A CRITICAL REVIEW OF RECHARGE ESTIMATION METHODS USED IN SOUTHERN AFRICA

by

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Thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy in the Faculty of Natural and Agricultural Sciences, Department of Geohydrology, University of the Free State, Bloemfontein, South Africa

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December 2003

Acknowledgements

Given that I arrived in Africa with nothing more than a backpack and desire to hitch hike around the continent until my savings ran out, it seems remarkable that I am submitting my doctoral thesis only a few years later. For that, I am indebted to many South Africans, not only for the opportunities that they offered me, but also their continuing kindness and hospitality. These include:

- My good friends Dirk Rudolph and Louis van Niekerk, the Managing Directors of Geo-Hydro Technologies (GHT), who not only suggested that I undertake research at the Institute of Groundwater Studies (IGS), but also provided financial and project support so that I might do so;
- My supervisor, Professor Gerrit van Tonder, who encouraged me when I deserved it, supported me when I needed it, and was honest with me when my concepts were flawed;
- Staff, colleagues, and students of the IGS, who provided a world-class learning environment;
- Mr Siep Talma of the Quaternary Dating Research Unit, Centre for Scientific and Industrial Research, Pretoria, who gave me the benefit of his many years practical experience, challenged my ideas, and was an invaluable source of information;
- Mr Piet Kotzee (SAMANCOR Hotazel Manganese Mines), Mr Frik Wessels (Matla Power Station) and Ms Gladys Yona (GHT) who sampled rainwater on my behalf;
- Ms Melanie Dalton (Matla Power Station), Ms Jana Klopper (Hendrina Power Station), Mr Solly Mathe (Matimba Power Station), Ms Erika Prinsloo (Kriel Power Station), Mr Oscar van Antwerpen (SAMANCOR Hotazel Manganese Mines), and Dr Johan van der Merwe (Department of Water Affairs and Forestry), each of whom had the vision to commit funds to isotope testing;
- My family in Australia, who provided the necessary emotional support to enable me to pursue my career in a foreign land, and managed my affairs back home in my absence;
- My girlfriend Lucina Burns, who made many sacrifices so that I might achieve my dream;
- Francois Fourie, William Patterton, and Louis van Niekerk for preparing the "Opsomming" of this thesis;
- My many African friends, who not only took me into the homes, but also let me into their hearts.

Abstract

This investigation provides an overview of recharge-related research undertaken in South Africa and its neighbouring countries to date, and where possible, integrates new findings such that regional recharge processes can be better understood. Particular emphasis was given to the use of environmental tracers, specifically chloride and the stable isotopes δ^2H and $\delta^{18}O$, due to the relatively low cost associated with applying these techniques. Episodic recharge processes were also considered, a field of study that appears to have received minimal attention in research undertaken to date in Southern Africa.

During the course of this investigation, refereed articles from local publications and international journals were widely consulted, with preference given to those relating to research undertaken on the African continent, or regions with a climate similar to semi-arid to arid Southern Africa. Wherever possible, published material was compared to field data collected during this study from various inland locations in South Africa, and differences and similarities between the respective datasets discussed. Case studies from different geohydrological environments in South Africa were also undertaken with a view to determining the applicability of environmental tracer methods for quantifying recharge processes in the region.

A new stable isotope-based technique, the Modified Amount Effect (MAE) Method, was developed during this study. This technique provides insight into episodic recharge processes by estimating the proportion of preferential pathway-to-matrix-derived flow entering an aquifer, and the amount of rainfall required to initiate recharge via the respective flow paths. Significantly, the proportion of bypass flow can be determined without undertaking expensive and time consuming unsaturated zone studies, both factors often of primary concern when undertaking recharge investigations in developing countries.

Four recharge thresholds can be identified using the MAE Method; the low and high recharge thresholds that must be exceeded before recharge occurs via preferential pathways or the matrix, respectively. These represent threshold limits, the low value only of importance following successive months of wet weather, the high value representing the rainfall that must be received to restore an aquifer system to equilibrium after prolonged dry spells. Once these thresholds are known, the recharge history of a site can be modelled using available rainfall data by adapting the Cumulative Rainfall Departure (CRD) Method. An important finding of modelling undertaken during this investigation is that in those semi-arid to arid areas where most recharge

water enters the aquifer via the matrix, the period of time that elapses between successive rainfall events that exceed the matrix recharge threshold often extends to scores of years. This has significant resource management implications for much of the region as it indicates that the current approach of basing allocations on average recharge estimates is only justified if sufficient groundwater is available for use over the entire period between recharge events. Indeed, in many instances it may be more realistic to base groundwater allocations on the proportion of bypass flow-derived recharge entering site aquifers initially, the allocations increasing once aquifer storage, recharge threshold, and recharge event return period characteristics are better understood.

Modelling of recharge processes could be significantly refined if long-term Static Water Level (SWL) and stable isotope data was available for a given aquifer. Indeed, the most important recommendation in this report is to encourage the collection of monthly rainfall, SWL, stable isotope and chemistry (rain, surface, and groundwater) data at selected sites in Southern Africa. Sites should be selected on the basis of land use, climatic zone, and aquifer type, with a view to extrapolating findings made there to similar locations elsewhere, and data stored and managed using centralized databases. This can be best achieved with government funds, although given the recent changes in legislation requiring industry to ensure site monitoring is undertaken in some countries in the region, there is considerable scope for private money to contribute to data collection. The development of a standardized monitoring code of practice for industries operating in the region, which outlines minimum monitoring frequencies for input parameters necessary for recharge estimation, should therefore be a priority.

In terms of recharge estimation, the Stable Isotope (SI) Method was found to return comparable results to the Chloride Mass Balance (CMB) Method in both wetter and drier inland areas of South Africa. However, both the SI and MAE Methods were found to be sensitive to the recharge history of the site, the returned recharge estimate significantly higher when calculated immediately after recharge via the matrix had occurred. This is not to say that these estimates were wrong (indeed they were representative of site recharge processes at the time of sampling), but that rainfall in the preceding months should be considered prior to sampling. In general though, sampling should be undertaken near the end of the dry season, which in the summer-dominant rainfall areas of Southern Africa is between September and November (allowing for a 30 to 60 day lag time between rainfall and subsequent recharge).

Given the observed sensitivity between SI and CMB Method estimates and site recharge history, there is a potential for those estimates based on unsaturated zone moisture concentrations to be a reflection of the last recharge event and not long-term recharge to the aquifer. As such, it is recommended that, in Southern Africa, estimates be based on chloride and stable isotope concentrations determined for saturated zone (i.e. groundwater) samples only.

While the CMB Method is an attractive recharge estimation option in Southern Africa, geomorphological and geological controls were found to significantly influence the techniques application, particularly at sites where recharge via preferential pathways occurs. Of concern, however, is that the method represents a long-term average condition, which dependent on the volume of groundwater stored in a given aquifer, could extend to thousands of years or more. Thus, the validity of applying the method could be questioned at some sites because of past land use and climatic changes, and indeed those that may be currently occurring as a result of global warming. To restore confidence in the method, steps should be taken to assess what influence these changes may have had on aquifer chloride concentrations using an inverse modelling approach. Further, the impact of future changes on the chemical and isotopic composition of recharge water should also be considered.

Given the limitations of the CMB Method, it may seem paradoxical that its use be recommended within some fractured rock terrains. On a regional scale, fractured rock aquifers are commonly regarded as equivalent porous mediums for modelling purposes, a necessity given the significant variations in porosity, hydraulic conductivity, and storage that occur between adjacent areas. Thus, even where long-term water level data is available, the hydraulic conditions that contribute to the observed water table response at a given site following recharge represent an average for the area surrounding a given borehole. The CMB Method negates the need for measuring or estimating these hydraulic parameters, as it already represents a long-term average of recharge. This is not to say that water levels should not be taken at fractured rock terrains, but rather that recharge calculated using water balance methods is checked using the CMB Method in those areas completely overlain by a porous unsaturated zone of significant thickness. Indeed, the comparison of results obtained using multiple estimation technique's is recommended during all recharge-based investigations, whether conducted in fractured rock or porous environments.

