997038 |  | Std Err of Y Est                                  | 14.87768 |  |
| R Squared                                              | 0.308408 |  | R Squared                                                 | 0.184085 |  | R Squared                                         | 0.000788 |  |
| No. of Observations                                    | 20       |  | No. of Observations                                       | 7        |  | No. of Observations                               | 17       |  |
| Degrees of Freedom                                     | 15       |  | Degrees of Freedom                                        | 15       |  | Degrees of Freedom                                | 15       |  |
| X Coefficient(s)                                       | 1.917783 |  | X Coefficient(s)                                          | -0.22585 |  | X Coefficient(s)                                  | -0.05360 |  |
| Std Err of Coef.                                       | 0.575322 |  | Std Err of Coef.                                          | 0.181818 |  | Std Err of Coef.                                  | 0.488184 |  |
| VRT vs Square Meters/Dev. Meter.<br>Regression Output: |          |  | VRT vs Slope Cost/Ton.<br>Regression Output:              |          |  | VRT vs Tons/Dev. Employee.<br>Regression Output:  |          |  |
| Constant                                               | 33.32608 |  | Constant                                                  | 5.913389 |  | Constant                                          | 53.59019 |  |
| Std Err of Y Est                                       | 0.297268 |  | Std Err of Y Est                                          | 5.501628 |  | Std Err of Y Est                                  | 17.00816 |  |
| R Squared                                              | 0.186084 |  | R Squared                                                 | 0.495538 |  | R Squared                                         | 0.008898 |  |
| No. of Observations                                    | 17       |  | No. of Observations                                       | 17       |  | No. of Observations                               | 15       |  |
| Degrees of Freedom                                     | 15       |  | Degrees of Freedom                                        | 15       |  | Degrees of Freedom                                | 13       |  |
| X Coefficient(s)                                       | -0.32218 |  | X Coefficient(s)                                          | 0.694584 |  | X Coefficient(s)                                  | 0.183805 |  |
| Std Err of Coef.                                       | 0.208853 |  | Std Err of Coef.                                          | 0.180805 |  | Std Err of Coef.                                  | 0.587276 |  |
| VRT vs Dev. Cost/Ton.<br>Regression Output:            |          |  | VRT vs Tons/Dev. Employee.<br>Regression Output:          |          |  | VRT vs Tons/Total Employee.<br>Regression Output: |          |  |
| Constant                                               | 28.16838 |  | Constant                                                  | 35.88474 |  | Constant                                          | 41.70828 |  |
| Std Err of Y Est                                       | 6.539139 |  | Std Err of Y Est                                          | 5.306638 |  | Std Err of Y Est                                  | 5.840438 |  |
| R Squared                                              | 0.477704 |  | R Squared                                                 | 0.040522 |  | R Squared                                         | 0.187688 |  |
| No. of Observations                                    | 14       |  | No. of Observations                                       | 14       |  | No. of Observations                               | 15       |  |
| Degrees of Freedom                                     | 12       |  | Degrees of Freedom                                        | 12       |  | Degrees of Freedom                                | 13       |  |
| X Coefficient(s)                                       | 0.461149 |  | X Coefficient(s)                                          | -0.10309 |  | X Coefficient(s)                                  | -0.44932 |  |
| Std Err of Coef.                                       | 0.215590 |  | Std Err of Coef.                                          | 0.271240 |  | Std Err of Coef.                                  | 0.260834 |  |

There may be some correlation between VRT and Cost/Ton Milled and possibly a stronger correlation between VRT and Slope Cost/Ton. With Kinross removed, R Squared for VRT and Sq.m./dev. meter increases to 0.318.

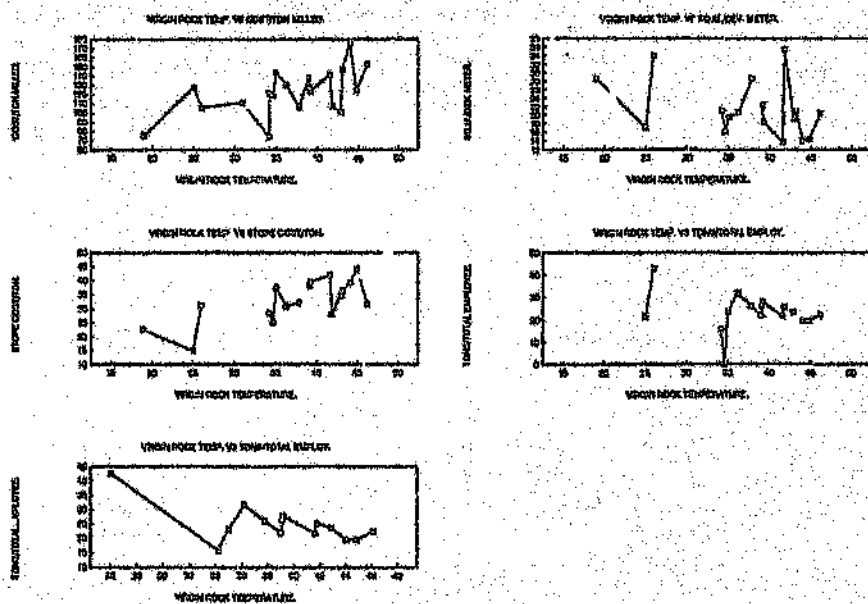


Figure 5.9.14.1.1

# VIRGIN ROCK TEMPERATURE AND PRODUCTIVITY STATISTICS.

WEST WITS MINES, A.L.Y.

| MINE     | VIRGIN<br>ROCK TEM | COST/TON<br>MILL '89 | SQ.MET./<br>STO.EMP. | TONS/<br>STO.EMP. | SQ.MET./<br>DEV.MET. | STO.COST<br>TONS/<br>(R) | DEV.COST<br>TONS/<br>DEV.EMP. | TONS/<br>UDG.EMP. | TONS/<br>TOT.EMP. |
|----------|--------------------|----------------------|----------------------|-------------------|----------------------|--------------------------|-------------------------------|-------------------|-------------------|
| DOORNFN  | 46.1               | 152.78               | 13.37                | 48.89             | 20.42                | 31.62                    | 57.74                         | 41.65             | 27.62             |
| WESTDEEF | 44.8               | 123.71               | 11.35                | 48.17             | 14.48                | 44.09                    | 78.14                         | 28.58             | 25.13             |
| KLOOF    | 44                 | 175.78               | 7.69                 | 36.07             | 14.01                | 59.18                    | 59.76                         | 57.78             | 23.49             |
| EASTDRIE | 39.2               | 123.09               | 9.42                 | 44.14             | 18.33                | 59.53                    | 72.37                         | 30.85             | 34.37             |
| ELANDSD  | 59                 | 137.55               | 10.28                | 68.74             | 28.43                | 52.05                    | 68.88                         | 29.25             | 28.08             |
| DEELIK'L | 37.8               | 106.02               | 11.99                | 54.24             | 20.48                | 30.79                    | 56.88                         | 35.35             | 33.17             |
| LIBANON  | 38.2               | 130.41               | 14.44                | 62.73             | 19.38                | 57.14                    | 78.34                         | 31.87             | 30.14             |
| WESTDRIE | 35                 | 143.83               | 11.69                | 47.08             | 19.38                | 57.14                    | 78.34                         | 31.87             | 30.14             |

| VRT vs Cost/Ton milled.<br>Regression Output: |  |          | VRT vs Square meters/Slope Employee.<br>Regression Output: |  |          | VRT vs Tons/Slope Employee.<br>Regression Output: |  |          |
|-----------------------------------------------|--|----------|------------------------------------------------------------|--|----------|---------------------------------------------------|--|----------|
| Constant                                      |  | 51.20851 | Constant                                                   |  | 15.84795 | Constant                                          |  | 94.64889 |
| Std Err of Y Est                              |  | 20.92037 | Std Err of Y Est                                           |  | 2.291483 | Std Err of Y Est                                  |  | 10.15548 |
| R Squared                                     |  | 0.172236 | R Squared                                                  |  | 0.039865 | R Squared                                         |  | 0.185047 |
| No. of Observations                           |  | 8        | No. of Observations                                        |  | 8        | No. of Observations                               |  | 8        |
| Degrees of Freedom                            |  | 6        | Degrees of Freedom                                         |  | 6        | Degrees of Freedom                                |  | 6        |
| X Coefficient(s)                              |  | 2.120051 | X Coefficient(s)                                           |  | -0.05957 | X Coefficient(s)                                  |  | -1.07771 |
| Std Err of Coef.                              |  | 1.897008 | Std Err of Coef.                                           |  | 0.207788 | Std Err of Coef.                                  |  | 0.920875 |

| VRT vs Square Meters/Dev.Meter.<br>Regression Output: |  |          | VRT vs Slope Cost/Ton.<br>Regression Output: |  |          | VRT vs Tons/Dev. Employee.<br>Regression Output: |  |          |
|-------------------------------------------------------|--|----------|----------------------------------------------|--|----------|--------------------------------------------------|--|----------|
| Constant                                              |  | 40.18588 | Constant                                     |  | 21.57611 | Constant                                         |  | 170.7943 |
| Std Err of Y Est                                      |  | 4.610115 | Std Err of Y Est                             |  | 5.185797 | Std Err of Y Est                                 |  | 13.76391 |
| R Squared                                             |  | 0.200155 | R Squared                                    |  | 0.108140 | R Squared                                        |  | 0.130914 |
| No. of Observations                                   |  | 7        | No. of Observations                          |  | 7        | No. of Observations                              |  | 7        |
| Degrees of Freedom                                    |  | 5        | Degrees of Freedom                           |  | 5        | Degrees of Freedom                               |  | 5        |
| X Coefficient(s)                                      |  | -0.51497 | X Coefficient(s)                             |  | 0.365076 | X Coefficient(s)                                 |  | .09135   |
| Std Err of Coef.                                      |  | 0.421200 | Std Err of Coef.                             |  | 0.479796 | Std Err of Coef.                                 |  | .287531  |

| VRT vs Dev.Cost/Ton.<br>Regression Output: |  |          | VRT vs Tons/Udg.Employee<br>Regression Output: |  |          | VRT vs Tons/Total Employee.<br>Regression Output: |  |          |
|--------------------------------------------|--|----------|------------------------------------------------|--|----------|---------------------------------------------------|--|----------|
| Constant                                   |  | -7.20441 | Constant                                       |  | 64.94294 | Constant                                          |  | 49.82155 |
| Std Err of Y Est                           |  | 10.13552 | Std Err of Y Est                               |  | 4.225921 | Std Err of Y Est                                  |  | 3.494270 |
| R Squared                                  |  | 0.213456 | R Squared                                      |  | 0.434807 | R Squared                                         |  | 0.405409 |
| No. of Observations                        |  | 7        | No. of Observations                            |  | 8        | No. of Observations                               |  | 8        |
| Degrees of Freedom                         |  | 5        | Degrees of Freedom                             |  | 6        | Degrees of Freedom                                |  | 6        |
| X Coefficient(s)                           |  | 1.078703 | X Coefficient(s)                               |  | -0.85747 | X Coefficient(s)                                  |  | -0.64219 |
| Std Err of Coef.                           |  | 0.926025 | Std Err of Coef.                               |  | 0.383196 | Std Err of Coef.                                  |  | 0.316851 |

There is a correlation between VRT and Tons/Total Employee and a stronger correlation between VRT and Tons/Udg.Employee.  
Without Western Deep Levels the correlation between VRT and Cost/ton milled increases to 0.361.  
Without Doornfontein the correlation between VRT and Slope cost increases to 0.547.  
Without West Drie the correlation between VRT and Tons/total employee increases to 0.636.

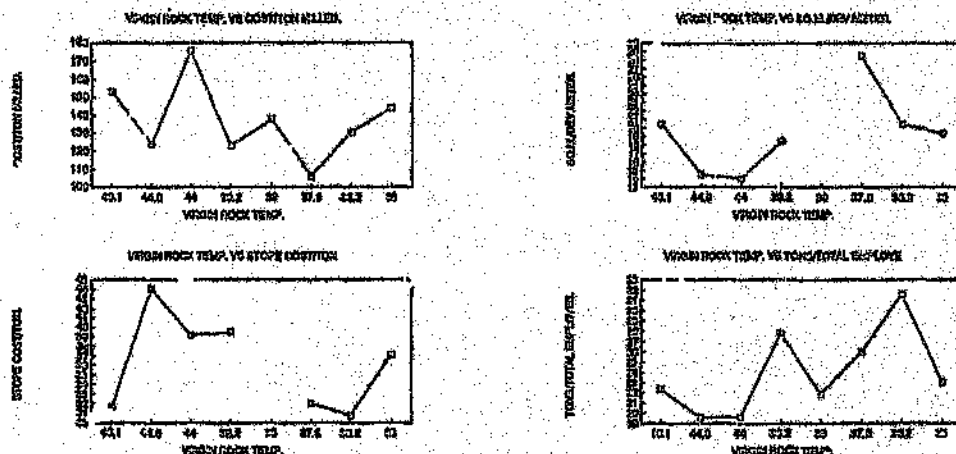


Figure 5.6.14.1.2

# WET BULB TEMPERATURE AND PRODUCTIVITY STATISTICS

| MINE     | WETBULB COST/TON | WETBULB SQ.MET/ | TONS/    | SQ.MET/ | STO.COST TONS/ | DEV.COST TON | TONS/ |
|----------|------------------|-----------------|----------|---------|----------------|--------------|-------|
| MILL '88 | STO.EMP.         | STO.EMP.        | DEV.MET. | TON (A) | DEV.EMP.       | TON (B)      | UDG   |
| DEELKRYL | 31.1             | 103.02          | 11.98    | 54.24   | 28.43          | 32.05        | 68.85 |
| KLOOF    | 31               | 175.78          | 7.68     | 38.07   | 14.01          | 29.18        | 57.78 |
| EASTDRIE | 30.3             | 123.08          | 8.42     | 44.14   | 18.88          | 35.53        | 72.37 |
| DOORNH'N | 30.1             | 152.78          | 15.37    | 45.88   | 20.42          | 31.82        | 57.74 |
| VAALREEF | 29.3             | 141.47          | 12.32    | 58.8    | 13.5           | 41.73        | 53.23 |
| WESTHOLT | 29.2             | 127.33          | 7.21     | 55.41   | 22.2           | 38.45        | 53.23 |
| WINKEL'K | 29               | 121.05          | 15       | 31.3    | 20.84          | 28.2         | 53.2  |
| WESTDEEF | 28.8             | 123.71          | 11.85    | 48.17   | 14.48          | 44.03        | 78.14 |
| LESLIE   | 28.8             | 110.71          | 18.48    | 77.25   | 35.44          | 28.03        | 50.55 |
| KINROSS  | 28.8             | 107.03          | 18.48    | 77.25   | 35.44          | 28.03        | 50.55 |
| STILFONT | 28.8             | 79.55           | 14.44    | 82.73   | 20.48          | 50.78        | 58.38 |
| LIBATION | 28.4             | 150.41          | 14.44    | 82.73   | 20.48          | 50.78        | 58.38 |
| PRESEBAN | 28.3             | 100.31          | 13.2     | 55.83   | 19.03          | 34.55        | 43.8  |
| BEATRIX  | 28.1             | 118.33          | 8.675    | 34.033  | 15.14          | 34.55        | 50.53 |
| STHELENA | 28.1             | 146.77          | 8.675    | 34.033  | 20.51          | 38.43        | 50.53 |
| WESTDRIE | 27.6             | 143.83          | 11.48    | 47.03   | 19.28          | 37.14        | 72.84 |
| ELANDS'D | 25.4             | 157.55          | 10.23    | 58.74   | 17.08          | 14.82        | 53    |
| BYACKEN  | 24.8             | 105.39          | 17.75    | 51.18   | 34.01          | 31.12        | 51.14 |
| GR'TVLEI | 21.8             | 127.21          | 8.31     | 20.47   | 17.08          | 14.82        | 53    |
| WRCONS   | 19.9             | 75.44           | 22.1     | 55.8    | 28.84          | 22.48        | 42.1  |

|                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                            |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Wet Bulb vs Cost/Ton Milled.</b><br><b>Regression Output:</b><br>Constant 32.85108<br>Std Err of Y Est 23.48411<br>R Squared 0.142185<br>No. of Observations 20<br>Degrees of Freedom 18<br>X Coefficient(s) 5.221691<br>Std Err of Coef. 1.865158         | <b>Wet Bulb vs Square Meters/Stopo Employees.</b><br><b>Regression Output:</b><br>Constant 24.65989<br>Std Err of Y Est 4.132582<br>R Squared 0.108442<br>No. of Observations 17<br>Degrees of Freedom 15<br>X Coefficient(s) -0.44188<br>Std Err of Coef. 0.328804 | <b>Wet Bulb vs Tons/Stopo Employees.</b><br><b>Regression Output:</b><br>Constant 54.42125<br>Std Err of Y Est 13.97980<br>R Squared 0.006592<br>No. of Observations 17<br>Degrees of Freedom 15<br>X Coefficient(s) -0.10255<br>Std Err of Coef. 1.188349 |
| <b>Wet Bulb vs Square Meters/Dev.Meter.</b><br><b>Regression Output:</b><br>Constant 38.75834<br>Std Err of Y Est 6.833735<br>R Squared 0.058254<br>No. of Observations 15<br>Degrees of Freedom 13<br>X Coefficient(s) -0.48553<br>Std Err of Coef. 0.536587 | <b>Wet Bulb vs Stopo Costs/Ton.</b><br><b>Regression Output:</b><br>Constant -12.3177<br>Std Err of Y Est 5.351803<br>R Squared 0.508259<br>No. of Observations 15<br>Degrees of Freedom 13<br>X Coefficient(s) 1.514278<br>Std Err of Coef. 0.438504               | <b>Wet Bulb vs Tons/Dev. Employees.</b><br><b>Regression Output:</b><br>Constant 23.10037<br>Std Err of Y Est 15.73980<br>R Squared 0.084688<br>No. of Observations 15<br>Degrees of Freedom 13<br>X Coefficient(s) 1.352980<br>Std Err of Coef. 1.288387  |
| <b>Wet Bulb vs Dev.Cost/Ton.</b><br><b>Regression Output:</b><br>Constant 25.24700<br>Std Err of Y Est 9.470103<br>R Squared 0.018468<br>No. of Observations 15<br>Degrees of Freedom 13<br>X Coefficient(s) 0.438232<br>Std Err of Coef. 0.773803            | <b>Wet Bulb vs Tons/UDg. Employee.</b><br><b>Regression Output:</b><br>Constant 24.65854<br>Std Err of Y Est 5.857388<br>R Squared 0.013056<br>No. of Observations 12<br>Degrees of Freedom 10<br>X Coefficient(s) 0.125182<br>Std Err of Coef. 0.714848            | <b>Wet Bulb vs Tons/Total Employees.</b><br><b>Regression Output:</b><br>Constant 24.63808<br>Std Err of Y Est 6.521523<br>R Squared 0.008002<br>No. of Observations 13<br>Degrees of Freedom 10<br>X Coefficient(s) -0.00265<br>Std Err of Coef. 0.525584 |

There seems to be a fairly strong correlation between Wet Bulb and Stopo Costs/Ton.  
 The correlation between Wet Bulb and Sq.m./dev. meter improves if one ignores Kinross and Leslie.

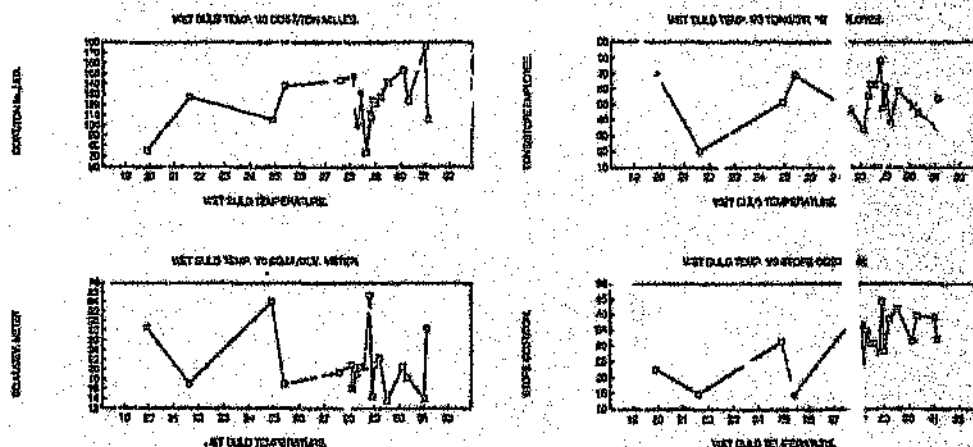


Figure 8.9.14.2.1

# WET BULB TEMPERATURE AND PRODUCTIVITY STATISTICS

WEST WITS MINE, ONLY

| MINE     | WETBULB, COST/TON | SQ. MET./ TONS/ | SQ. MET./ | STO. COST TONS/ | DEV. COST TONS/ | TONS/    |           |         |       |       |
|----------|-------------------|-----------------|-----------|-----------------|-----------------|----------|-----------|---------|-------|-------|
| MILL 39  | STO. EMP.         | STO. EMP.       | DEV. MET. | /TON (R)        | DEV. EMP.       | /TON (R) | UDG. EMP. | Y. EMP. |       |       |
| DEELKRL  | 31.1              | 108.02          | 11.89     | 54.24           | 28.43           | 32.08    | 69.35     | 28.28   | 32.55 | 25.87 |
| KLOOF    | 31                | 173.70          | 7.50      | 36.07           | 14.01           | 39.18    | 56.70     | 57.70   | 23.49 | 19.59 |
| EASTDRIE | 30.3              | 123.02          | 5.42      | 44.11           | 15.39           | 38.58    | 72.57     | 36.88   | 34.37 | 27.77 |
| DOORNFN  | 30.1              | 192.70          | 13.37     | 46.09           | 20.42           | 51.02    | 57.74     | 41.85   | 27.32 | 22.35 |
| WESTDEEP | 29.8              | 128.71          | 11.85     | 48.17           | 14.46           | 44.09    | 75.14     | 28.58   | 25.13 | 19.67 |
| LISANON  | 22.4              | 130.41          | 14.44     | 82.73           | 20.48           | 30.79    | 69.38     | 38.35   | 39.17 | 31.51 |
| WESTDRIE | 27.9              | 133.83          | 11.09     | 47.08           | 19.36           | 37.14    | 78.34     | 31.37   | 30.14 | 23.02 |
| FLANDSD  | 25.3              | 137.69          | 10.26     | 69.74           | 17.09           | 14.92    | 63        | 80.08   | 26.08 | 21.64 |

| Wet Bulb vs Cost/Ton Mined.<br>Regression Output:           |          |  | Wet Bulb vs Square Meters/Slope Employees.<br>Regression Output: |          |  | Wet Bulb vs Tons/Slope Employees.<br>Regression Output: |          |  |
|-------------------------------------------------------------|----------|--|------------------------------------------------------------------|----------|--|---------------------------------------------------------|----------|--|
| Constant                                                    | 150.7113 |  | Constant                                                         | 16.50398 |  | Constant                                                | 180.6922 |  |
| Std Err of Y Est                                            | 22.90094 |  | Std Err of Y Est                                                 | 2.304978 |  | Std Err of Y Est                                        | 0.018293 |  |
| R Squared                                                   | 0.000349 |  | R Squared                                                        | 0.023572 |  | R Squared                                               | 0.892486 |  |
| No. of Observations                                         | 8        |  | No. of Observations                                              | 8        |  | No. of Observations                                     | 8        |  |
| Degrees of Freedom                                          | 6        |  | Degrees of Freedom                                               | 6        |  | Degrees of Freedom                                      | 6        |  |
| X Coefficient(s)                                            | 0.304338 |  | X Coefficient(s)                                                 | -0.17780 |  | X Coefficient(s)                                        | -3.75398 |  |
| Std Err of Coef.                                            | 4.484571 |  | Std Err of Coef.                                                 | 0.447676 |  | Std Err of Coef.                                        | 1.557016 |  |
| Wet Bulb vs Square Meters/Dev. Meter.<br>Regression Output: |          |  | Wet Bulb vs Steps Costs/Ton.<br>Regression Output:               |          |  | Wet Bulb vs Tons/Dev. Employees.<br>Regression Output:  |          |  |
| Constant                                                    | 1.36889  |  | Constant                                                         | -30.0721 |  | Constant                                                | 113.9543 |  |
| Std Err of Y Est                                            | 4.596881 |  | Std Err of Y Est                                                 | 7.443174 |  | Std Err of Y Est                                        | 12.85944 |  |
| R Squared                                                   | 0.071495 |  | R Squared                                                        | 0.597817 |  | R Squared                                               | 0.076058 |  |
| No. of Observations                                         | 8        |  | No. of Observations                                              | 8        |  | No. of Observations                                     | 8        |  |
| Degrees of Freedom                                          | 6        |  | Degrees of Freedom                                               | 6        |  | Degrees of Freedom                                      | 6        |  |
| X Coefficient(s)                                            | 0.118309 |  | X Coefficient(s)                                                 | 2.877584 |  | X Coefficient(s)                                        | -1.76950 |  |
| Std Err of Coef.                                            | 0.912018 |  | Std Err of Coef.                                                 | 1.445344 |  | Std Err of Coef.                                        | 2.618457 |  |
| Wet Bulb vs Dev. Cost/Ton.<br>Regression Output:            |          |  | Wet Bulb vs Tons/Total Employees.<br>Regression Output:          |          |  | Wet Bulb vs Tons/Total Employees.<br>Regression Output: |          |  |
| Constant                                                    | -28.9232 |  | Constant                                                         | 24.84241 |  | Constant                                                | 20.17278 |  |
| Std Err of Y Est                                            | 9.862155 |  | Std Err of Y Est                                                 | 8.712970 |  | Std Err of Y Est                                        | 4.527069 |  |
| R Squared                                                   | 0.190107 |  | R Squared                                                        | 0.003788 |  | R Squared                                               | 0.003948 |  |
| No. of Observations                                         | 8        |  | No. of Observations                                              | 8        |  | No. of Observations                                     | 8        |  |
| Degrees of Freedom                                          | 6        |  | Degrees of Freedom                                               | 6        |  | Degrees of Freedom                                      | 6        |  |
| X Coefficient(s)                                            | 2.197892 |  | X Coefficient(s)                                                 | 0.167571 |  | X Coefficient(s)                                        | 0.180316 |  |
| Std Err of Coef.                                            | 1.876235 |  | Std Err of Coef.                                                 | 1.109358 |  | Std Err of Coef.                                        | 0.878087 |  |

There seems to be a fairly strong correlation between Wet Bulb and Tons/Slope Employees and a somewhat weaker one with Steps Costs/Ton.

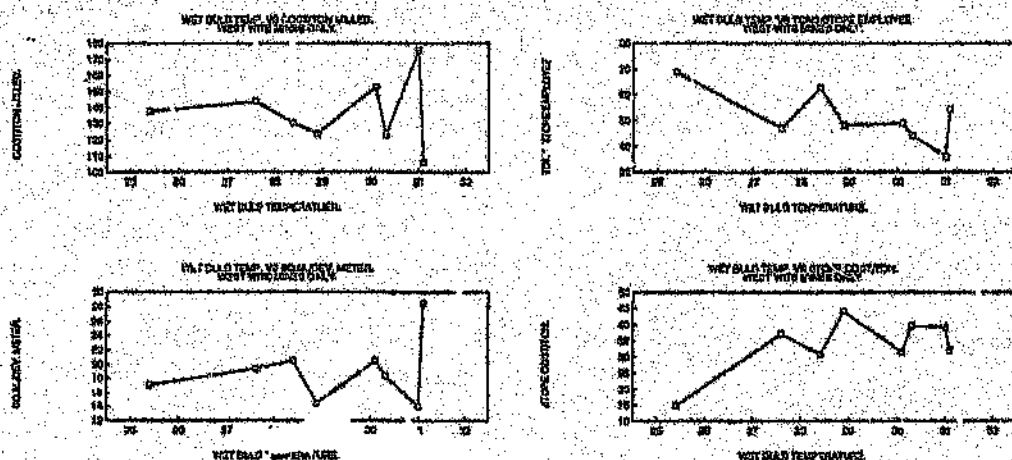


Figure 5.6.14.2.2

Figure 5.6.14.3.2 seems to confirm these relationships for stoping and development, for the select group.

Figure 5.6.14.3.1. (general group) apparently does the same. In this case however, the correlation between Wet Kata and sq.m./stope employee is proved markedly if one excludes Elandsrand and Grootvlei.

Face velocity.

As expected, Figure 5.6.14.4.1/2 show that there is no apparent correlation between face velocity and productivity and costs. This is also the conclusion reached.

#### FACE ADVANCE AND PRODUCTIVITY.

Various research projects (Dos Santos, Jones, Smith) have all indicated that there should be an improvement in costs with an increase in face advance rates. The savings accrue mainly in ventilation and refrigeration costs. Other possible savings can occur through better utilisation of capital type equipment (winches, electrical switchgear etc.) and better supervision. The research concludes however that a major factor is the percentage of "lost blasts". Where this percentage is high then costs will increase and labour productivities decrease.