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List of symbols and abbreviations

‰	Parts per thousand (per mill)
a	Proportion of rainfall from a given rainfall event contributing to recharge
a	Chemical activity co-efficient for a given element
A	Nuclear mass number
A_{aq}	Total aquifer area (m^2)
A_b	Total catchment area (m^2)
ABA	Acid Base Accounting
A_f	Depression floor area for a given catchment (m^2)
AMD	Acid Mine Drainage
A_r	Area through which recharge occurs (m^2)
A_{total}	Total aquifer area (m^2)
b	Constant
BHP	Broken Hill Proprietary
BIF	Banded Iron Formation
c	Constant
C	Constant
ccSTP	Solution rate at Standard Temperature and Pressure (g/H_2O/yr)
CBOM	Commonwealth Bureau of Meteorology
CFC	Chlorofluorocarbon
Cl_d	Chloride concentration in sampled precipitation derived from dry fallout (mg/L)
Cl_{gw}	Chloride concentration of groundwater (mg/L)
Cl_p	Chloride concentration of precipitation (mg/L)
Cl_{pp}	Chloride concentration of unsaturated zone preferential pathway-derived moisture (mg/L)
Cl_{ro}	Chloride concentration of run-off (mg/L)
Cl_{rw}	Chloride concentration of recharge water (mg/L)
Cl_{uzm}	Chloride concentration of unsaturated zone matrix-derived moisture (mg/L)
CMB	Chloride Mass Balance
CRD	Cumulative Rainfall Departure
CSIR	Centre for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organization
CTIA	Cape Town International Airport
d	Regression constant
d_{aq}	Average thickness of the aquifer (m)
d_{dry}	Deuterium excess for dry season precipitation (‰)
d_{gw}	Deuterium excess for groundwater (‰)
DO	Dissolved Oxygen (%)
DR	Drainage Resistance (Δh/time unit)
d_{uz}	Average thickness of the unsaturated zone (m)
DWAF	Department of Water Affairs and Forestry
d_{wet}	Deuterium excess for wet season precipitation (‰)
E	Vibrational energy (MeV)
EC	Electrical Conductivity (mS/m)
EMPR	Environmental Management Programme Report
ET	Environmental Tracer
ETM	Evapo-Transpiration and Mixing Zone
EWL	Evaporated Water Line
EWL-U	Evaporated water line for matrix water in the unsaturated zone

GHT	Geo-Hydro Technologies
GMWL	Global Meteoric Water Line
GPS	Global Positioning System
GW_{ave}	Average concentration of groundwater (mg/L and ‰)
GW-E	Groundwater with an evaporated signature
GWL	Groundwater Line
h	Piezometric head (m)
h	Planck's constant
H	Potential head (m)
HMM	Hotazel Manganese Mines
I	Total inflows into a study area (m^3/yr)
IAEA	International Atomic Energy Agency
I_{ave}	Average annual aquifer inflow into a study area (m^3/yr)
IFD	Intensity Frequency Duration
IGS	Institute for Groundwater Studies
ITCZ	Inter-Tropical Convergence Zone
k	Extraction co-efficient
k	Boltzmann's constant
K	Recession constant or hydraulic conductivity (m/s), dependent on context
LEWL	Local Evaporated Water Line
LMWL	Local Meteoric Water Line
LOI	Loss On Ignition
LSU	Livestock Unit (1 LSU = 1 Full-grown steer)
m	Number of months denoting short-term memory
m	Molecular mass
MAE	Modified Amount Effect
mamsl	Metres above mean sea level
MAP	Mean Annual Precipitation (mm)
MDR	Minimum Data Requirements
MRT	Mean Residence Time (yr)
MWL-U	A line offset from, and parallel to, the LMWL
n	Number of months denoting long-term memory
N	Number of neutrons
n_{aq}	Fractional effective porosity of an aquifer (%)
$\mathrm{n_{aq}}$	Effective porosity of an aquifer (%)
NATO	North Atlantic Treaty Organization
n_{uz}	Effective water filled porosity of the unsaturated zone (%)
$\mathrm{n_{uz}}$	Effective porosity of the unsaturated zone (%)
O	Total outflows from a recharge study area (m^3/yr)
O_{ave}	Average annual aquifer outflow from a study area (m^3/yr)
P	Precipitation (mm)
P_{ave}	Average precipitation over a given period (mm)
pp	Preferential pathway
PMB	Physical Mass Balance
PP_{flow}	Preferential pathway-derived flow
PSD	Particle Size Distribution
PVC	Poly Vinyl Chloride
Q	Total volume of water lost from a given aquifer (m^3/yr)
q	Dating correction factor
q	Specific discharge (m/s)

Q	Bond strength (MeV)
QUADRU	Quaternary Dating Research Unit
R	Effective recharge (m^3/yr)
R_{ave}	Average recharge (mm)
RC	Recession Constant
R_m	Matrix-derived recharge
ro	Run-off
R_{pp}	Preferential pathway-derived recharge
RT_{ave}	Average threshold to be exceeded before recharge occurs (mm)
RT_{high}	Average threshold to be exceeded before recharge via matrix occurs (mm)
$RT_{high-pp}$	Highest recharge threshold to be exceeded before PP_{flow} occurs (on average; mm)
$RT_{high-uzm}$	Highest recharge threshold to be exceeded before matrix flow occurs (on average; mm)
RT_{low}	Average threshold to be exceeded before recharge via preferential pathways occurs (mm)
RT_{low-pp}	Lowest recharge threshold to be exceeded before PP_{flow} occurs (on average; mm)
$RT_{low-uzm}$	Lowest recharge threshold to be exceeded before matrix flow occurs (on average; mm)
S	Storativity
SG	Specific Gravity
SI	Stable Isotope
SOI	Southern Oscillation Index
SVF	Saturated Volume Fluctuation
SWL	Static Water Level (m or mamsl)
t	Time (yr)
T	Absolute temperature (^{0}K)
t_{ac}	Average transit time through confined aquifers in a given system (yr)
t_{au}	Average transit time through unconfined aquifers in a given system (yr)
TDS	Total Dissolved Solids
TMG	Table Mountain Group
TRI	Technology Research Institute
t_{total}	The sum of the average transit times through a given aquifer system (yr)
TU	Tritium Unit (1 TU = 0.118 Bq/L)
t_{uz}	Average transit time through the unsaturated zone in a given catchment (yr)
UCT	University of Cape Town
upp	Unsaturated zone preferential pathways
USA	United States of America
USC	Unified Soil Classification
uz	Unsaturated zone
uzm	Unsaturated zone matrix
V	Saturated volume stored in the aquifer (m^3)
v	Molecular velocity (m/s)
WMO	World Meteorological Organization
X	Proportion derived from preferential pathway-derived recharge
X	Reactant or proportioning factor, depending on context
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
y	Head regression factor
Y	Proportion derived from matrix-derived recharge
Y	Reaction product

z	Height of sampling point within aquifer (m)
Z	Number of protons
α	Fractionation factor
β	Constant
δ	Relative difference in concentration between a sample and a known standard (‰)
θ	Volumetric moisture content (%)
Δd	Difference in the depth of the recharge front (m)
Δh	Change in piezometric head (m)
ΔS	Change in aquifer storage (m^3)
Δt	Change in time (yr)
ν	Frequency of vibration (Hz)
ρ	Bulk density of aquifer material (g/cm^3)
σ	Symmetry value used in fractionation calculations

1 Introduction

There can be no doubt that the water industry in Southern Africa has been profoundly transformed in recent decades, with millions of Rands invested in water infrastructure aimed at ensuring every inhabitant has access to fresh drinking water. In drier, more isolated areas, this has often meant that available groundwater resources must be exploited. As such, government and non-government organizations have invested in research associated with developing new assessment techniques so that these resources can be managed sustainably. In common with all these strategies is the need for recharge processes to be understood, and if possible, quantified.