Figure 5.6.15.2 shows that there is a direct relationship between face advance and stope cost/ton for the select group of mines. This finding is not necessarily in conflict with the research referred to earlier, if we assume that the mines which have the highest rates are also operating at a high "lost blast" rate (Western Deep Levels and Elandsrand). However, there are too few mines to confirm this. There may also be a direct relationship between face advance and tons/development employee. This may also, in fact be true as high face advance rates require that development be pushed, particularly in longwall mining situations. This could lead to higher productivity.

Figure 5.6.15.1. apparently shows an inverse relationship between Face advance and Cost/ton milled. There is also an inverse relationship between Face advance and Square meters/stope employee. Once again, this does not necessarily contradict the research findings. There is a direct relationship between Face advance and Stope cost/ton, which improves considerably if one excludes WDL levels,

# WET KATA READING AND PRODUCTIVITY STATISTICS

| MINE     | WET KATA | COST/TON SO. MET / MILL '69 | TONS/ STO. EMP. | TONS/ STO. EMP. | SO. MET. / DEV. NET. | STO. COST TONS/ /TON (F) | DEV. COST TONS/ /TON (F) | UDG EMP. | TONS/ TOT. EMP. |
|----------|----------|-----------------------------|-----------------|-----------------|----------------------|--------------------------|--------------------------|----------|-----------------|
| WOODS    | 21.2     | 75.44                       | 22.1            | 28.6            | 20.94                | 22.48                    | 42.1                     | 88.91    |                 |
| ELANDSD  | 17.2     | 157.65                      | 10.29           | 60.74           |                      |                          |                          | 28.05    | 21.74           |
| BEATRICK | 16.9     | 118.35                      |                 |                 | 18.14                | 24.08                    |                          |          |                 |
| GATVLEI  | 16.8     | 127.21                      | 8.91            | 20.43           | 17.09                | 14.08                    | 63                       | 30.08    | 27.51           |
| KINROSS  | 15.5     | 107.08                      | 18.48           | 77.55           | 35.44                | 28.03                    | 60.55                    | 39.83    | 60.55           |
| SHACKEN  | 15.1     | 105.89                      | 17.75           | 31.15           | 34.01                | 31.12                    | 51.19                    | 35.97    | 42.67           |
| WESTDRE  | 14.6     | 143.83                      | 11.88           | 47.08           | 19.55                | 37.14                    | 78.84                    | 31.37    | 30.14           |
| DOORFEN  | 13.4     | 153.78                      | 18.37           | 48.65           | 20.42                | 31.62                    | 57.74                    | 41.63    | 27.62           |
| STHELENA | 13.3     | 156.77                      | 2.575           | 34.033          | 20.91                | 33.43                    | 20.33                    | 50.23    |                 |
| PREBBURN | 12.0     | 160.01                      | 16.2            | 33.63           | 19.06                | 34.63                    | 48.9                     | 39.21    | 19.15           |
| STILFOM  | 12.2     | 73.59                       |                 |                 |                      |                          |                          |          | 23.51           |
| WESTDEEP | 12       | 123.71                      | 11.85           | 48.17           | 14.48                | 44.09                    | 73.14                    | 28.58    | 25.18           |
| VAALREEF | 11.9     | 141.47                      | 12.22           | 58.5            | 13.5                 | 41.74                    |                          | 20.88    | 21.67           |
| LIBANON  | 11.7     | 130.41                      | 18.44           | 62.72           | 20.46                | 30.79                    | 59.89                    | 35.35    | 33.17           |
| WESTHOLT | 10.9     | 127.33                      | 7.21            | 38.41           | 7.12                 | 38.45                    | 33.29                    | 27.89    | 26.05           |
| WINKELIN | 10.8     | 121.05                      | 15              | 61.3            | 20.94                | 28.2                     | 68.2                     | 30.03    | 21.4            |
| LESUE    | 9.8      | 110.71                      |                 |                 |                      |                          |                          |          | 15.8            |
| EASTDRE  | 9.9      | 123.09                      | 6.42            | 44.14           | 18.59                | 29.63                    | 72.37                    | 35.93    | 34.37           |
| DEELKRIP | 8        | 105.02                      | 11.29           | 54.24           | 20.43                | 32.03                    | 63.55                    | 29.25    | 25.57           |
| ILCOF    | 7.4      | 175.78                      | 7.63            | 59.07           | 14.01                | 33.15                    | 33.75                    | 57.78    | 23.49           |

|                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Wet Kata vs Cost/Ton Millers</b><br><b>Regression Output:</b><br>Constant 152.3970<br>Std Err of Y Est 24.00220<br>R Squared 0.103915<br>No. of Observations 20<br>Degrees of Freedom 18<br>X Coefficient(s) -2.60503<br>Std Err of Coef. 1.897488         | <b>Wet Kata vs Square meters/Stone Employee</b><br><b>Regression Output:</b><br>Constant 4.856368<br>Std Err of Y Est 3.014783<br>R Squared 0.235595<br>No. of Observations 17<br>Degrees of Freedom 15<br>X Coefficient(s) 0.592549<br>Std Err of Coef. 0.270332 | <b>Wet Kata vs Tons/Stone Employee</b><br><b>Regression Output:</b><br>Constant 85.90043<br>Std Err of Y Est 14.33228<br>R Squared 0.085049<br>No. of Observations 17<br>Degrees of Freedom 15<br>X Coefficient(s) 1.107719<br>Std Err of Coef. 1.014312 |
| <b>Wet Kata vs Square Meters/Day Worker</b><br><b>Regression Output:</b><br>Constant 18.67456<br>Std Err of Y Est 6.437029<br>R Squared 0.103362<br>No. of Observations 17<br>Degrees of Freedom 15<br>X Coefficient(s) 0.592949<br>Std Err of Coef. 0.483573 | <b>Wet Kata vs Stone Cost/Ton</b><br><b>Regression Output:</b><br>Constant 50.65409<br>Std Err of Y Est 5.902160<br>R Squared 0.418973<br>No. of Observations 17<br>Degrees of Freedom 15<br>X Coefficient(s) -1.38474<br>Std Err of Coef. 0.420268               | <b>Wet Kata vs Tons/Dev. Employee</b><br><b>Regression Output:</b><br>Constant 75.37637<br>Std Err of Y Est 18.51729<br>R Squared 0.059860<br>No. of Observations 15<br>Degrees of Freedom 13<br>X Coefficient(s) -1.17931<br>Std Err of Coef. 1.230274  |
| <b>Wet Kata vs Dev. Cost/Ton</b><br><b>Regression Output:</b><br>Constant 49.15115<br>Std Err of Y Est 6.63702<br>R Squared 0.012976<br>No. of Observations 14<br>Degrees of Freedom 12<br>X Coefficient(s) -0.28421<br>Std Err of Coef. 0.665186             | <b>Wet Kata vs Tons/UDG Employee</b><br><b>Regression Output:</b><br>Constant 28.63607<br>Std Err of Y Est 5.402338<br>R Squared 0.005609<br>No. of Observations 14<br>Degrees of Freedom 12<br>X Coefficient(s) -0.13819<br>Std Err of Coef. 0.432819            | <b>Wet Kata vs Tons/Total Employee</b><br><b>Regression Output:</b><br>Constant 21.02518<br>Std Err of Y Est 6.480988<br>R Squared 0.016509<br>No. of Observations 15<br>Degrees of Freedom 13<br>X Coefficient(s) 0.233037<br>Std Err of Coef. 0.571855 |

There appears to be a correlation between Wet Kata and Stone Cost/Ton.  
 There may be a correlation between Wet Kata and Square meters per stone employee.  
 This correlation increases considerably if we exclude Elandsd and Grootvlei.

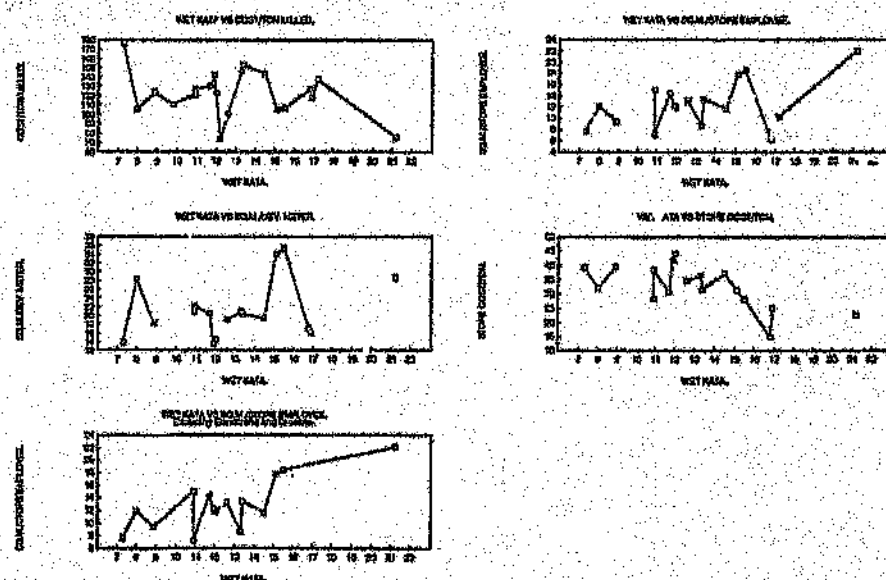


Figure 5.6.14.3.1

# WET KATA READING AND PRODUCTIVITY STATISTICS

WEST WITS MINES ONLY

| MINE     | WET KATA | COST/TON MILL. '89 | SQ. MET./STO. EMP. | TONS/STO. EMP. | SQ. MET./DEV. MET. | STO. COST/TON (R) | DEV. COST/TON (R) | UDG. EMP. | TOT. EMP. |
|----------|----------|--------------------|--------------------|----------------|--------------------|-------------------|-------------------|-----------|-----------|
| ELANDSD  | 17.2     | 137.65             | 10.26              | 68.74          |                    |                   |                   | 26.08     | 21.84     |
| WESTDRIE | 14.5     | 143.53             | 11.69              | 47.08          | 19.38              | 37.14             | 76.54             | 31.37     | 33.02     |
| DOORNH'N | 13.4     | 152.75             | 13.37              | 48.69          | 20.42              | 31.62             | 57.74             | 41.68     | 22.85     |
| WESTDEEF | 12       | 123.71             | 11.85              | 48.17          | 14.48              | 44.03             | 78.14             | 28.58     | 18.67     |
| LIJANON  | 11.7     | 130.41             | 14.44              | 62.73          | 20.46              | 30.79             | 59.38             | 35.35     | 31.81     |
| EASTDRIE | 9.9      | 123.08             | 9.42               | 44.14          | 18.38              | 38.53             | 72.57             | 30.86     | 34.37     |
| DEELKR'L | 9        | 108.02             | 11.99              | 54.24          | 28.43              | 32.05             | 68.85             | 29.25     | 25.97     |
| KLOOF    | 7.3      | 175.78             | 7.69               | 36.07          | 14.01              | 39.18             | 89.78             | 57.78     | 23.46     |

|                                                             |  |          |                                                                |  |          |                                                        |  |          |
|-------------------------------------------------------------|--|----------|----------------------------------------------------------------|--|----------|--------------------------------------------------------|--|----------|
| Wet Kata vs Cost/Ton Milled.<br>Regression Output:          |  |          | Wet Kata vs Square meters/Stop Employee.<br>Regression Output: |  |          | Wet Kata vs Tons/Stop Employee.<br>Regression Output:  |  |          |
| Constant                                                    |  | 132.6409 | Constant                                                       |  | 0.830501 | Constant                                               |  | 28.22875 |
| Std Err of Y Est                                            |  | 27.25849 | Std Err of Y Est                                               |  | 2.194608 | Std Err of Y Est                                       |  | 8.812089 |
| R Squared                                                   |  | 0.003082 | R Squared                                                      |  | 0.110578 | R Squared                                              |  | 0.386893 |
| No. of Observations                                         |  | 8        | No. of Observations                                            |  | 8        | No. of Observations                                    |  | 8        |
| Degrees of Freedom                                          |  | 6        | Degrees of Freedom                                             |  | 6        | Degrees of Freedom                                     |  | 6        |
| X Coefficient(s)                                            |  | 0.045510 | X Coefficient(s)                                               |  | 0.215763 | X Coefficient(s)                                       |  | 1.894845 |
| Std Err of Coef.                                            |  | 2.638768 | Std Err of Coef.                                               |  | 0.242478 | Std Err of Coef.                                       |  | 0.973637 |
| Wet Kata vs Square Meters/Dev. Meter.<br>Regression Output: |  |          | Wet Kata vs Stop Cost/Ton.<br>Regression Output:               |  |          | Wet Kata vs Tons/Dev. Employee.<br>Regression Output:  |  |          |
| Constant                                                    |  | 20.96604 | Constant                                                       |  | 39.44288 | Constant                                               |  | 41.98391 |
| Std Err of Y Est                                            |  | 5.234784 | Std Err of Y Est                                               |  | 5.453166 | Std Err of Y Est                                       |  | 13.30802 |
| R Squared                                                   |  | 0.007369 | R Squared                                                      |  | 0.011597 | R Squared                                              |  | 0.187410 |
| No. of Observations                                         |  | 7        | No. of Observations                                            |  | 7        | No. of Observations                                    |  | 7        |
| Degrees of Freedom                                          |  | 6        | Degrees of Freedom                                             |  | 6        | Degrees of Freedom                                     |  | 6        |
| X Coefficient(s)                                            |  | -0.14831 | X Coefficient(s)                                               |  | -0.19391 | X Coefficient(s)                                       |  | 2.056286 |
| Std Err of Coef.                                            |  | 0.768540 | Std Err of Coef.                                               |  | 0.800600 | Std Err of Coef.                                       |  | 1.953952 |
| Wet Kata vs Dev. Cost/Ton.<br>Regression Output:            |  |          | Wet Kata vs Tons/UDG. Employee.<br>Regression Output:          |  |          | Wet Kata vs Tons/Total Employee.<br>Regression Output: |  |          |
| Constant                                                    |  | 70.98548 | Constant                                                       |  | 32.88020 | Constant                                               |  | 28.40678 |
| Std Err of Y Est                                            |  | 10.73415 | Std Err of Y Est                                               |  | 5.853698 | Std Err of Y Est                                       |  | 4.682883 |
| R Squared                                                   |  | 0.117803 | R Squared                                                      |  | 0.024373 | R Squared                                              |  | 0.029330 |
| No. of Observations                                         |  | 7        | No. of Observations                                            |  | 8        | No. of Observations                                    |  | 8        |
| Degrees of Freedom                                          |  | 6        | Degrees of Freedom                                             |  | 6        | Degrees of Freedom                                     |  | 6        |
| X Coefficient(s)                                            |  | -1.28770 | X Coefficient(s)                                               |  | -0.24184 | X Coefficient(s)                                       |  | -0.21021 |
| Std Err of Coef.                                            |  | 1.575924 | Std Err of Coef.                                               |  | 0.624663 | Std Err of Coef.                                       |  | 0.498704 |

There appears to be a correlation between Wet Kata and Tons/Stop Employee.  
There may be a correlation between Wet Kata and Tons/Dev. Employee.

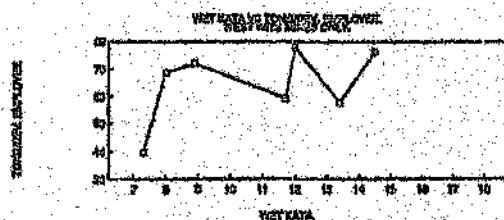
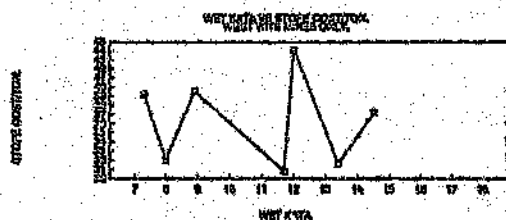
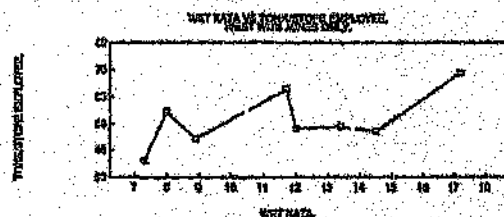
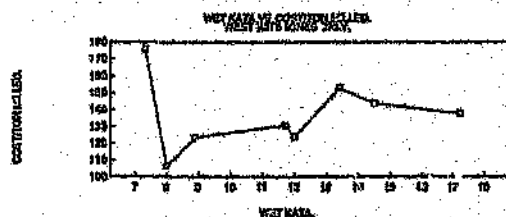


Figure 5.6.14.3.2

# FACE VELOCITY AND PRODUCTIVITY STATISTICS.

| MINE     | FACE<br>VELOCITY<br>MILL/89 | DOST/TON<br>SQ. MET./<br>STO. EMP. | TONS/<br>STO. EMP. | SQ. MET./<br>STO. EMP. | STO. COST<br>TONS/<br>DEV. EMP. | TONS/<br>DEV. EMP. | DEV. COST<br>TONS/<br>UDG. EMP. | TONS/<br>UDG. EMP. | TONS/<br>TOT. EMP. |
|----------|-----------------------------|------------------------------------|--------------------|------------------------|---------------------------------|--------------------|---------------------------------|--------------------|--------------------|
| LESLIE   | 4.5                         | 110.7                              |                    |                        |                                 |                    |                                 |                    |                    |
| WINKEL   | 4.2                         | 121.05                             | 15                 | 61.3                   | 20.94                           | 26.2               | 66.2                            | 50.08              | 21.4               |
| DOORNFN  | 1.28                        | 152.76                             | 13.97              | 48.53                  | 20.42                           | 31.62              | 57.74                           | 41.68              | 27.62              |
| KINROSS  | 1.27                        | 107.46                             | 18.48              | 77.95                  | 35.44                           | 28.03              | 60.85                           | 33.52              | 30.59              |
| SEATRICK | 1.02                        | 118.33                             |                    |                        | 16.14                           | 24.95              |                                 |                    |                    |
| WESTDEEP | 0.81                        | 129.71                             | 11.85              | 48.17                  | 14.48                           | 44.09              | 78.14                           | 28.58              | 28.13              |
| WESTDRIE | 0.8                         | 49.83                              | 11.94              | 47.08                  | 19.28                           | 37.14              | 76.34                           | 1.37               | 30.14              |
| STIELENA | 0.8                         | 146.77                             | 8.878              | 34.033                 | 20.91                           | 36.45              | 30.38                           | 50.23              |                    |
| VAALBEEF | 0.79                        | 141.47                             | 12.22              | 56.8                   | 13.6                            | 41.74              |                                 | 28.88              | 21.67              |
| KLOOF    | 0.7                         | 175.76                             | 7.69               | 66.07                  | 14.07                           | 39.18              | 59.78                           | 57.78              | 23.49              |
| PRESEBAN | 0.8                         | 100.01                             | 13.2               | 55.83                  | 19.08                           | 34.65              | 49.9                            | 29.21              | 19.13              |
| ELANDSD  | 0.6                         | 137.65                             | 10.26              | 68.74                  |                                 |                    |                                 | 26.08              | 21.84              |
| DEELKRI  | 0.54                        | 108.02                             | 11.59              | 54.24                  | 28.43                           | 32.05              | 68.65                           | 29.28              | 32.53              |
| LIBANON  | 0.52                        | 130.41                             | 14.44              | 62.78                  | 20.48                           | 30.78              | 59.48                           | 35.45              | 39.17              |
| EASTDRIE | 0.5                         | 129.08                             | 9.42               | 44.14                  | 18.36                           | 39.53              | 72.37                           | 30.98              | 24.37              |
| WESTHOLT | 0.5                         | 127.33                             | 7.21               | 38.41                  | 22.2                            | 38.45              | 53.28                           |                    | 27.88              |
| STILFONT | 0.46                        | 73.89                              |                    |                        |                                 |                    |                                 |                    |                    |
| WIDONS   | 0.46                        | 78.44                              | 22.1               | 68.8                   | 28.64                           | 22.48              | 42.1                            | 39.81              |                    |
| ORTYLS   | 0.43                        | 127.21                             | 6.31               | 20.43                  | 17.09                           | 14.92              | 63                              | 30.05              | 27.81              |
| BRACKEN  | 0.38                        | 105.89                             | 17.75              | 51.19                  | 30.01                           | 31.12              | 51.19                           | 35.87              |                    |

|                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Face Velocity vs Cost/Ton Milled.</b><br><b>Regression Output:</b><br>Constant 122.6621<br>Std Err of Y Est 25.35382<br>R Squared 0.000185<br>No. of Observations 20<br>Degrees of Freedom 19<br>X Coefficient(s) -0.26582<br>Std Err of Coef. 5.030022          | <b>Face Velocity vs Square Meters/Stop Employee.</b><br><b>Regression Output:</b><br>Constant 11.84118<br>Std Err of Y Est 4.299119<br>R Squared 0.035697<br>No. of Observations 17<br>Degrees of Freedom 15<br>X Coefficient(s) 0.896009<br>Std Err of Coef. 1.203245 | <b>Face Velocity vs Tons/Stop Employee.</b><br><b>Regression Output:</b><br>Constant 49.78121<br>Std Err of Y Est 14.54723<br>R Squared 0.067359<br>No. of Observations 17<br>Degrees of Freedom 15<br>X Coefficient(s) 5.893282<br>Std Err of Coef. 4.072232  |
| <b>Face Velocity vs Square Meters/Dev. Meter.</b><br><b>Regression Output:</b><br>Constant 21.57088<br>Std Err of Y Est 6.784195<br>R Squared 0.000798<br>No. of Observations 17<br>Degrees of Freedom 15<br>X Coefficient(s) -0.20582<br>Std Err of Coef. 1.807443 | <b>Face Velocity vs Stop Cost/Ton.</b><br><b>Regression Output:</b><br>Constant 33.81101<br>Std Err of Y Est 7.691557<br>R Squared 0.01478<br>No. of Observations 17<br>Degrees of Freedom 15<br>X Coefficient(s) -1.02814<br>Std Err of Coef. 2.182445                | <b>Face Velocity vs Tons/Dev. Employee.</b><br><b>Regression Output:</b><br>Constant 59.33077<br>Std Err of Y Est 17.09609<br>R Squared 0.000875<br>No. of Observations 15<br>Degrees of Freedom 13<br>X Coefficient(s) 1.326363<br>Std Err of Coef. 4.784407  |
| <b>Face Velocity vs Dev. Cost/Ton.</b><br><b>Regression Output:</b><br>Constant 38.14155<br>Std Err of Y Est 8.781639<br>R Squared 0.029015<br>No. of Observations 14<br>Degrees of Freedom 12<br>X Coefficient(s) -1.4877<br>Std Err of Coef. 2.484391             | <b>Face Velocity vs Tons/UDG. Employee.</b><br><b>Regression Output:</b><br>Constant 30.14735<br>Std Err of Y Est 5.003148<br>R Squared 0.148085<br>No. of Observations 14<br>Degrees of Freedom 12<br>X Coefficient(s) -2.07112<br>Std Err of Coef. 1.433687          | <b>Face Velocity vs Tons/Total Employee.</b><br><b>Regression Output:</b><br>Constant 27.49594<br>Std Err of Y Est 5.725887<br>R Squared 0.229118<br>No. of Observations 13<br>Degrees of Freedom 11<br>X Coefficient(s) -3.18123<br>Std Err of Coef. 1.518407 |

There does not appear to be any real correlation between Face Velocity and productivity.

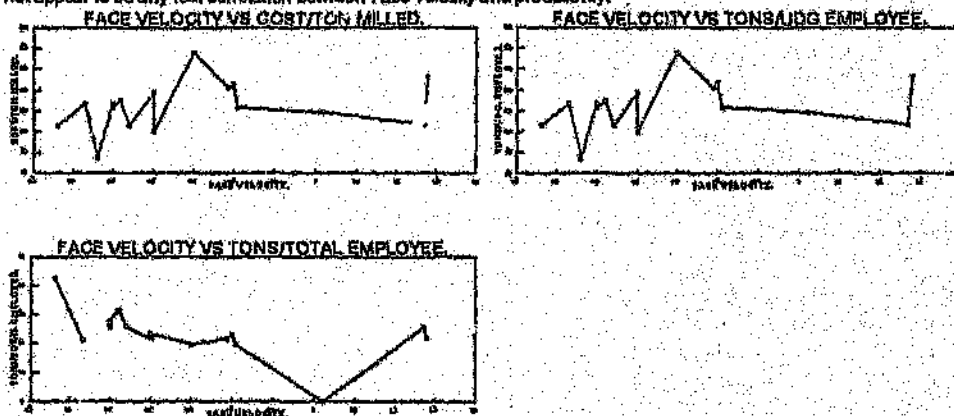


Figure 5.8.14.4.1

# FACE VELOCITY AND PRODUCTIVITY STATISTICS. WEST WITS MINES ONLY.

| MINE      | FACE<br>VELOCITY | COST/TON<br>MILL'S | SQ.MET./<br>STO.EMP. | TONS/<br>STO.EMP. | SQ.MET./<br>DEV.MET. | STO.COST<br>/TON (R.) | DEV.COST<br>/TON (R.) | TONS/<br>UDG.EMP. | TONS/<br>TJT.EMP. |
|-----------|------------------|--------------------|----------------------|-------------------|----------------------|-----------------------|-----------------------|-------------------|-------------------|
| DOORNFIN  | 1.28             | 152.78             | 13.37                | 48.88             | 20.42                | 81.82                 | 57.74                 | 41.88             | 22.35             |
| WESTDEEP  | 0.61             | 123.71             | 11.06                | 48.17             | 14.48                | 44.09                 | 78.14                 | 28.58             | 19.57             |
| WESTDRIE  | 0.8              | 143.83             | 11.89                | 47.08             | 18.38                | 37.14                 | 76.34                 | 31.37             | 23.02             |
| KLOOF     | 0.7              | 179.78             | 7.69                 | 36.07             | 14.01                | 39.18                 | 39.78                 | 57.78             | 19.89             |
| ELANDS'D  | 0.5              | 157.85             | 10.44                | 68.74             |                      |                       |                       | 26.08             | 21.84             |
| DEELKRIJL | 0.54             | 103.02             | 11.99                | 54.24             | 28.43                | 32.05                 | 68.85                 | 28.23             | 25.97             |
| LIBANON   | 0.52             | 150.11             | 14.44                | 62.73             | 20.46                | 30.78                 | 59.36                 | 35.35             | 31.61             |
| EASTORE   | 0.6              | 123.08             | 9.42                 | 44.14             | 18.36                | 39.53                 | 72.37                 | 30.85             | 27.77             |

| Face Velocity vs Cost/Ton Milled. |          |  | Face Velocity vs Square Meters/Stone Employee |          |  | Face Velocity vs Tons/Stone Employee. |          |  |
|-----------------------------------|----------|--|-----------------------------------------------|----------|--|---------------------------------------|----------|--|
| Regression Output:                |          |  | Regression Output:                            |          |  | Regression Output:                    |          |  |
| Constant                          | 109.8616 |  | Constant                                      | 5.635703 |  | Constant                              | 59.00403 |  |
| Std Err of Y Est                  | 20.52694 |  | Std Err of Y Est                              | 2.240089 |  | Std Err of Y Est                      | 10.84584 |  |
| R Squared                         | 0.209138 |  | R Squared                                     | 0.079584 |  | R Squared                             | 0.070866 |  |
| No. of Observations               | 8        |  | No. of Observations                           | 8        |  | No. of Observations                   | 8        |  |
| Degrees of Freedom                | 6        |  | Degrees of Freedom                            | 6        |  | Degrees of Freedom                    | 6        |  |
| X Coefficient(s)                  | 37.2813  |  | X Coefficient(s)                              | 2.359457 |  | X Coefficient(s)                      | -10.7778 |  |
| Std Err of Coef                   | 30.14474 |  | Std Err of Coef                               | 3.288672 |  | Std Err of Coef                       | 15.93218 |  |

| Face Velocity vs Square Meters/Day/Meter. |          |  | Face Velocity vs Stone Cost/Ton. |          |  | Face Velocity vs Tons/Day/Employee. |          |  |
|-------------------------------------------|----------|--|----------------------------------|----------|--|-------------------------------------|----------|--|
| Regression Output:                        |          |  | Regression Output:               |          |  | Regression Output:                  |          |  |
| Constant                                  | 21.61397 |  | Constant                         | 37.58959 |  | Constant                            | 68.97059 |  |
| Std Err of Y Est                          | 5.173674 |  | Std Err of Y Est                 | 5.461575 |  | Std Err of Y Est                    | 14.65885 |  |
| R Squared                                 | 0.030433 |  | R Squared                        | 0.008543 |  | R Squared                           | 0.014118 |  |
| No. of Observations                       | 7        |  | No. of Observations              | 7        |  | No. of Observations                 | 7        |  |
| Degrees of Freedom                        | 5        |  | Degrees of Freedom               | 5        |  | Degrees of Freedom                  | 5        |  |
| X Coefficient(s)                          | -3.08365 |  | X Coefficient(s)                 | -1.59451 |  | X Coefficient(s)                    | -5.81    |  |
| Std Err of Coef                           | 7.783354 |  | Std Err of Coef                  | 8.183894 |  | Std Err of Coef                     | 21.91214 |  |

| Face Velocity vs Day/Cost/Ton. |          |  | Face Velocity vs Tons/UDg. Employee. |          |  | Face Velocity vs Tons/Total Employee. |          |  |
|--------------------------------|----------|--|--------------------------------------|----------|--|---------------------------------------|----------|--|
| Regression Output:             |          |  | Regression Output:                   |          |  | Regression Output:                    |          |  |
| Constant                       | 29.67655 |  | Constant                             | 36.66312 |  | Constant                              | 69.79336 |  |
| Std Err of Y Est               | 11.09435 |  | Std Err of Y Est                     | 5.074868 |  | Std Err of Y Est                      | 3.835485 |  |
| R Squared                      | 0.057604 |  | R Squared                            | 0.213901 |  | R Squared                             | 0.24705  |  |
| No. of Observations            | 7        |  | No. of Observations                  | 8        |  | No. of Observations                   | 8        |  |
| Degrees of Freedom             | 5        |  | Degrees of Freedom                   | 6        |  | Degrees of Freedom                    | 6        |  |
| X Coefficient(s)               | 9.187794 |  | X Coefficient(s)                     | -9.5228  |  | X Coefficient(s)                      | -8.10902 |  |
| Std Err of Coef                | 16.58329 |  | Std Err of Coef                      | 7.452678 |  | Std Err of Coef                       | 5.779407 |  |

There appears to be some correlation between Face velocity and Cost/ton milled, Tons/UDg. and Total employee.