An understanding of site recharge behaviour is far more important than many geohydrologists realize, and goes beyond estimating the average proportion of rainfall entering a given aquifer. For example, from a planning viewpoint, groundwater ingress into a mine is seldom problematic to mine management providing it is constant; problems occur when unpredicted increases occur, such as those associated with the sudden entry of recharge water into surrounding aquifers. Thus, through understanding the episodic nature of recharge in semi-arid and arid areas, and therefore the thresholds that must be exceeded before recharge occurs, geohydrologists are better able to provide predictive advice for their clients.

This investigation seeks to provide an overview of recharge-related research undertaken in Southern Africa to date, and where possible, integrate findings such that regional recharge processes can be better understood. It is important to note that a considerable body of research has been undertaken on the subject in the region, with significant contributions made by investigators including Kirchner et al. (1991), Bredenkamp et al. (1995), and Beekman et al. (1997a). In this instance, particular emphasis was given to assessing the use of environmental tracers during recharge studies, specifically chloride and the stable isotopes δ^2H and $\delta^{18}O$, due to the relatively low cost associated with applying these techniques. Further, episodic recharge processes were also considered, a field of study that appears to have received minimal attention in research undertaken to date in the region.

During the course of this investigation, refereed articles from local publications and international journals were widely consulted, with preference given to those relating to investigations undertaken on the African continent, or regions with a climate similar to semi-arid to arid Southern Africa. Wherever possible, published material was compared to field data collected from various inland locations in South Africa during this study (refer **Figure 1**), and differences and similarities between the respective datasets discussed. Case studies from different geohydrological environments in South Africa were also undertaken with a view to determining the applicability of environmental tracer methods for quantifying recharge processes in the region.

With a view to best integrating findings made by other researchers with those made during this investigation, this thesis has been structured as follows:

i. Literature review. Recharge estimation methods are assessed in Section 2, with particular attention given to discussing data requirements and the limitations of the respective techniques. A tabulated summary of all reviewed methods has also been included at the end of this section so that those methods with potential for application in a given study area can be easily identified;
ii. Assessment of precipitation and surface water characteristics. An understanding of the chemical and isotopic characteristics of site precipitation is required when applying environmental tracer techniques during recharge studies. These characteristics are discussed within a separate chapter (Section 3), which includes a literature review and an assessment of pre-existing data with that collected during this investigation. The isotopic characteristics of surface water at sites sampled as part of this study are also discussed (Section 4);
iii. Geohydrological case studies. Three field-based case studies undertaken during the course of this investigation are discussed in Sections 5, 7 and 8. These studies, which were based in areas adjacent to Hotazel, Petrusburg and Kriel and Matla Power Stations (refer **Figure 1**), were initially aimed at determining the applicability of the Chloride Mass-Balance and Stable Isotope Methods for estimating recharge in semi-arid South Africa. However, during the course of these investigations, a new stable isotope-based technique for assessing episodic recharge behaviour, herein referred to as the Modified Amount Effect Method, was developed (refer Section 6). As a consequence, the assessment of potential applications for this new method was included within the scope of this investigation.

The spatial distribution of data was considered at several sites during this investigation, the default kriging setting in the program "Surfer" (Golden Software, 2002) used to contour each. This standardized approach was taken because there was insufficient data to allow site-specific contouring methodologies to be developed, and because efforts to obtain such data would have shifted available financial resources away from the primary aim of the study.

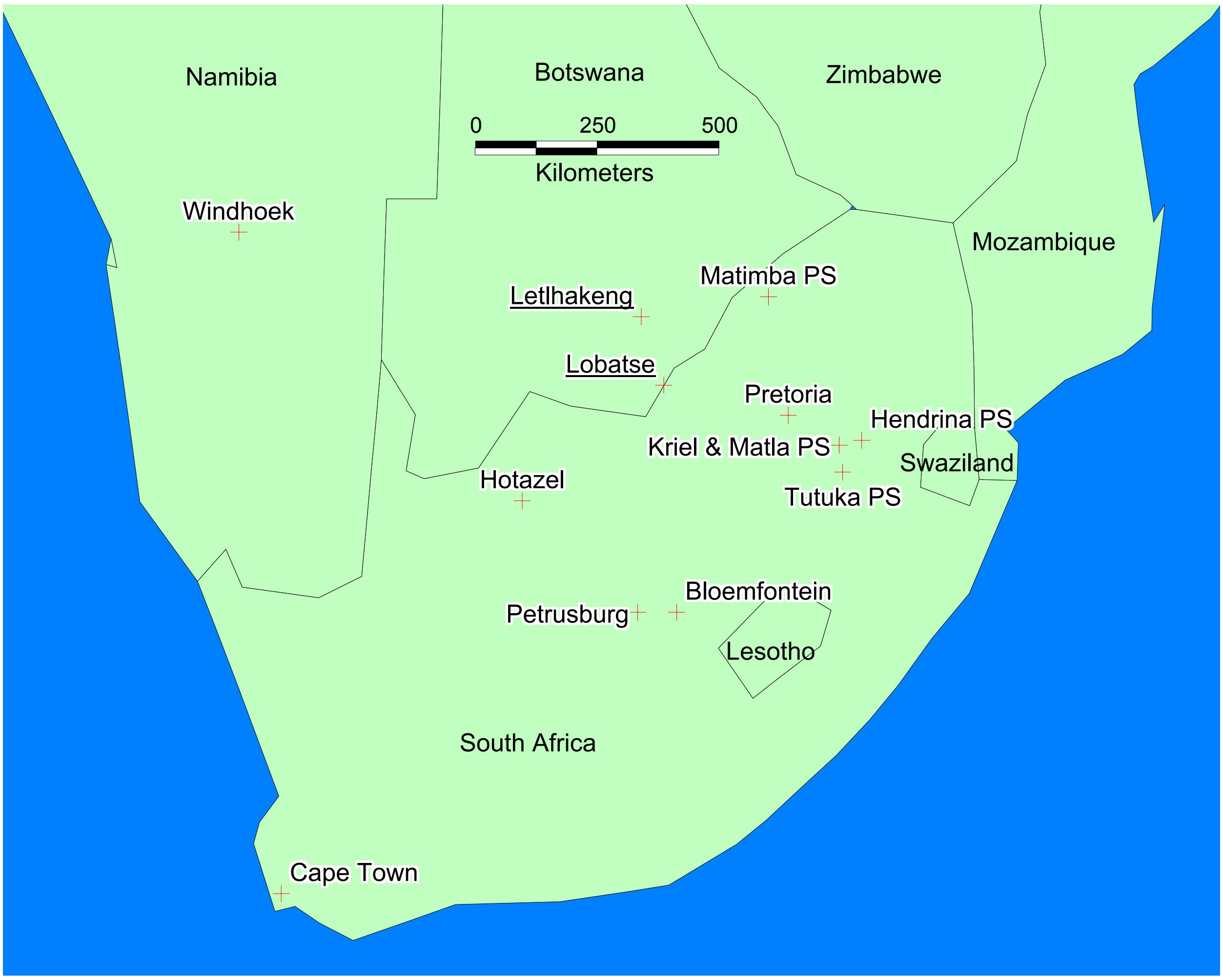


Figure 1 *Map of Southern Africa showing sites where case studies were undertaken. Note that interpreted rainfall data for Cape Town, Pretoria, and Windhoek was obtained from existing databases. Those sites where findings of significance to this investigation were made by other researchers are also shown (underlined).*

2 A review of some recharge estimation methods

2.1 Introduction

This review focuses on common, practical recharge estimation methods, which in broadest terms, are either of physical mass balance, or environmental tracer, type. Attention has also be given to describing how these can be applied so that a better understanding of site recharge processes is obtained, which is often of equal importance from a catchment management perspective.