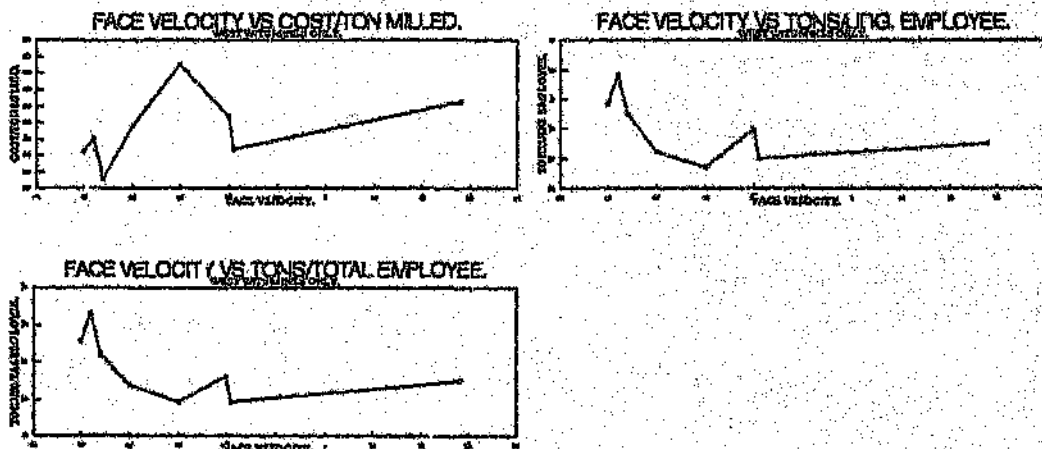


Figure 5.6.14.42

# FACE ADVANCE AND PRODUCTIVITY STATISTICS.

| MINE           | AVG. FACE COST/TON SQ. MET/ | TONS/     | SQ. MET/  | STO. COST TONS/ | DEV. COST TONS/ | TONS/   |
|----------------|-----------------------------|-----------|-----------|-----------------|-----------------|---------|
| ADVANCE MILL/3 | STO. EMP.                   | STO. EMP. | DEV. MET. | TON (5)         | DEV. EMP.       | TON (5) |
| STILPONT       | 12                          | 73.58     | 11.53     | 48.17           | 14.48           | 44.08   |
| WESTDEEF       | 10                          | 128.71    | 11.53     | 48.17           | 14.48           | 44.08   |
| WACONS         | 8.2                         | 76.44     | 22.1      | 88.2            | 28.84           | 22.48   |
| BEATRUX        | 8                           | 116.33    | 12.22     | 55.2            | 10.14           | 24.85   |
| VAALREEF       | 8                           | 141.47    | 10.28     | 88.74           | 13.2            | 41.74   |
| ELANDSD        | 8.5                         | 137.85    | 10.28     | 88.74           | 13.2            | 41.74   |
| STHELENA       | 8.1                         | 149.77    | 8.978     | 84.034          | 20.81           | 58.43   |
| UEBLIE         | 8.1                         | 110.71    | 17.78     | 51.18           | 34.01           | 31.12   |
| BRACKEN        | 8                           | 105.28    | 17.78     | 51.18           | 34.01           | 31.12   |
| PRESBRIAN      | 7.8                         | 103.01    | 19.2      | 54.83           | 18.08           | 34.85   |
| KUNDOSS        | 7.4                         | 107.08    | 18.48     | 77.88           | 28.24           | 28.08   |
| WINKELK        | 7.4                         | 121.03    | 15        | 81.3            | 28.84           | 28.2    |
| OPTVLEI        | 6.8                         | 127.21    | 8.31      | 20.43           | 17.08           | 14.82   |
| WESTHOLL       | 6.7                         | 127.23    | 7.21      | 38.41           | 32.2            | 38.45   |
| WESTDRE        | 6.1                         | 149.83    | 11.88     | 47.08           | 18.28           | 37.14   |
| DEELHOUT       | 6.1                         | 108.02    | 11.88     | 84.84           | 20.48           | 32.08   |
| LEBANON        | 6.1                         | 139.41    | 17.44     | 82.73           | 20.48           | 30.78   |
| ELSTORIE       | 6.1                         | 123.08    | 8.42      | 44.14           | 18.38           | 38.88   |
| KLOC-          | 5                           | 135.78    | 7.63      | 38.07           | 14.01           | 38.18   |
| DOORNFN        | 4.8                         | 182.71    | 13.27     | 48.88           | 20.42           | 31.82   |

| Face Advance vs Cost, Ton Milled.        |          |  | Face Advance vs Square Meter/Stop Employee |          |  | Face Advance vs Ton/Stop Employee.  |          |  |
|------------------------------------------|----------|--|--------------------------------------------|----------|--|-------------------------------------|----------|--|
| Regression Output                        |          |  | Regression Output                          |          |  | Regression Output                   |          |  |
| Constant                                 | 182.4838 |  | Constant                                   | 87.70168 |  | Constant                            | 87.78182 |  |
| Std. Err. of Y Est                       | 20.50148 |  | Std. Err. of Y Est                         | 3.267588 |  | Std. Err. of Y Est                  | 13.27718 |  |
| R Squared                                | 0.348844 |  | R Squared                                  | 0.448183 |  | R Squared                           | 0.214302 |  |
| No. of Observations                      | 20       |  | No. of Observations                        | 17       |  | No. of Observations                 | 17       |  |
| Degrees of Freedom                       | 18       |  | Degrees of Freedom                         | 15       |  | Degrees of Freedom                  | 15       |  |
| X Coefficient(s)                         | -7.97728 |  | X Coefficient(s)                           | -0.18007 |  | X Coefficient(s)                    | -0.2888  |  |
| Std. Err. of Coef.                       | 2.863048 |  | Std. Err. of Coef.                         | 0.08483  |  | Std. Err. of Coef.                  | 0.14158  |  |
| Face Advance vs Square Meter/Dev. Meter. |          |  | Face Advance vs Stop Cost/Ton.             |          |  | Face Advance vs Ton/Dev. Employee.  |          |  |
| Regression Output                        |          |  | Regression Output                          |          |  | Regression Output                   |          |  |
| Constant                                 | 43.84002 |  | Constant                                   | 18.21879 |  | Constant                            | 68.88622 |  |
| Std. Err. of Y Est                       | 8.22883  |  | Std. Err. of Y Est                         | 8.880148 |  | Std. Err. of Y Est                  | 18.87848 |  |
| R Squared                                | 0.580708 |  | R Squared                                  | 0.181889 |  | R Squared                           | 0.012474 |  |
| No. of Observations                      | 19       |  | No. of Observations                        | 18       |  | No. of Observations                 | 18       |  |
| Degrees of Freedom                       | 14       |  | Degrees of Freedom                         | 14       |  | Degrees of Freedom                  | 13       |  |
| X Coefficient(s)                         | -0.17482 |  | X Coefficient(s)                           | 0.132848 |  | X Coefficient(s)                    | -1.2122  |  |
| Std. Err. of Coef.                       | 0.057288 |  | Std. Err. of Coef.                         | 0.076283 |  | Std. Err. of Coef.                  | .393175  |  |
| Face Advance vs Cost/Ton.                |          |  | Face Advance vs Ton/Dev. Employee.         |          |  | Face Advance vs Ton/Total Employee. |          |  |
| Regression Output                        |          |  | Regression Output                          |          |  | Regression Output                   |          |  |
| Constant                                 | 44.14848 |  | Constant                                   | 29.48424 |  | Constant                            | 46.71881 |  |
| Std. Err. of Y Est                       | 8.718882 |  | Std. Err. of Y Est                         | 8.418381 |  | Std. Err. of Y Est                  | 5.68888  |  |
| R Squared                                | 0.408476 |  | R Squared                                  | 0.001583 |  | R Squared                           | 0.188113 |  |
| No. of Observations                      | 14       |  | No. of Observations                        | 14       |  | No. of Observations                 | 18       |  |
| Degrees of Freedom                       | 12       |  | Degrees of Freedom                         | 12       |  | Degrees of Freedom                  | 13       |  |
| X Coefficient(s)                         | -1.0861  |  | X Coefficient(s)                           | -0.01032 |  | X Coefficient(s)                    | -0.12818 |  |
| Std. Err. of Coef.                       | 1.838547 |  | Std. Err. of Coef.                         | 0.076284 |  | Std. Err. of Coef.                  | 0.078681 |  |

There appears to be some correlation between Face Advance and the following: Cost/Ton Milled, Square Meter/Stop Employee and Square Meter/Dev. Meter. The correlation between Face Advance and Stop Cost/Ton Improves if W/L levels, Vaal Reef and Groenewald are omitted.

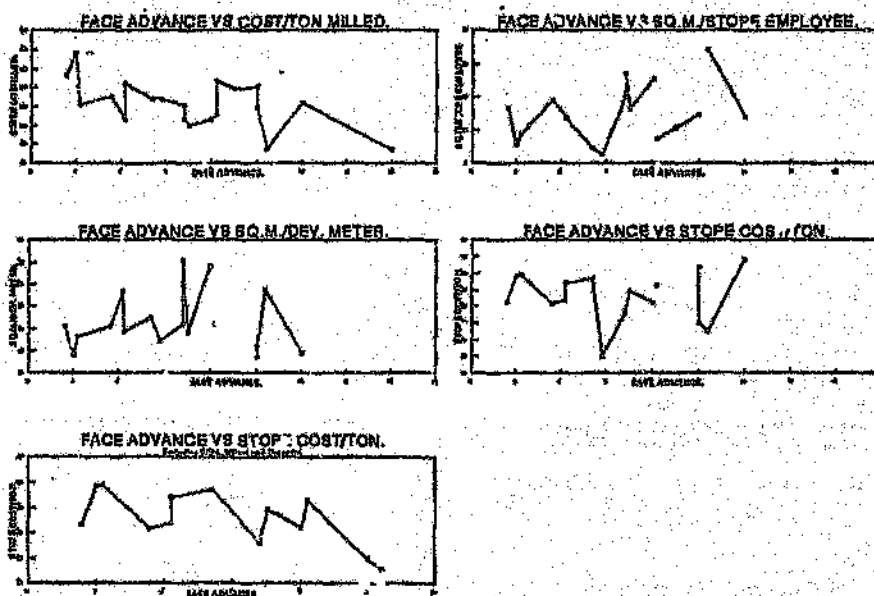


Figure B.8.13.1

# FACE ADVANCE AND PRODUCTIVITY STATISTICS.

WEST WITS MINES ONLY.

| MINE     | AVG. FACE/ST/TON | SQ. MET./<br>ADVANCE MILL. '89 | TONS/<br>STO. EMP. | STO. MET./<br>DEV. MET. | STO. COST TONS/<br>(TON) (R). | DEV. COST TONS/<br>(TON) (R). | TONS/<br>UDG. EMP. | TONS/<br>TOT. EMP. |       |       |
|----------|------------------|--------------------------------|--------------------|-------------------------|-------------------------------|-------------------------------|--------------------|--------------------|-------|-------|
| WESTDEEP | 10               | 125.71                         | 11.85              | 48.17                   | 14.48                         | 41.08                         | 78.14              | 28.58              | 25.13 | 18.57 |
| ELANDS'D | 8.5              | 187.85                         | 10.26              | 88.74                   |                               |                               |                    | 28.08              | 21.84 |       |
| WESTDRIE | 8.1              | 143.33                         | 11.89              | 47.08                   | 19.38                         | 37.14                         | 78.34              | 31.37              | 30.14 | 23.02 |
| DEELKR'L | 8.1              | 108.02                         | 11.98              | 54.24                   | 28.48                         | 32.05                         | 68.85              | 29.25              | 32.58 | 25.87 |
| LIBANON  | 5.8              | 130.41                         | 14.44              | 62.73                   | 20.48                         | 30.78                         | 68.38              | 35.35              | 39.17 | 31.81 |
| EASTDRIE | 8.1              | 125.08                         | 3.42               | 44.14                   | 18.36                         | 38.53                         | 72.37              | 30.80              | 34.37 | 27.77 |
| KLOOF    | 5                | 175.78                         | 7.39               | 38.07                   | 14.01                         | 35.18                         | 33.78              | 57.79              | 23.49 | 15.39 |
| DOORNFW  | 4.8              | 152.78                         | 13.37              | 48.88                   | 20.42                         | 31.82                         | 67.74              | 41.66              | 22.35 |       |