2.2 Physical mass balance methods

So as to satisfy the Law of Mass Conservation, the annual hydrologic balance for a given aquifer is (Fetter, 1994):

$$I = O \pm (\Delta S / \Delta t) \quad \textbf{Equation 1}$$

Which in simplest terms equates to (adapted from Sungaro et al., 2000):

$$R = Q \pm (\Delta S / \Delta t) \quad \textbf{Equation 2}$$

Where I = Total inflows (m^3/yr); O = Total outflows (m^3/yr); Δt = Change in time (yr); R = Effective recharge (m^3/yr); Q = Total volume of water lost from a given aquifer as baseflow and artificial extraction (m^3/yr), and; ΔS = Change in aquifer storage (m^3). It is this equation that forms the basis of physical mass balance approaches to recharge estimation as pioneered by Theis (1937), although in a South African context, it was the development of the Saturated Volume Fluctuation (SVF) Method by van Tonder (1989), and subsequent application by van Tonder and Kirchner (1990), that popularised the approach. The advantage of the SVF Method over earlier physical mass balance approaches was that annual recharge to a portion of the aquifer, as opposed to the aquifer as a whole, could be rapidly assessed by using a computer to calculate boundary flow conditions shown in the equation:

$$R = Q + (\Delta S / \Delta t) + O_{Ave} - I_{Ave} \quad \textbf{Equation 3}$$

Where O_{Ave} and I_{Ave} define average annual aquifer outflows and inflows, respectively. While the finite element model developed by van Tonder (1989) was purpose built, finite difference models developed upon the Modflow (McDonald and Harbaugh, 1984) code platform are equally effective in larger study areas where hydrologic boundary conditions are poorly defined (Fetter, 1994).

As with all recharge estimation methods, the accuracy of physical mass balance methods is largely dependent on the quality and quantity of data available for interpretation. Thus, the concept of Minimum Data Requirements (MDR) is inferred, which for the reliable application of the SVF Method requires a comprehensive understanding of aquifer characteristics. Of importance, however, is that it is not only physical attributes such as storativity and permeability that must be known; the data set must also confirm whether spatial variations in these parameters are represented across a given aquifer. To do this, sufficient boreholes and test data must be available from across the entire aquifer so as to confirm whether an isotopic or anisotropic system is represented.

The scale of identified aquifer variations is also of significance. Pump testing undertaken in the Hotazel area (Northern Cape) during this study indicated that gravel-bearing, porous aquifers there were anisotropic, and aligned along inferred palaeo-tributaries that had developed parallel to the interface between two older, sub-cropping, geological formations (refer Section 5). However, logs for hundreds of exploration boreholes drilled on a 50 x 50 m grid in the vicinity of the pumped bore indicated that the pumped gravel aquifer had limited extent, and thus on a regional scale, identified anisotropy and heterogeneity was insignificant. It should be appreciated though, that these conclusions could not have been made without a significant body of geological data.

The problem of anisotropy and scale is even more apparent in the fractured rock aquifers of Southern Africa due to the significant variation between the hydraulic properties of the individual fractures and the adjoining matrix. For modelling purposes, these systems are generally regarded as being equivalent to a porous medium (Middlemis et al., 2000), a further assumption being that any hydraulic boundaries (i.e. the contact between a fault and undisturbed country rock) are clearly defined. However, as the size of the study area increases, the data set coverage required to define such boundaries also increases, be it borehole, geophysical, or otherwise. Additionally, it is often assumed that the hydraulic characteristics along a designated boundary are consistent, which may not be the case under field conditions.

Unless a given aquifer in its entirety is modelled, boundary conditions can prove problematic in other ways as the outflow/inflow flux for a given aquifer segment must often be assumed on the basis of available Static Water Level (SWL) data. The reliability of these flux estimates is questionable, however, unless long-term seasonal variations in SWL, discharge, and extraction can be determined from a data set of sufficient resolution (i.e. measurements taken at monthly intervals). Such data sets are often non-existent for most aquifers in remote semi-arid to arid areas of Southern Africa, thereby limiting the application of the SVF Method in these areas.

Work undertaken by Bredenkamp et al. (1995) indicates that the Cumulative Rainfall Departure (CRD) Method can be applied in areas with incomplete SWL datasets. Since aquifers are constrained by hydrological mass balance conditions, the piezometric head within a given aquifer can be expected to either increase or decrease in response to recharge and discharge, respectively. It is therefore unsurprising that a good correlation exists between piezometric head and the departure from long-term average annual rainfall, with increases in water level observed in wetter than average years, and decreases in drier years (refer **Figure 2**). While artificial withdrawals from an aquifer system will obviously impact upon the observed water level response to rainfall, Bredenkamp et al. (1995) showed that a modified CRD/piezometric head relationship could still be determined for exploited aquifers providing extraction was relatively constant over time. Thus, the CRD Method provides a relatively simple means of regressing recent water level data using long-term rainfall records, such records available for most of Southern Africa.

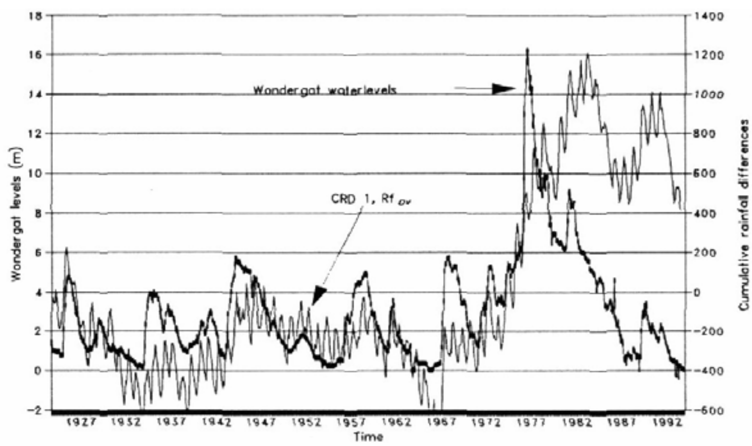


Figure 2 *Relationship between SWL and CRD at Wondergat, Northwest Province, South Africa (from Bredenkamp et al., 1995).*

Bredenkamp et al. (1995) summarized the derivation of the CRD Method, the main attributes of which are outlined here. They note that the exponential decline in groundwater head within an aquifer receiving no recharge, or where no artificial discharge is occurring, can be simplified to (Ernst, 1962):

$$h = h_o.c$$ **Equation 4**

Where h = head, and $c = 1 - yt$, y representing the head decline factor over time t within the aquifer. Piezometric head response to recharge can therefore be summarized as:

$$h_i = (h_{i-1}.c) + (R_i / S) \qquad \textbf{Equation 5}$$

R representing recharge, at time i. In terms of the proportion of rainfall from a given rainfall event (P_i) that contributes to recharge (a), R_i can be re-written as:

$$R_i = a(P_i - b) \qquad \textbf{Equation 6}$$

Where b is a constant. Thus, the change in head between recharge events becomes:

$$\Delta h_i = \{h_{i-1}.(c-1)\} + \{(a/S)(P_i - b)\} \qquad \textbf{Equation 7}$$

Or, for the current status j in relation to all previous periods i:

$$\sum_{j=1}^{j=1} \Delta h_j = \sum_{j=1}^{j=1} h_{j-1}(c-1) + a/S \sum_{j=1}^{j=1} (P_i - b) \qquad \textbf{Equation 8}$$

Since, for an aquifer in long-term equilibrium $\Delta h \approx 0$, this becomes:

$$\sum_{j=1}^{j=1} h_{j-1}(c-1) = -a/S_i (P_{ave} - b) \qquad \textbf{Equation 9}$$

Or:

$$h_{i-1}(c-1) = \{(-a/S)(P_{ave} - b)\} \qquad \textbf{Equation 10}$$

Where P_{ave} = Average precipitation for the investigated period. Therefore, with reference to Equation 7:

$$\Delta h_i = \{(a/S)(P_i - b)\} - \{(a/S)(P_{ave} - b)\} = \{(a/S)(P_i - P_{ave})\} \qquad \textbf{Equation 11}$$

Which can be written as:

$$\Delta h_i = (a/S)\{(P_i - (k.P_{ave})\} \qquad \textbf{Equation 12}$$

The term k a co-efficient used to account for natural (no artificial extraction; $k = 1$) and artificial ($k > 1$) site conditions, which can be calculated using (Verhagen et al., 2001):

$$k = 1 + \frac{Q}{A_{total}}.P_{ave} \qquad \textbf{Equation 13}$$

Q and A_{total} representing abstraction from the aquifer, and total aquifer area, respectively. Since the magnitude of the observed response in the piezometric head of the aquifer is a function of storativity, Equation 12 becomes:

$$R = a\{P_i - (k.P_{ave})\}$$ **Equation 14**

Given the similarity between CRD and water level response, a linear relationship is implied between rainfall and storage within the aquifer, whereby:

$$V_i = (c.CRD) + d$$ **Equation 15**

V_i representing the saturated volume stored in the aquifer, c, a proportional constant where $c = a/S$, and d, a regression constant, with CRD values determined from the following equation:

$$_{ave}^{1}CRD_i = (P_i - P_{ave}) + _{ave}^{1}CRD_{i-1}$$ **Equation 16**

Where $_{ave}^{1}CRD$ = represent cumulative rainfall departure for month i. This can be related to the average recharge (R_{ave}) for the period under investigation by adapting Equation 14:

$$R_{ave} = \frac{a}{n}\sum_{i=1}^{n}(P_i - P_{ave})$$ **Equation 17**

n, representing the total number of months where $P_i - P_{ave} > 0$.

While the CRD Method obviously compliments the SVF Method in many instances, caution is nevertheless required when applying the technique in areas where there is a poor understanding of site characteristics. The use of a representative storativity value at a specific site is particularly significant, and indeed on a catchment scale, the use of many values may be required to account for the spatial, and perhaps more importantly, depth-related variations, that occur. Thus, any potential geological controls on storativity (i.e. dykes, faults, facies changes, etc) must be identified prior to undertaking catchment-scale recharge investigations, and their influence on site storage characteristics assessed.

It is also important for the aquifer type to be known when applying either the CRD or SVF Methods. Bean (2000) showed that the lag time between rainfall and water level response across a basaltic aquifer in Northern Australia varied proportionally with unsaturated zone thickness, which is to be expected in an unconfined/semi-confined aquifer system draped by an unsaturated zone with relatively consistent physical characteristics on a regional scale. In confined systems, however, piston flow generally occurs (Geyh et al., 2000), and thus no response may be apparent at some sites due to head losses associated with groundwater flow within the aquifer in accordance with Darcy's Law (Darcy, 1856). Observed piezometric response in confined systems may be further complicated by lunar cycles, which have been shown to influence head pressures in some confined aquifers of Australia's Great Artesian Basin. Therefore, as a recharge estimation tool, the use of CRD and SVF Methods will be restricted to unconfined/semi-confined aquifer systems in all but exceptional cases where a significant body of aquifer data is available from the point of recharge to the area under investigation.

Lag time can also be of significance when applying the CRD Method, the term "memory" sometimes used to describe its importance (Verhagen et al., 2001). Lag times are influenced by climate, geology and geomorphology, and thus vary with location. For example, in Karoo Basin aquifers near Bloemfontein in the Southern Free State the lag is typically one month (Verhagen et al., 2001), although this can vary from less than a month to about six months depending on the distance of the water table observation point from the recharge area (Kirchner et al., 1991). In equivalent Central Botswana aquifers, a response is typically observed about four months after significant rainfall (Van Rensburg and Bush, 1995). These short-term lags (or alternatively, short-term memories) can be easily incorporated into the CRD Method, particularly where they occur within a particular year as would occur in summer rainfall climates in the Southern Hemisphere. However, difficulties occur when the CRD Method is used to predict recharge in areas where rainfall from preceding years contributes current water table response (i.e. the long-term memory of the aquifer is of significance). This can be overcome by adapting Equation 16 (Bredenkamp et al., 1995):

$$ {}_{n}^{m}CRD_{i} = \frac{1}{m}\sum_{j=i-(m-1)}^{i} - k\frac{1}{n}\sum_{j=1-(n-1)}^{i} + CRD_{i-1} \qquad \textbf{Equation 18} $$

Where m and n denote the number of months denoting the short and long-term memory, respectively.

A shortcoming with most models in that uniform recharge over the model area is assumed, which may not be the case, particularly on a regional scale. However, unless detailed, and often expensive, investigations are undertaken initially, it is almost impossible to identify areas of preferred recharge. Research undertaken by Kirchner et al. (1991) near Bloemfontein indicated that the main recharge areas there were associated with deposits of coarse sediments at dolerite hill bases (Kirchner et al., 1991). Later work by van Tonder (van Tonder and Bean, 2003) suggests recharge can be twice as high in these low-lying areas, which infers that the component of recharge derived from run-off standing in surface water depressions is greater than that derived directly from rainfall. Similar recharge behaviour has been observed elsewhere, particularly in semi-arid to arid areas (Vogel and van Urk, 1975; Wood and Sandford, 1995; Bazuhair and Wood, 1996).

Moisture retention within the unsaturated zone, particularly in semi-arid to arid areas draped with thick sand sediments, can have a significant influence on recharge associated with a given rainfall event (Foster et al., 1982; de Vries et al., 2000). While recharge is diffusive in these environments, the recharge pulse is only mobilized by extraordinary rainfall, and is thus episodic in character. Indeed, long-term water level data for a dolomitic aquifer in the North West Province of South Africa indicates that substantial recharge had only occurred five times in the period between 1940 and 1970 (Bredenkamp and Vogel, 1970). Thus, unless long-term climatic and water level data is available for a given semi-arid or arid study area, model-derived recharge estimates should be treated with caution. Further, in terms of effectively managing groundwater resources in these areas, it is not only essential that average annual recharge be quantified, but also:

- The amount of rainfall that is required to initiate recharge (herein referred to as the "recharge threshold");
- Potential changes in resource requirements (i.e. a new groundwater supply for a mine or town is required) are considered, with resource allocations based on the total amount of water that can be used between recharge return periods rather than the annual average.

Physical mass balance methods are not restricted to the saturated zone, however, and various workers have developed recharge estimation techniques that incorporate unsaturated zone variables such as soil moisture content and its influence on hydraulic conductivity and retention capacity, vegetation type and rooting depth (Thornthwaite, 1948; Thornthwaite and Mather, 1955; Foster et al., 1982; Johannson, 1988). Thus, the MDR necessary to allow recharge to be estimated for any given catchment can be significant, particularly where conditions vary constantly (Kirchner et al., 1991). Of more concern though is the uncertainty associated with using parameter values suggested from laboratory or field tests. As van Tonder and Bean (2003) note, a pump test determined hydraulic conductivity for a sandy aquifer represents an average for those profiles influenced by water table draw down, both spatially and with depth. In comparison, a sand permeability can be determined in the laboratory on a sample the size of a match box, the result no doubt correct for that particular sample, but in all likelihood much less representative of the aquifer as a whole. Further, it is assumed that:

- In situ samples have not been disturbed during sampling;
- Remoulded disturbed samples are representative of site conditions;
- In situ measuring devices, such as lysimeters, have been sited at a location representative of the unsaturated zone as a whole, their installation not having impacted upon site hydraulic behaviour.

The use of unsaturated zone techniques is further complicated when the potential for catchment-scale diffuse (the term "dispersion flow" is also used) and localized preferred pathway flow to occur at a given site during different seasons is considered, such as would be expected where surficial highly plastic clays occur. At these sites, rapid recharge via shrinkage cracks could be expected at the start of the wet season, with diffuse processes becoming more important as the clay swells in response to moisture content increases with continuing rainfall. Indeed, in Burkina Faso, rapid recharge via fractures was identified during the wet season, the slower moving, matrix-derived unsaturated moisture not entering the aquifer until the following dry season (Mathieu and Bariac, 1996). The prevailing climate would also be of importance at these sites, the depth of seasonal moisture variation (and thus the depth of shrinkage crack development) greater in semi-arid and arid areas, as opposed to sub-tropical zones.