| Face Advance vs Cost/Ton Milled.<br>Regression Output:          |          |  | Face Advance vs Square Meters/Stopa Employee<br>Regression Output: |          |  | Face Advance vs Tons/Stopa Employee.<br>Regression Output: |          |  |
|-----------------------------------------------------------------|----------|--|--------------------------------------------------------------------|----------|--|------------------------------------------------------------|----------|--|
| Constant                                                        | 162.4088 |  | Constant                                                           | 10.86817 |  | Constant                                                   | 67.03631 |  |
| Std Err of Y Est                                                | 21.54531 |  | Std Err of Y Est                                                   | 2.330303 |  | Std Err of Y Est                                           | 10.3434  |  |
| R Squared                                                       | 0.122109 |  | R Squared                                                          | 0.009955 |  | R Squared                                                  | 0.155441 |  |
| No. of Observations                                             | 8        |  | No. of Observations                                                | 8        |  | No. of Observations                                        | 8        |  |
| Degrees of Freedom                                              | 6        |  | Degrees of Freedom                                                 | 6        |  | Degrees of Freedom                                         | 6        |  |
| X Coefficient(s)                                                | -4.50811 |  | X Coefficient(s)                                                   | 0.073243 |  | X Coefficient(s)                                           | 2.213415 |  |
| Std Err of Coef.                                                | 4.38742  |  | Std Err of Coef.                                                   | 0.474536 |  | Std Err of Coef.                                           | 2.106297 |  |
| Face Advance vs Square Meters/Dev. Meter.<br>Regression Output: |          |  | Face Advance vs Stopa Cost/Ton.<br>Regression Output:              |          |  | Face Advance vs Tons/Dev. Employee.<br>Regression Output:  |          |  |
| Constant                                                        | 23.78378 |  | Constant                                                           | 23.21767 |  | Constant                                                   | 38.21643 |  |
| Std Err of Y Est                                                | 5.063325 |  | Std Err of Y Est                                                   | 4.428042 |  | Std Err of Y Est                                           | 12.10487 |  |
| R Squared                                                       | 0.072452 |  | R Squared                                                          | 0.348278 |  | R Squared                                                  | 0.327798 |  |
| No. of Observations                                             | 7        |  | No. of Observations                                                | 7        |  | No. of Observations                                        | 7        |  |
| Degrees of Freedom                                              | 6        |  | Degrees of Freedom                                                 | 6        |  | Degrees of Freedom                                         | 6        |  |
| X Coefficient(s)                                                | -0.72114 |  | X Coefficient(s)                                                   | 1.652129 |  | X Coefficient(s)                                           | 4.314335 |  |
| Std Err of Coef.                                                | 1.155728 |  | Std Err of Coef.                                                   | 1.010708 |  | Std Err of Coef.                                           | 2.762058 |  |
| Face Advance vs Dev. Cost/Ton.<br>Regression Output:            |          |  | Face Advance vs Tons/UDg. Employee.<br>Regression Output:          |          |  | Face Advance vs Tons/Tot. Employee.<br>Regression Output:  |          |  |
| Constant                                                        | 54.01544 |  | Constant                                                           | 38.42512 |  | Constant                                                   | 28.87383 |  |
| Std Err of Y Est                                                | 9.848359 |  | Std Err of Y Est                                                   | 5.339744 |  | Std Err of Y Est                                           | 4.170911 |  |
| R Squared                                                       | 0.24253  |  | R Squared                                                          | 0.129701 |  | R Squared                                                  | 0.134262 |  |
| No. of Observations                                             | 5        |  | No. of Observations                                                | 8        |  | No. of Observations                                        | 8        |  |
| Degrees of Freedom                                              | 5        |  | Degrees of Freedom                                                 | 6        |  | Degrees of Freedom                                         | 6        |  |
| X Coefficient(s)                                                | -2.87082 |  | X Coefficient(s)                                                   | -1.02823 |  | X Coefficient(s)                                           | -0.59853 |  |
| Std Err of Coef.                                                | 2.27073  |  | Std Err of Coef.                                                   | 1.087389 |  | Std Err of Coef.                                           | 0.849351 |  |

There appears to be some correlation between Face Advance and the following: Stopa Cost/Ton, and Tons/Dev. Employee.  
The correlation between Face advance and Cost/ton milled improves if one excludes Deelkraal.  
The same applies to Tons/Stopa and Udg. employee if one excludes WJ Levels and Kloof respectively.

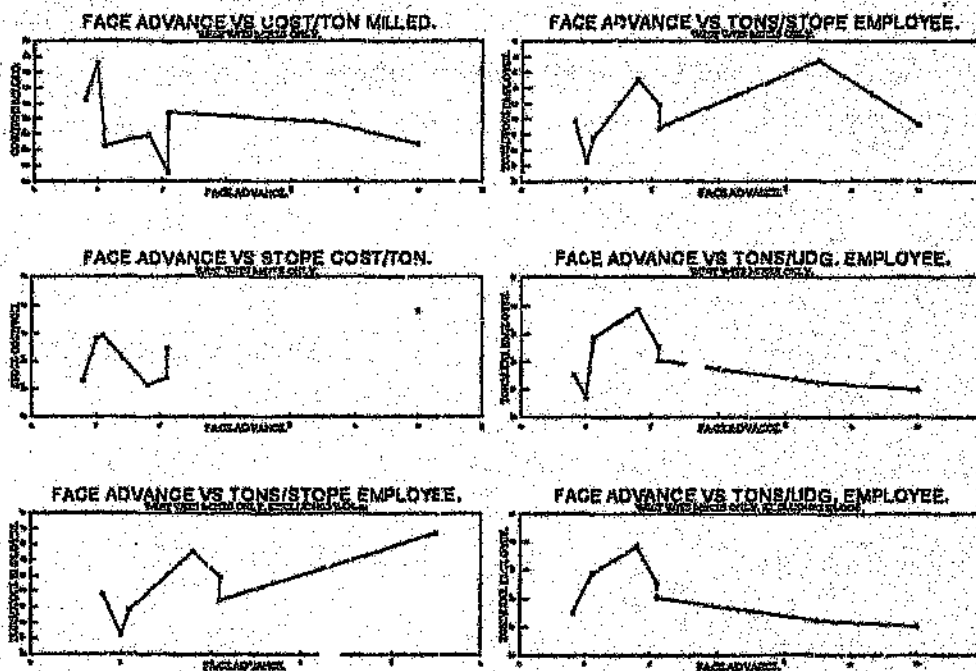


Figure 5.8.15.2

Vaal Reefs and Grootvlei. There is also an inverse relationship between Face advance and Square meters/development meter. This would also seem to be logical as more orepasses can improve face cleaning and advance rates.

The general conclusion reached therefore, is that an increase in face advance rate must not result in an increase in the percentage of "lost blasts" if it is to result in improvements in productivity and costs.

#### PRODUCTION RATE AND PRODUCTIVITY.

One would expect to achieve economies of scale in any production type operation. It should pay one to operate a mine at the highest practical level of production.

Figure 5.6.16.1 does not however indicate any correlation between the scale of operation and labour productivity and costs, for the general group of mines.

Figure 5.6.16.2, for the select group, also shows no apparent correlation.

#### POWER CONSUMPTION AND PRODUCTIVITY.

Power consumption is indicative of mining conditions and the level of production. We have dealt with Production rate and its effect on productivity and costs. There was no apparent correlation between the two. From Figures 5.6.17.1/2 there is also no correlation between Power consumption and Cost/ton milled. This was to be expected from the previous paragraph as total power consumption is also directly related to production.

Figure 5.6.17.3 shows that there is also no correlation between the unit power costs and other costs although one could reasonably have expected such a relationship. There is also no improvement in the correlation if one removes three mines which could be regarded as anomalous (Grootvlei, West Rand Cons. and Stilfontein), nor does there appear to be any relationship for the mines of the West Wits Line.

### 5.7 IDENTIFYING THOSE FACTORS WHICH AFFECT OUTPUT (GOLD AND REVENUE).

#### STOPING AND DEVELOPMENT.

# PRODUCTION RATE AND PRODUCTIVITY

| MINE       | TONS<br>MINED<br>(000'S) | COST/<br>TON MILL. | SQ.MET./<br>STO.EMP. | TONS/<br>STO.EMP. | SQ.MET./<br>DEV.MET. | STOPING<br>COST/TON | TONS/DEV.<br>EMPLOYEE | DEVOP.<br>COST/TON | TONS/<br>UDG.EMP. | TONS/<br>TOT.EMP. |
|------------|--------------------------|--------------------|----------------------|-------------------|----------------------|---------------------|-----------------------|--------------------|-------------------|-------------------|
| Vaal Reef  | 1083                     | 141.47             | 12.22                | 58.8              | 13.5                 | 41.74               |                       |                    | 28.36             | 21.87             |
| West Deep  | 480                      | 123.71             | 11.85                | 48.17             | 14.48                | 44.05               | 78.14                 | 28.58              | 26.13             | 19.57             |
| Pfessbranc | 585                      | 100.01             | 13.2                 | 55.63             | 19.08                | 34.85               | 48.9                  | 39.21              | 18.13             | 23.51             |
| Westhold   | 353                      | 127.53             | 7.21                 | 36.41             | 22.2                 | 38.45               | 83.23                 |                    | 27.88             | 25.08             |
| Eastdrie   | 323                      | 123.08             | 9.42                 | 44.14             | 18.38                | 39.53               | 72.37                 | 30.58              | 34.37             | 27.77             |
| Westdrie   | 310                      | 143.83             | 11.69                | 47.06             | 19.36                | 37.14               | 78.34                 | 31.37              | 30.14             | 23.02             |
| Kloof      | 270                      | 175.78             | 7.69                 | 38.07             | 14.01                | 39.18               | 39.78                 | 57.73              | 23.49             | 19.59             |
| Beatrix    | 225                      | 118.33             | 21.3                 |                   | 15.14                | 24.83               |                       |                    |                   |                   |
| Lebanon    | 219                      | 139.41             | 14.44                | 62.73             | 20.48                | 30.79               | 59.38                 | 38.35              | 59.17             | 31.61             |
| Elandsd    | 211                      | 137.85             | 10.26                | 66.74             |                      |                     |                       |                    | 26.05             | 21.84             |
| Winkel-Hk  | 209                      | 121.05             | 15                   | 61.3              | 20.54                | 28.2                | 68.2                  | 30.06              | 21.4              | 15.8              |
| Kinross    | 205                      | 107.05             | 18.48                | 77.95             | 35.44                | 28.08               | 80.65                 | 33.93              | 30.59             | 25.31             |
| Doornfont  | 186                      | 152.78             | 13.37                | 48.89             | 20.42                | 31.82               | 57.74                 | 41.58              | 27.62             | 22.35             |
| St Helena  | 173                      | 148.77             | 8.676                | 34.033            | 20.81                | 36.43               | 30.33                 | 50.23              |                   |                   |
| Deelkraal  | 159                      | 108.02             | 11.98                | 54.24             | 28.43                | 32.03               | 68.86                 | 28.25              | 32.55             | 25.97             |
| Ventersd   | 153                      | 122.8              | 11.8                 | 49.9              | 29.11                | 29.74               | 45.7                  | 33.35              | 26.1              | 20.85             |
| Stilfont   | 79                       | 75.59              | 15.18                |                   |                      |                     |                       |                    |                   |                   |
| Grtvle     | 67                       | 127.21             | 8.31                 | 20.41             | 17.09                | 14.92               | 63                    | 30.08              | 27.61             | 21.46             |
| Leslie     | 53                       | 110.71             | 15.7                 |                   |                      |                     |                       |                    |                   |                   |
| Bracken    | 52                       | 105.39             | 17.75                | 51.17             | 34.01                | 31.12               | 51.19                 | 35.97              |                   | 42.57             |
| Wroons     | 33                       | 75.44              | 22.1                 | 60.2              | 28.84                | 22.48               | 42.1                  | 39.81              |                   |                   |

| Production rate and Cost/ton milled. |          |  | Production rate and Tons/total employee. |          |  | Production rate and Tons/underground employee |          |  |
|--------------------------------------|----------|--|------------------------------------------|----------|--|-----------------------------------------------|----------|--|
| Regression Output:                   |          |  | Regression Output:                       |          |  | Constant                                      |          |  |
| Constant                             | 115.2255 |  | Constant                                 | 26.27718 |  | Constant                                      | 28.35871 |  |
| Std Err of Y Est                     | 23.17144 |  | Std Err of Y Est                         | 8.134973 |  | Std Err of Y Est                              | 5.229058 |  |
| R Squared                            | 0.118491 |  | R Squared                                | 0.088559 |  | R Squared                                     | 0.002807 |  |
| No. of Observations                  | 21       |  | No. of Observations                      | 18       |  | No. of Observations                           | 18       |  |
| Degrees of Freedom                   | 19       |  | Degrees of Freedom                       | 14       |  | Degrees of Freedom                            | 13       |  |
| X Coefficient(s)                     | 0.036877 |  | X Coefficient(s)                         | -0.00672 |  | X Coefficient(s)                              | -0.00714 |  |
| Std Err of Coef.                     | 0.023078 |  | Std Err of Coef.                         | 0.006823 |  | Std Err of Coef.                              | 0.007358 |  |

There is no apparent correlation between Production rate and cost's or labour productivity.