In South Africa, Kirchner et al. (1991) inferred recharge via preferential pathways near the Free State town of Dewetsdorp, which is located 80 km southeast of Bloemfontein. Of the 18 moisture tubes taken at the study site following 450 mm of rainfall over a three-day period in 1988, only two showed any significant increase in moisture content below a depth of 1 m. Water levels in site boreholes increased significantly during this period, however, indicating the rapid percolation of recharge water into the aquifer via preferential pathways as opposed to catchment-scale diffuse flow from the site surface.

Van der Lee and Gehrels (1990) developed the lumped parameter model EARTH for use during a long-term recharge study in semi-arid Botswana, although they note that variations of the model have also been applied in more humid areas. In simplest terms, EARTH relates the mass balance of the unsaturated zone to that of the underlying aquifer by considering the saturated hydraulic conductivity and retention capacity of unsaturated zone material, equivalent root zone depth, interception capacity at the surface, and the aquifer co-efficient of storage. As a consequence, inputs into the hydrological balance for a given study area, such as precipitation, run-off, standing water in low-lying areas, evapo-transpiration, movement of moisture through the unsaturated zone, and recharge, can be represented.

On the basis of the required input parameters, it is clear that seasonal unsaturated zone behaviour must be well understood before applying the EARTH model, with the authors noting that the model is particularly sensitive to changes in unsaturated zone retention capacity. However, recharge to site aquifers can be estimated using groundwater level data alone if aquifer storativity is known i.e.

$$h = (RC.R/S) - RC.\frac{dh}{dt} \quad \textbf{Equation 19}$$

Where (from van der Lee, 1989)

$$RC = \beta.DR.S \quad \textbf{Equation 20}$$

RC and DR representing a Recession Constant and Drainage Resistance, respectively. Both RC and DR are site-specific parameters, RC being determined from the trend of decreasing groundwater levels over time, with DR measured directly from these recession curves in cases where S is known. Thus, the parameter h_i can be solved as follows:

$$h_i = h_{i-1} - \frac{\Delta t}{RC}.h_{i-1} + \frac{R}{S}\Delta t \quad \textbf{Equation 21}$$

Note that unlike the CRD Method solution proposed by Bredenkamp et al. (1995), van der Lee and Gehrels (1990) have incorporated the rate of exponential decay in piezometric head into the derivation of h_i. In the event that S is not known, recharge can still be estimated by calibrating soil moisture and groundwater level data.

2.3 Environmental tracer methods

2.3.1 Chloride-mass balance method

Since being initially proposed by Eriksson and Khunakasem (1969), the Chloride-Mass Balance (CMB) Method has been widely applied in recent time (Edmunds and Gaye, 1994; Wood and Sanford, 1995; Bazuhair and Wood, 1996; Beekman et al., 1997a). The value of using chloride for mass balance-calculations is due to the conservative character of the anion, whereby it is generally neither absorbed or desorbed during flow through a given aquifer (Geyh et al., 2000). In its simplest form, the method assumes that chloride in recharge water percolating vertically through the unsaturated zone and into the aquifer is derived entirely from precipitation (i.e. no chloride is derived from site lithologies), the chloride concentration of the recharge water controlled by evapo-transpiration processes. Further, unsaturated zone flow must be diffuse, thereby ensuring that recharge water, while moving at different velocities throughout the zone, has been thoroughly mixed such that recharge water has a consistent chloride concentration upon entry into the aquifer (adapted from Geyh et al., 2000). Thus, the proportion of rainfall (*R*, expressed as an equivalent depth in mm) that actually enters the aquifer as recharge is:

$$R = (Cl_p / Cl_{uzm}).P \qquad \textbf{Equation 22}$$

Where *P* = Precipitation (mm), and Cl_p and Cl_{uzm} represent the chloride concentration (mg/L) of precipitation and recharge water percolating through the matrix of unsaturated zone, respectively.

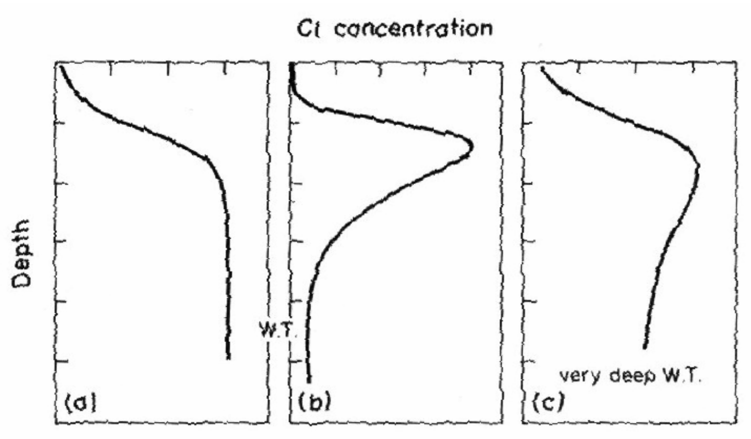


Figure 3 *Characteristics of unsaturated zone chloride profiles for varying recharge conditions (from Allison, 1988). Profile (a) represents diffuse flow; (b) preferential flow, and; (c) either the movement of chloride with the recharge water pulse associated with a particular rainfall event, or a variation in the chloride concentration of recharge water over time, possibly as a result of climatic changes.*

Cl_{uzm} can be determined directly from soil samples taken below the zone of influence of evapo-transpiration once mixing has occurred, referred to as the Evapo-Transpiration and Mixing Zone (ETM) by Beekman et al. (1997b), although in many instances analogous to the root zone. Gardner (1967) noted that unsaturated zone chloride concentrations should increase with depth within the root zone, stabilizing below the zone of influence from evapo-transpiration, which in most areas occurs at a maximum depth of 2 to 3 m (Wood, 1999). However, unsaturated zone chloride concentration profiling undertaken by Foster et al. (1982), Sharma and Hughes (1985), Wood and Sanford (1995), and a summary of findings made by researchers worldwide prepared by Edmunds and Verhagen (2000), clearly indicates that this is often not the case, particularly in semi-arid to arid areas. Such variations from expected profile characteristics have been attributed to the presence of preferential pathways within the unsaturated zone, and the influence of climatic changes on recharge processes by Allison (1988; **Figure 3**).

During their investigation of recharge processes in a coastal sand aquifer of Western Australia, Sharma and Hughes (1985) suggested that vegetation-induced soil moisture changes were limited to the upper 10 m of the profile. Indeed, supporting data on root distribution confirmed that major roots were generally restricted to the top 5 m of the study area, significantly deeper than the ETM zone limit suggested by Woods (1999). They therefore assumed that the chloride concentration of soil moisture determined on samples taken below 10 m represented Cl_{uzm}. Further investigation revealed, however, that the average chloride concentration of groundwater in the underlying aquifer, Cl_{gw} (mg/L), was approximately half Cl_{uzm}, and thus the entry of recharge water into the aquifer was not solely a result of diffuse flow through the unsaturated zone. To explain this, Sharma and Hughes (1985) developed the concept of bypass flow, whereby recharge water not only enters the aquifers via diffuse flow through the unsaturated zone matrix, but also via preferential pathways (also referred to as macropores). For a given recharge event, this can be expressed mathematically as (adapted from Sharma and Hughes, 1985):

$$R = R_{pp} + R_m \qquad \textbf{Equation 23}$$

Where R_{pp} and R_m represent the contribution of recharge (mm) derived from preferred pathways and the matrix, respectively, the respective contributions of chloride to groundwater given by:

$$R_m = R.(Cl_{gw} - Cl_{pp})/(Cl_{uzm} - Cl_{pp}) \qquad \textbf{Equation 24}$$

And

$$R_{pp} = R.(Cl_{uzm} - Cl_{gw})/(Cl_{uzm} - Cl_{pp}) \qquad \textbf{Equation 25}$$