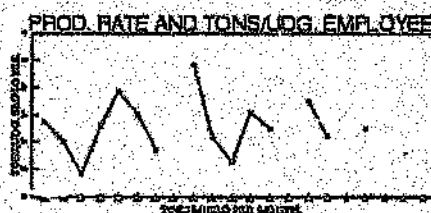
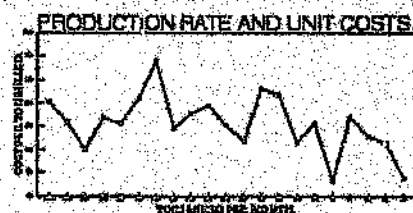


Figure 5.6.18.1

# PRODUCTION RATE AND PRODUCTIVITY

## WEST WITS MINES ONLY

| MINE     | TONS<br>MINED<br>(000'S) | COST/<br>TON MILL. | SQ MET./<br>STD. EMP. | TONS/<br>STD. EMP. | SQ MET./<br>DEV. MET. | STOPING<br>COST/TON EMPLOYEE | TONS/DEV. EMP. | DEVELOP.<br>COST/TON UDG. EMP. | TONS/<br>UDG. EMP. | TONS/<br>TOT. EMP. |
|----------|--------------------------|--------------------|-----------------------|--------------------|-----------------------|------------------------------|----------------|--------------------------------|--------------------|--------------------|
| WESTDEEP | 480                      | 123.71             | 11.25                 | 48.17              | 14.48                 | 44.08                        | 78.14          | 23.58                          | 25.13              | 19.57              |
| EASTDRIE | 323                      | 123.08             | 9.42                  | 44.14              | 18.36                 | 39.58                        | 72.37          | 30.96                          | 34.37              | 27.77              |
| WESTDRIE | 310                      | 143.83             | 11.69                 | 47.08              | 19.36                 | 37.14                        | 76.34          | 31.37                          | 30.14              | 23.02              |
| KLOOF    | 270                      | 175.70             | 7.64                  | 38.57              | 14.01                 | 39.18                        | 38.78          | 57.78                          | 23.49              | 19.89              |
| LIBANON  | 219                      | 130.41             | 14.44                 | 62.73              | 20.46                 | 30.79                        | 59.88          | 35.35                          | 39.17              | 51.61              |
| ELANDSD  | 211                      | 137.65             | 10.28                 | 55.74              |                       |                              |                |                                | 26.09              | 21.84              |
| DOORNPN  | 189                      | 162.75             | 13.87                 | 48.89              | 20.42                 | 31.62                        | 57.74          | 41.66                          | 27.62              | 22.85              |
| DEELKRIJ | 153                      | 106.02             | 11.99                 | 64.24              | 28.43                 | 32.05                        | 68.85          | 29.25                          | 32.55              | 25.97              |
| VENTERSH | 153                      | 122.5              | 11.8                  | 49.9               | 29.11                 | 26.74                        | 46.7           | 33.35                          | 28.1               | 20.65              |

| Production rate and Cost/ton milled.<br>Regression Output |  |          | Production rate and Tons/total employee.<br>Regression Output |  |          | Production rate and Tons/underground employee.<br>Regression Output |  |          |
|-----------------------------------------------------------|--|----------|---------------------------------------------------------------|--|----------|---------------------------------------------------------------------|--|----------|
| Constant                                                  |  | 133.3491 | Constant                                                      |  | 25.93712 | Constant                                                            |  | 31.55159 |
| Std Err of Y Est                                          |  | 21.54104 | Std Err of Y Est                                              |  | 4.223125 | Std Err of Y Est                                                    |  | 5.553209 |
| R Squared                                                 |  | 0.001222 | R Squared                                                     |  | 0.054522 | R Squared                                                           |  | 0.028788 |
| No. of Observations                                       |  | 8        | No. of Observations                                           |  | 8        | No. of Observations                                                 |  | 8        |
| Degrees of Freedom                                        |  | 7        | Degrees of Freedom                                            |  | 7        | Degrees of Freedom                                                  |  | 7        |
| X Coefficient(s)                                          |  | 0.006889 | X Coefficient(s)                                              |  | -0.00114 | X Coefficient(s)                                                    |  | -0.00114 |
| Std Err of Coef.                                          |  | 0.07414  | Std Err of Coef.                                              |  | 0.014394 | Std Err of Coef.                                                    |  | 0.018348 |

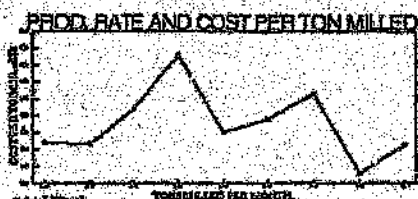


Figure 5.6.16.2

# POWER CONSUMPTION AND COST PER TON MILLED.

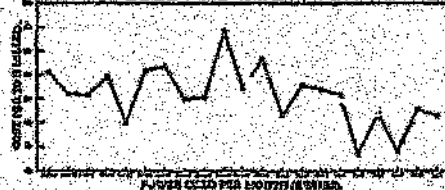
| MINE      | MW.HRS/<br>MONTH | COST/<br>TON MILL. | SQ.MET./<br>STO.EMP. | TONS/<br>STO.EMP. | SQ.MET./<br>DEV.MET. | STOPING TONS/DEV. | DEVELOP. TONS/DEV. | DEVELOP. TONS/UDG.EMP. | TONS/<br>TOT.EMP. |
|-----------|------------------|--------------------|----------------------|-------------------|----------------------|-------------------|--------------------|------------------------|-------------------|
| VAALPHEEF | 142260           | 141.47             | 12.22                | 58.3              | 13.5                 | 41.74             |                    | 28.08                  | 21.87             |
| WESTDEEF  | 109708           | 128.71             | 11.85                | 48.17             | 14.48                | 44.09             | 78.14              | 26.58                  | 19.57             |
| EASTDRIE  | 58456            | 123.08             | 9.42                 | 44.14             | 18.88                | 39.53             | 72.37              | 30.90                  | 27.77             |
| ELANDSD   | 17150            | 137.65             | 10.26                | 66.74             |                      |                   |                    | 26.08                  | 21.85             |
| PRESBRAN  | 45525            | 100.01             | 13.2                 | 38.63             | 18.06                | 34.65             | 48.9               | 38.21                  | 23.51             |
| WESTORIE  | 37000            | 143.83             | 11.89                | 47.08             | 19.38                | 37.14             | 76.84              | 31.37                  | 30.14             |
| STHELENA  | 36378            | 146.77             | 8.575                | 34.083            | 20.91                | 36.43             | 50.33              | 59.23                  |                   |
| BEATWY    | 28704            | 118.38             | 21.3                 |                   | 15.14                | 24.85             |                    |                        |                   |
| WINKELHAK | 27549            | 121.05             | 15                   | 61.3              | 20.94                | 28.2              | 68.2               | 58.08                  | 21.4              |
| KLOOF     | 26200            | 175.78             | 7.69                 | 36.07             | 14.01                | 39.18             | 38.78              | 67.78                  | 23.39             |
| GRUYLE    | 21224            | 127.21             | 6.31                 | 20.43             | 17.09                | 14.92             | 63                 | 50.08                  | 27.51             |
| DOORNFN   | 15500            | 152.78             | 13.37                | 48.89             | 20.42                | 31.52             | 57.74              | 41.66                  | 27.62             |
| DEELKRL   | 12112            | 106.02             | 11.99                | 54.24             | 23.43                | 32.06             | 68.86              | 29.25                  | 32.55             |
| LIBANON   | 11272            | 130.41             | 14.44                | 62.73             | 20.46                | 30.79             | 58.36              | 35.36                  | 39.17             |
| WESTHOL   | 10557            | 127.33             | 7.21                 | 38.41             | 22.2                 | 38.45             | 93.28              | 27.68                  | 26.08             |
| VENTERS'T | 8820             | 122.8              | 11.8                 | 40.9              | 29.11                | 28.74             | 45.7               | 33.35                  | 26.1              |
| STILFONT  | 8180             | 73.69              | 15.16                |                   |                      |                   |                    |                        |                   |
| KINFOS    | 7898             | 107.08             | 15.48                | 77.95             | 35.44                | 28.08             | 60.65              | 33.83                  | 30.89             |
| WRCONS    | 5335             | 75.44              | 22.1                 | 65.8              | 28.64                | 22.48             | 42.1               | 39.81                  |                   |
| LESLIE    | 2174             | 110.71             | 15.7                 |                   |                      |                   |                    |                        |                   |
| BRACKEN   | 417              | 105.39             | 17.75                | 51.19             | 34.01                | 31.12             | 51.19              | 85.97                  | 42.67             |

Power consumption and Cost/ton milled.  
Regression:

|                     |          |
|---------------------|----------|
| Constant            | 115.8872 |
| Std Err of Y Est    | 28.49949 |
| R Squared           | 0.093854 |
| No. of Observations | 21       |
| Degrees of Freedom  | 19       |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.000206 |
| Std Err of Coef. | 0.000148 |

POWER USED AND COST / TON MILLED.



There is no apparent correlation between power consumption and cost per ton milled.

Figure 5.6.17.1

# POWER CONSUMPTION AND COST PER TON MILLED.

WEST WITS MINES ONLY.

| MINE      | MW.HRS/<br>MONTH | COST/<br>TON MILL | SQ.MET/<br>STO.EMP. | TONS/<br>STO.EMP. | SQ.MET/<br>DEV.MET. | STOPING TONS/DEV. | DEVELOP. TONS/DEV. | DEVELOP. TONS/UPG. | TONS/<br>TOT.EMP. |
|-----------|------------------|-------------------|---------------------|-------------------|---------------------|-------------------|--------------------|--------------------|-------------------|
| WESTDEEF  | 109785           | 123.71            | 11.65               | 68.17             | 14.48               | 44.09             | 79.14              | 28.66              | 25.19             |
| EASTDRIE  | 58458            | 123.08            | 8.42                | 44.14             | 18.35               | 39.53             | 72.37              | 30.96              | 34.37             |
| ELANDS'D  | 47150            | 137.65            | 10.28               | 58.74             |                     |                   |                    |                    | 28.06             |
| WESTDRIE  | 37000            | 143.83            | 11.69               | 47.08             | 19.36               | 37.14             | 76.34              | 31.37              | 30.14             |
| KLOOF     | 26200            | 175.78            | 7.69                | 36.07             | 14.01               | 39.18             | 39.78              | 57.78              | 23.49             |
| DOORNH'N  | 15500            | 162.78            | 13.37               | 49.89             | 20.42               | 31.82             | 57.74              | 41.68              | 27.62             |
| DEELKRIJL | 12112            | 106.02            | 11.88               | 54.24             | 28.43               | 32.05             | 68.85              | 28.25              | 32.55             |
| LIBANON   | 11272            | 133.41            | 14.44               | 62.73             | 20.45               | 30.79             | 59.88              | 35.25              | 39.17             |
| VENTERS'P | 5920             | 122.8             | 11.8                | 49.5              | 29.11               | 28.74             | 45.7               | 33.95              | 28.1              |

Power consumption and Cost/ton milled.

Regression:

|                     |          |
|---------------------|----------|
| Constant            | 139.0546 |
| Std Err of Y Est    | 21.67109 |
| R Squared           | 0.016706 |
| No. of Observations | 9        |
| Degrees of Freedom  | 7        |

|                  |          |
|------------------|----------|
| X Coefficient(s) | -6.1E-05 |
| Std Err of Coef. | 0.000235 |

POWER USED AND COST / TON MILLED.



There is no apparent correlation between power consumption and cost per ton milled.

Figure 5.3.17.2

# POWER CONSUMPTION AND UNIT COSTS

| ALL SURVEY MINES |                    |                     | ALL SURVEY MINES (LESS 3) |                    |                     | WEST WITS MINES ONLY |                    |                     |
|------------------|--------------------|---------------------|---------------------------|--------------------|---------------------|----------------------|--------------------|---------------------|
| MINE             | COST/TON<br>MILLED | MW.HRS/<br>KILO-TON | MINE                      | COST/TON<br>MILLED | MW.HRS/<br>KILO-TON | MINE                 | COST/TON<br>MILLED | MW.HRS/<br>KILO-TON |
| GRUYLER          | 127.21             | 817                 | WESTDEEP                  | 123.71             | 223                 | WESTDEEP             | 123.71             | 223                 |
| WESTDEEP         | 123.71             | 223                 | ELANDSD                   | 137.85             | 223                 | ELANDSD              | 137.85             | 223                 |
| ELANDSD          | 137.85             | 223                 | STHELENA                  | 146.77             | 210                 | EASTDRIE             | 123.08             | 181                 |
| STHELENA         | 146.77             | 210                 | EASTDRIE                  | 123.08             | 181                 | WESTDRIE             | 143.83             | 116                 |
| EASTDRIE         | 123.08             | 181                 | WINKELH                   | 121.08             | 132                 | KLOOF                | 175.78             | 87                  |
| WINKELH          | 121.08             | 132                 | VAALREEF                  | 141.47             | 131                 | DOORNPA              | 152.78             | 83                  |
| VAALREEF         | 141.47             | 131                 | BEATRIX                   | 118.33             | 128                 | DEELKR'L             | 123.02             | 78                  |
| BEATRIX          | 118.33             | 128                 | WESTDRIE                  | 143.83             | 116                 | VENTERS              | 122.0              | 58                  |
| WESTDRIE         | 143.83             | 116                 | PRESBRAN                  | 100.01             | 119                 | LIBANON              | 130.41             | 51                  |
| PRESBRAN         | 100.01             | 119                 | KLOOF                     | 175.78             | 87                  |                      |                    |                     |
| STILFONT         | 79.58              | 108                 | DOORNPA                   | 152.78             | 83                  |                      |                    |                     |
| KLOOF            | 175.78             | 87                  | DEELKR'L                  | 123.02             | 78                  |                      |                    |                     |
| DOORNPA          | 152.78             | 83                  | VENTERS                   | 122.0              | 58                  |                      |                    |                     |
| DEELKR'L         | 123.02             | 78                  | LIBANON                   | 130.41             | 51                  |                      |                    |                     |
| VENTERS          | 122.0              | 58                  | LESLIE                    | 110.71             | 41                  |                      |                    |                     |
| LIBANON          | 130.41             | 51                  | KINROSS                   | 107.08             | 39                  |                      |                    |                     |
| LESLIE           | 110.71             | 41                  | WESTHOL                   | 127.33             | 31                  |                      |                    |                     |
| KINROSS          | 107.08             | 39                  | BRACKEN                   | 105.39             | 8                   |                      |                    |                     |
| WESTHOL          | 127.33             | 31                  |                           |                    |                     |                      |                    |                     |
| BRACKEN          | 105.39             | 8                   |                           |                    |                     |                      |                    |                     |

| Power consumption and Cost/ton milled.<br>Regression Output: |          | Power consumption and Cost/ton milled.<br>Regression Output: |          | Power consumption and Cost/ton milled.<br>Regression Output: |          |
|--------------------------------------------------------------|----------|--------------------------------------------------------------|----------|--------------------------------------------------------------|----------|
| Constant                                                     | 117.2151 | Constant                                                     | 116.2481 | Constant                                                     | 133.1338 |
| Std Err of Y Est                                             | 24.41163 | Std Err of Y Est                                             | 19.26802 | Std Err of Y Est                                             | 21.78019 |
| R Squared                                                    | 0.018188 | R Squared                                                    | 0.083324 | R Squared                                                    | 0.008778 |
| No. of Observations                                          | 21       | No. of Observations                                          | 19       | No. of Observations                                          | 8        |
| Degrees of Freedom                                           | 19       | Degrees of Freedom                                           | 16       | Degrees of Freedom                                           | 7        |
| X Coefficient(s)                                             | 0.042839 | X Coefficient(s)                                             | 0.034737 | X Coefficient(s)                                             | -0.02427 |
| Std Err of Coef.                                             | 0.070246 | Std Err of Coef.                                             | 0.06892  | Std Err of Coef.                                             | 0.111058 |

There is no apparent correlation between power consumption and unit costs.

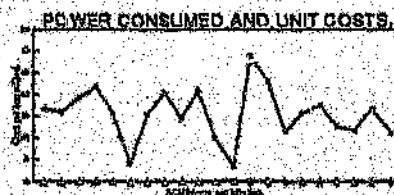


Figure 5.6.17.3

Gold bearing rock is produced during the development of tunnels on the reef plane. This ore is usually contaminated by waste rock and may or may not be sent to the reduction works for extracting the gold.