Where Cl_{pp} = chloride concentration of recharge water entering the aquifer via preferred pathways (mg/L). For bypass flow to occur, however, the unsaturated zone must have dual-porosity, whereby the matrix, while potentially having significant storage potential, has a much lower hydraulic conductivity than the pathways along which preferential flow occurs. Further, this conductivity contrast must be sufficiently great such that water flowing along preferential pathways is less enriched in chloride than matrix water due to reduced exposure to evapo-transpiration (i.e. $Cl_{uzm} > Cl_{pp}$). Thus, in an ideal dual-porosity aquifer where no matrix-preferred pathway water mixing occurs during flow from the site surface to the aquifer, recharge can be expressed as:

$$R_{ave} = \{(Cl_p / Cl_{uzm}).MAP\} + \{(Cl_p / Cl_{pp}).MAP\}$$ **Equation 26**

Where R_{ave} = average annual recharge as a proportion of Mean Annual Precipitation (*MAP*, expressed in mm). The resulting difference between Cl_{uzm} and Cl_{pp} also highlights the influence of varying residence times on resulting soil water concentrations. Indeed, for the CMB Method to be applicable, the unsaturated zone must act as a buffer, whereby all recharge water (i.e. rainfall that does not leave the system as run-off) is stored within the unsaturated zone for a period of time prior to recharge.

It should also be appreciated that, unless all water from a given recharge event drains from the aquifer before the arrival of the next recharge pulse, Cl_{gw} represents a long-term average of several recharge events. Indeed, the storage and drainage characteristics of some aquifers are such that the resulting groundwater chloride concentration represents a long-term average of recharge over many (in some cases thousands) of years. Thus, in a case where all recharge water enters an aquifer, be it via diffuse flow through the matrix or preferential pathways, the governing mass balance ratio can be adapted to:

$$R_{ave} = (Cl_p / Cl_{gw}).MAP$$ **Equation 27**

This is convenient because:

- Values for Cl_{uzm} and Cl_{pp}, which must often be determined via relatively expensive and time consuming unsaturated zone studies, do not have to be determined for recharge to be estimated;
- Of the potential for significant variations in Cl_{uzm} and Cl_{pp} to be observed between different unsaturated zone profiles taken within the same study area. This is to be expected when results obtained from relatively small samples taken from a limited number of profiles are assumed to be representative of the unsaturated zone in its entirety;
- Anion exclusion, the process whereby negatively charged clay particles repel the similarly charged chloride ions, the chloride moving more rapidly through the unsaturated zone as a result, may be a problem in some heavier textured soils (Gvirtzman et al., 1986);

- It allows a direct recharge estimate to be made on the basis of the amount of chloride in the aquifer, rather than the amount of chloride that may possibly reach the aquifer via the unsaturated zone.

As Wood (1999) notes, steady-state equilibrium is another of the limiting assumptions of the CMB Method. This is problematic as aquifers in some areas may have been recharged thousands, and in some cases millions, of years previously. By considering the cumulative chloride concentration and moisture content of samples taken at different depths within the unsaturated zone, Allison et al. (1985) inferred that either the recharge rate, or the chloride concentration of recharging water, or some combination thereof, had changed over time, these generally correlating with changes in climate. Given that the climate in Southern Africa has changed significantly and often during the course of the last 30000 years (Partridge et al., 1990), any assumption of long-term rainfall equilibrium would seem invalid. Further, rain and groundwater chloride concentrations should have remained constant over time, although this cannot be stated with any certainty unless long-term monitoring data is available. Indeed, even if monitoring were to begin now, the collected data may no longer be representative of past conditions, particularly if global warming-induced climate change does occur.

Land use changes can also influence the validity of the recharge estimates obtained using the CMB Method. Work undertaken in semi-arid Northeastern Australia by Thorburn et al. (1991) showed that recharge fluxes in catchments with similar geomorphology and site soils varied with land use. Sites compared during their study were within native forests, recently cleared areas where pasture had been established, and recently cleared areas where crops had been planted. On the basis of unsaturated zone observations following an abnormally wet rainy season, they noted that recharge was significantly higher in recently cleared areas as compared to forested sites, with the highest recharge occurring in the cropped study area. With the return of a more normal wet season, however, no significant difference was reported in recharge rates between the respective sites. These observations are important because they not only highlight the vulnerability of basing recharge estimates on one-off studies of site unsaturated zones, but also the significance of episodic recharge in semi-arid environments. Further, they demonstrate changes in land use have the potential to significantly alter site hydrology such that it is no longer in steady-state equilibrium. Indeed, relatively recent land use changes in southern regions of Australia (i.e. the replacement of native forests with pastures and crops) have so increased recharge such that thousands of hectares of previously productive agricultural land are lost to water-logging and dryland salinity processes annually.

While a relatively straightforward recharge estimation technique, it is apparent that the CMB Method is not without limitations. Some relating to the use and determination of input parameters include:

1. *Lack of data*. With perhaps the exception of Botswana (Beekman et al., 1997a), and to a lesser extent Zimbabwe (Beekman and Sungaro, 2002), there is limited long term rainwater chloride concentration data for Southern Africa, and insufficient data to allow temporal variations in rainwater chloride concentration to be explained;
2. *Spatial variations and sampling practices*. Work undertaken in Botswana by Beekman et al. (1997a) indicates that, not only can significant spatial variations in average annual rainwater chloride concentration occur in Southern Africa, but also rainfall chloride concentrations can vary with the gauge type used at a given sampling site;
3. *Laboratory practices*. Rainwater chloride concentrations must be accurate and precise to at least 0.1 mg/L (van Tonder and Bean, 2003), which is beyond the capability of many Southern African testing facilities;
4. *Pollution*. Rainwater, and the gauges used for sampling, is prone to contamination from airborne dust and bird droppings. Airborne dust is particularly problematic in semi-arid to arid areas as it can also contribute chloride to a site surface as dry fall out (Cl_d), and thus in these regions, the chloride-mass balance becomes:

$$R = \{(Cl_p + Cl_d)/Cl_{gw}\}.MAP \qquad \textbf{Equation 28}$$

5. *Site geology*. It is commonly assumed that the recharge pulse moves vertically through the unsaturated zone, although within the Southern African Carboniferous to Jurassic aged Karoo Basin, where shallow, sandy soils can overlie less permeable sedimentary sequences on gently sloping ground, this probably rarely occurs (Sami and Hughes, 1996). Under these conditions, interflow/throughflow and the formation of perched aquifers is encouraged, resulting in higher soil water chloride concentrations than would be expected if only vertical flow through the unsaturated zone occurred (i.e. a horizontal distance flow path is longer, allowing more chloride from the zone of evapo-transpiration to be dissolved);
6. *Site geomorphology*. The surface characteristics of a given catchment area also influence the chloride concentration of recharge water, particularly in those areas where it is derived from surface water bodies. In areas where significant run-off occurs prior to recharge, chloride

deposited as dry fall out is remobilised to lower lying areas. Should water accumulate in these areas and recharge occur, contained chloride will have been derived not only from precipitation, but also catchment run-off. Wood and Sanford (1995) note that, for closed depressions, recharge can be estimated as follows:

$$R = \{(Cl_p / Cl_{rw}).P\} + \{(A_b.Cl_{ro} / A_f.Cl_{rw}).ro \qquad \textbf{Equation 29}$$

Where *ro* = equivalent depth of run-off (mm) with a chloride concentration of Cl_{ro} (mg/L) from a catchment with area A_b (m^2), and A_f = the area of the depression floor (m^2), the limiting assumptions being all chloride in the catchment, both surface and sub-surface, moves to the depression. Note that in those areas where lateral movement occurs, the value Cl_{ro} will comprise chloride mobilized directly from the catchment surface, and that derived from throughflow. Further, the chloride concentration of interflow in influent stream areas will also be of significance. Thus, it is the chloride concentration of the standing surface water, which is derived from run-off, throughflow, rainwater, and where necessary, interflow, that must be determined. In terms of recharge assessment in semi-arid and arid Southern Africa, this is often problematic because these samples must be taken as soon as possible after rainfall, and often from remote or poorly accessible areas.