The bulk of the gold bearing rock is obtained from the stoping operation, where every effort is made to minimise the loss of gold and dilution by waste rock. With regard to dilution, attempts are made to extract the gold bearing ore with a minimal amount of external waste. Mining at the minimum stoping width has been shown to be the single most important factor in improving revenue (N.G.W.Cook, 1969).

In the stoping environment other measures which can be taken to improve the recovery of gold include better sweepings and eliminating gold losses (in waste packing, timber and other support, worked out areas, under falls of ground, strike gullies, roadways and drains, reef left un-mined in the hanging and footwall).

Gold can also be lost in the general underground environment. For example, ore can be tipped into waste - passes. On the surface of the mine, ore can be transported and dumped on the waste dumps. Collectively, all the foregoing items, contribute to a better or worse mine-call factor.

#### PLANT RECOVERY.

Gold is also lost in the plant tailings. This gold can be in the form of undissolved gold (inefficient milling etc.) or dissolved gold ( inefficient filtration etc.).

#### OTHER SOURCES OF REVENUE.

Where plant capacity is available, it is sometimes possible to supplement the production of gold by treating low grade ore from the following sources:- sub-economic blocks, development rock, low grade ore stockpiles, waste dumps, current waste washings.

Instead of paying a higher level of dividends, money can be retained to source future capital expenditure. In the interim, interest is being generated to supplement revenue. Inventories can be reduced and unwanted assets can be realised. It may even be worthwhile entering into a lease agreement with a neighboring mine to generate additional revenue from royalties.

## 6 CONCLUSIONS TO BE DRAWN FROM THE FOREGOING ANALYSIS.

From the foregoing objective as well as subjective analysis (Section 5) the following parameters are put forward as the most influential ones as far as productivity and costs are concerned.

### **Age of mine.**

There is no substantial evidence that the age of a mine has a bearing on the productivity and costs. One thinks of older mines as having many shafts (cost centres) and long lines of communication. On the other hand they are generally mining low grade ore as the better areas have long since been mined out and this type of marginal operation has to conserve its resources to remain profitable. To summarise therefore age per se has no real bearing on productivity.

### **Shaft layout.**

Long lines of communication and many cost centres adversely affect productivity. For this reason only, smaller shafts, serving smaller areas have the advantage over larger centralised systems. Many mining engineers in recent years have justified the sinking of new mother shafts to service sub-vertical shafts, rather than incur longer travelling times. On the other hand, large shaft systems enjoy the benefits of scale of operations. However in deep new mines, the capital cost of the shaft system can represent a major portion of the initial pre-production expenditure. To exacerbate matters, the larger the system and the deeper it goes the longer the pre-production period becomes, with adverse effects on the value of the project.

To summarise therefore, relatively shallow mines should have smaller shafts serving smaller areas provided these can be accessed quickly and inexpensively. Early revenue can be used to finance future expenditure. Deep orebodies will have to be served by a single shaft system located near the centre of gravity of the high grade ore.

Wherever possible new projects will have to be accessed from existing mines for the following reasons:-

- \*to improve prospect drilling and evaluation
- \*to expedite pre-production work
- \*to minimise pre-production time
- \*to reduce pre-production expenditure

\*to minimise the risk to the investor.

In conclusion therefore, the shaft layout is a major design factor and it has a major effect on productivity and costs.

#### The development layout.

The provision of tunnels is an expensive exercise both from an initial (capital) as well as an on-going (operational) point of view. They are necessary in that they provide access for men, material, equipment, ventilation, and rock. They are also necessary for determining the payable areas. More tunnels means better access but at an ever increasing cost (initial and on-going costs). The ratio of square meters/development meter is the best indicator of the density of tunnels (encompasses inter-level spacing, raise/crosscut spacing and the total orepass capacity). The survey of mines and subsequent analysis corroborates the importance of these parameters and the extent to which labour productivity and costs are affected by them.

#### Effective shift time.

Although this parameter was not covered in the survey, there can be little doubt as to its importance and the effect that it has, not only on labour productivity and production costs, but also on the revenue generated. Individual mines, such as West Rand Cons. and Beatrix, which are mining close to surface, would appear to confirm this.

#### Management philosophy and policy.

In the last few years, management has made some giant steps towards increasing the productivity and profitability of the mines under their direction. In most cases this has been born out of necessity rather than choice. This is not a derogatory statement as far as the personal quality of the people concerned but rather an indictment of the nature and development of these massive, labour intensive organizations. It is difficult to bring about change in a persons attitudes and perspectives, particularly if these have been fostered over a period of a century or more. Industrial relations have been practiced between management and their skilled employees (whites) for close on 70 to 80 years (S.Bendix, 1989) but for probably less than a decade with the unskilled and semi-skilled ones (blacks). Therefore the management style has tended to be a very "autocratic" one particularly with regard to the latter group. In the face of a much more aggressive stance by the National Union of Mineworkers (NUM), many Mining Houses and their top management have changed to a "participa-

tive" management style. This approach has led to an increase in "trust" in management which was being undermined by the training and education provided by NUM. Other techniques such as Quality Circles, Small Problem Solving Groups, Composite Crews, Multi-skilling and so on, have also been introduced in an effort to involve the workers in the decision making process and to accept responsibility and accountability. Motivation has improved as a result and together with properly constructed incentive schemes have led to major improvements to productivity. Other cost cutting and wastage reduction schemes have also led to a reduction in costs.

From a gold and revenue point of view, steps have been taken to curtail the mining of sub-economic ore even if this meant a reduction in the milling rate. Steps have also been taken to reduce all forms of waste dilution and improve the recovery of gold. New technology has played a major role in the drive to improve productivity and reduce costs.

#### Stope width

Although the correlation between stope width and tons/employee is somewhat fragile, the logic would suggest that as the stoping width increases from a low point (say 0.7 meter) so should productivity, as the conditions for breaking and removing the rock improve. Similarly, as the stope width increases above say 1.8 meters so productivity should decline, breaking, cleaning and support operations become more onerous. The mines in the survey fall into a group, which is between the extremes mentioned and this may account for the apparent lack of correlation.

#### Mining method.

There has been sufficient literature to prove that certain mining methods contribute more towards greater productivity than others. For example, trackless mechanised mining methods (TM3) and continuous scrapers can lead to stoping and development layouts which are far less costly. Similarly, "throw-blasting" has the potential to improve labour productivity (West Rand Cons.), as has the previously mentioned methods. The former methods have also been dealt with under the heading "Square meters /development meter". No evidence of the effect of this parameter (mining method) were gathered during the survey, except that there appears to be a definite correlation between cost/ton milled and square meters/development meter. It appears to be an inverse relationship as expected.

#### Rock engineering.

Rock engineering aspects were not measured directly. However rock engineering principles dictate development layouts, type of support etc. and therefore affect productivity and costs. These aspects have been dealt with under different sections.

Degree of mechanization and the use of new technology.

Although this is a major consideration in the planning of a new mine and will no doubt have a major effect on total productivity (G.L.Smith, 1991), there is no evidence of this in the survey, probably because of the limited extent to which new techniques and equipment is being utilised at present.

Geological factors.

Adverse geological conditions can have a major impact on the development layout, productivity and costs on a mine. There is no statistical evidence to this effect, in the survey. Mines like Vaal Reefs and Kloof probably attribute their poor performance (at least in part) to this parameter.

Depth of mining operations.

One can accept that labour productivity will decline and costs increase with an increase in the average depth of the workings. The survey seems to corroborate the fact that depth is a major parameter which affects labour and total productivity and costs.

The dip of the reef.

From the survey and logically one should conclude that the dip of the reef is not a major parameter as far as productivity is concerned.

Grade of the ore and the percentage payability.

The survey shows (and this is supported by a certain logic) that a direct relationship exists between grade of ore and working costs and an inverse one with productivity. Grade of ore is a major parameter in this respect. No statistics were obtained from the mines regarding the percentage payability. However where the ore is more difficult to locate, more development will have to be done, the ratio of square meters / development meter will decrease and so will productivity.

Environmental conditions.

The results of the survey seem to confirm a fairly strong relationship between environmental conditions and productivity and costs. Thus parameters such as Virgin Rock Temperature, Wet Bulb Temperature and Wet Kata Reading are strong indicators as one would logically expect. The same does not apply to Face Velocity.

#### Face advance rate.

The survey would seem to confirm the importance of this parameter as an indicator of productivity and costs even though the sample is a small one and there may be other over-riding factors. Where there is an indication that the reverse is true, this is probably due to the adverse effect of a high "lost blast" rate.

#### Dilution.

There is no indication of the amount of dilution on the mines covered by the survey. However, several studies into this parameter have shown that the dilution has an inverse relationship with the panel length. For conventional mining methods (face and strike scraping) the percentage dilution varies from about 6% to 10%. For TM3 the dilution can increase to above 15%. However there exists the possibility of separating most of the waste in the reef plane, which means that in theory at least, the dilution can be reduced to zero. Other factors which affect the dilution are the dimensions of the gullies and the amount of waste sorting and packing which is being done. From a logical point of view there can be no doubt that revenue and square meters/stope employee will vary inversely with the dilution while stope costs will vary directly. One can concur with other authors that dilution is a major parameter as far as total productivity is concerned.

#### The production rate.

In some respects, it pays one to operate a mine at the highest practical level of production. In this way one can benefit from the scale of operations and reduce unit costs. Secondly, because the ore reserve is mined out in a shorter period, the overhead costs (over the life of the mine) are reduced. On the other hand one needs to fully utilise the expensive capital equipment. For example shafts have an effective life of several decades. Thus one needs to compromise between the level of capital and operating cost to obtain the highest level of productivity. In this way one can arrive at the optimum level of production. (C.D.Patterson, T.M.Espach, 1988)

The major parameters affecting productivity and costs.

In summary therefore, the following parameters have a major effect on labour productivity and expenditures:-

- \*the shaft layout
- \*the development layout
- \*the stope layout
- \*effective shift time
- \*management philosophy and policy
- \*mining method
- \*rock engineering
- \*degree of mechanization and technology
- \*geological factors
- \*depth of mining
- \*grade of ore mined and percentage payability
- \*environmental conditions
- \*face advance rate
- \*dilution
- \*production rate.

To a large extent the ability of mine management to improve productivity is governed by decisions made during the planning and design phases of the mine. Items such as shaft and development layout, mining method, degree of mechanization and technology and production rate fall into this category. On the other hand, items such as depth, rock pressure and stress, virgin rock temperature, geological factors, grade of ore and percentage payability, depth of mining are to a very large extent beyond the control of management.

The items which management must attempt to control and exert maximum influence on are thus:-

- \*the stope layout
- \*effective shift time
- \*management philosophy and policy
- \*environmental conditions
- \*face advance rate
- \*dilution

## 7. THE IDEAL MINE AND LAYOUT.

The ideal shaft layout, from a financial point of view, is one which will give the best Net Present Value (NPV) or Rate of Return on the investment. It will of necessity be a compromise between initial capital spending and the operating costs over the life of the mine. With deep orebodies this is likely to be a single shaft system situated near the centre of gravity of the payable ore. With shallow orebodies, a series of shafts is preferable, to enable the orebody to be exploited expeditiously and at minimal pre-production capital cost.

The ideal development layout is one which provides the necessary access and services effectively at the minimum cost (amount of tunnelling). Inter-level spacings should be increased to the maximum amount - 144 to 200 meters - and raise spacing to at least 400 meters. There should be only one orepass per stope. The logistics of servicing the stopes can be accommodated by the new equipment and technology presently available.

The best mining (stopping) method is the one which will produce the ore at the lowest cost (labour and stores - less than R30/ton, 1989 money), with the highest face advance rate - plus 20 meters/month (and minimum "lost blasts") and with a minimum of dilution (less than 4%) and minimum loss of gold. Once again, the latest equipment and technology must be utilised to achieve this. (TM3, Impact Ripper, diamond impregnated rope rock cutter, water-jet cleaning, Continuous Scrapers, Transvac etc.).

Effective shift time must be maximised by optimising the transport system (matching cages in shafts with passenger trains in high speed haulages etc).

Management style must engender trust, motivate and utilise the work-force to its fullest potential. Rock engineering principles must be adhered to in order to reduce pressure bursts and falls of ground, with minimum cost and loss of mineable ore.

The appropriate degree of mechanization and level of technology must be utilised to maximise productivity. In this regard, hydro-power, backfilling, refrigeration, TM3, "impact breaking", rock cutting, communications would appear to hold out the most promise for the future.

Environmental engineering principles must be adhered to in order to provide healthy and safe conditions, conducive to reasonable and sustainable levels of physical exertion.

## 8 CONCLUSION.

An attempt has been made to determine the factors which affect productivity and the level of working expenditure on the gold mines, members of the Chamber of Mines of S.A. A cross section of mines from the various districts was selected for examination and comparison. The comparison was supposed to be both objective as well as subjective. Mainly because of the limited information available, the selection of mines for the survey and the presence of inter acting and over-riding factors, the investigation turned out to be much more subjective than was originally hoped. Fifteen parameters were identified as having a major impact on productivity. These are:- the shaft, development and stoping layout, effective shift time, management philosophy and policy, mining method, rock stress conditions, degree of mechanization and technology, geological factors, depth of mining, grade of ore mined and percentage payability, environmental conditions, face advance rate, dilution and production rate.

Those factors which are within the control of mine management and which should receive most of his attention are:- the stoping layout and method, effective shift time, management philosophy and policy, environmental and rock conditions, face advance rate, dilution.

## 2 FURTHER RESEARCH.

This project started out as an investigation into the different types of development and stoping layouts in use in the gold mines. The objective was to try to establish how labour productivity and costs were affected by the differences in these layouts. The investigation showed that in fact, there were not that many differences and that whatever effect the layout had on working costs and productivity, there were other, possibly over-riding factors, which could also affect the results obtained. A decision was then made, to identify the main parameters which affected the important issues, using the information already obtained from the mines. During the course of the analytical work however, it soon became obvious that the sample of mines was too small (particularly for the select group) to make the statistical (objective) analysis convincing.

Nevertheless, it was decided to proceed because the author was more familiar with those mines and the information available was much more detailed. This enabled the subjective analysis to be more convincing.

A new investigation should be launched, hopefully with the same amount of co-operation as was given to the author in the first instance, by the management of the mines and this investigation should concentrate on the main parameters identified (making use of a more specific questionnaire) and including all the mines. This should make the objective analysis more acceptable. Management could be asked to identify any site-specific factor, which in their opinion, may have an over-riding influence.

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