There are cases in Southern Africa where CMB Method-derived recharge estimates have been unrealistic, although perhaps unsurprisingly when the methods many limitations are considered. Murray (2002) estimated recharge to a 213-km^2 portion of Namibia's Windhoek Aquifer to be approximately 2% and 20% MAP using physical and CMB methods, respectively. When the geology of the site was also considered, however, it was apparent that low chloride groundwater (approaching 5 mg/L in some instances) was associated with fault zones that occur within the quartzites of the Aus Mountains, which van Tonder and Bean (2003) attributed to rapid recharge along the trend of these structures. Indeed, recharge along these preferential pathways was probably sufficiently rapid that there was virtually no storage, and therefore no opportunity for evapo-transpiration-induced enrichment, within the unsaturated zone. Further, given that weighted average Cl_p = 1 mg/L, observed increases in the chloride concentration of groundwater could be attributed to the dissolution of dust-derived chloride on the catchment surface as opposed to evapo-transpiration effects. If this is true, then some chloride could also have bypassed the fault zones as surface run-off with characteristics $Cl_p + Cl_d = Cl_{ro}$, for which there is strong evidence given the order of magnitude difference between the two recharge estimates of

Murray (2002). Therefore, while point-recharge may have been between 20 and 100%, recharge to the aquifer as a whole, is significantly less.

Another high CMB Method-derived recharge estimate was obtained during preliminary investigations undertaken near Cape Town, South Africa, where recharge approaching 50% MAP was suggested by Weaver and Talma (2000). In common with the Windhoek Aquifer, aquifers of the Table Mountain Group (TMG) are fractured, with visual observations indicating that there is little, and in many places no, unsaturated zone. Conditions are therefore ideal for site-specific, rapid recharge along preferential pathways, and the transfer of chloride with run-off to sites within the catchment where unsaturated zone storage could occur. A further complication is the proximity of the study area to the coast, which could facilitate the movement of chloride out of the catchment altogether. Thus, as with the Windhoek Aquifer, a holistic understanding of the distribution and movement of chloride within the entire catchment, and not just a selected area within it, will be required before recharge to TMG aquifers can be reliably estimated using the CMB Method.

2.3.2 Stable isotope (^{18}O and ^{2}H) method

2.3.2.1 Theoretical background

Atomic nuclei are bound by strong forces between protons and neutrons, each contributing to the mass of a given nucleus (referred to as a nuclide) such that (Mook and de Vries, 2000):

$$A = Z + N \qquad \textbf{Equation 30}$$

Where A = the nuclear mass number, and Z and N refer to the number of protons and neutrons in the nucleus, respectively. For the sake of convention, the relationship between A, Z, and N for the element X, can written:

$$^{A}_{Z}X_{N} \qquad \textbf{Equation 31}$$

Or simplified to:

$$^{A}X \qquad \textbf{Equation 32}$$

Neutrons within a given nuclide have a stabilizing influence, counteracting the repulsive forces that develop between the like-charged protons. Stable nuclides for light elements are often characterized by an equal number of protons and neutrons, although a slight excess of neutrons may not necessarily result in instability. For example, $^{2}_{1}H_{1}$, $^{12}_{6}C_{6}$, $^{14}_{7}N_{7}$, and $^{16}_{8}O_{8}$ are all light element stable nuclides with an equal number of protons and neutrons (i.e. $Z = N$), whereas

$^{13}{}_{6}C_{7}$, $^{15}{}_{7}N_{8}$, and $^{18}{}_{8}O_{10}$, while still stable, have an excess of neutrons (i.e. $Z < N$). In all cases, those light element nuclides where $Z = N$ are naturally in abundance, with the exception of hydrogen, where the predominant nuclide is $^{1}{}_{1}H_{0}$. In some cases, however, an excess of protons or neutrons can result in instability, these unstable nuclides, which are commonly termed radioactive, decaying to form new elements or isotopes (Fetter, 1994). $^{3}{}_{1}H_{2}$ and $^{14}{}_{6}C_{8}$ are two (there are numerous) radioactive nuclides that have been used geohydrological investigations.

The term isotope is commonly used to describe those elements that have multiple nuclides, $^{16}{}_{8}O_{8}$ and $^{18}{}_{8}O_{10}$ examples of stable isotopes for the element oxygen. Thus, with respect to a given element, the terms "nuclide" and "isotope" are interchangeable.

While the chemical characteristics of a given elements different isotopes are virtually identical, minor variations develop in response to mass differences, these only important in light elements where they amount to a significant proportion of the total atomic mass (Drever, 1997). The process that causes these chemical variations is called isotope fractionation, or less commonly, isotope discrimination (Mook and de Vries, 2000), which causes:

1. *Heavier isotopes (i.e. those with greater mass) to have less mobility*. This is demonstrated in the formula:

$$kT = \tfrac{1}{2}mv^2 \qquad \textbf{Equation 33}$$

Where k = Boltzmann's constant, T = absolute temperature, and m and v represent molecular mass and average molecular velocity, respectively. Thus, since molecules must have the same value of $\frac{1}{2}mv^2$ regardless of the isotope present, heavier molecules must have a lower velocity, which reduces both the diffusion velocity and the collision frequency. Given the relationship between collision frequency and reaction rates (i.e. high collision frequency = high reaction rate), it is unsurprising that, for a given element, lighter isotopes generally react faster than heavier ones;

2. *Heavier isotopes have higher binding energies*. Faure (1986; 1998) notes that the strength of a covalent bond resulting from attraction between two atoms in a given divalent molecule is related to that molecules vibrational energy. This is perhaps best demonstrated by the formula:

$$E = \tfrac{1}{2}h\nu \qquad \textbf{Equation 34}$$

Where E, h, and *v* represent vibrational energy, Planck's constant, and the frequency of vibration, respectively. Since:

$$\nu = 1/\sqrt{m}$$ **Equation 35**

Then, for a given element, E and *v* will be lower for heavier isotopes. Because a reduction in E is required before two atoms bond, it follows that this bond will strengthen with decreasing E, resulting in stronger bonds in heavier, as opposed to lighter, isotopes for a given element.

The term "isotope fractionation" is used to describe the process whereby, in response to differences in reaction rate, reactant and product concentrations of respective isotopes are disproportionate for a given thermodynamic reaction. This can be expressed mathematically as:

$$\alpha_{X-Y} = R_x / R_Y = \{(Q*_X / Q_X)/(Q*_Y / Q_Y)\}$$ **Equation 36**

Where α = the fractionation factor, X = the reactant, Y = the reaction product, and Q and Q* = the bond strength (often referred to as "partition functions") of the respective isotopes. Since E is temperature-dependent i.e.:

$$Q = \sigma m^{3/2} \sum e^{-E/kT}$$ **Equation 37**

Fractionation is encouraged as T decreases ($\alpha \neq 1$; σ is a symmetry value), with α approaching 1 at high T.

The thermodynamic reaction involving the production of vapour from water (i.e. evaporation) for the common oxygen stable isotopes is written (as shown in Clark and Fritz, 1997):

$$\alpha^{18}O_{water-vapour} = (^{18}O/^{16}O)_{water} / (^{18}O/^{16}O)_{vapour}$$

For evaporation to occur, the bond between an evaporating water molecule and hydrogen in liquid water must be broken, the required energy a function of vapour pressure and T at the surface of the water body. Thus, as vapour pressure and T increase, so does the rate of evaporation. However, as the humidity at the surface of the water body rises, the reaction direction can reverse (i.e. condensation can occur) as a function of concentration. Thus, under equilibrium conditions where there is no net evaporation or condensation:

$$H_2O_{water} \leftrightarrow H_2O_{vapour}$$ **Equation 38**

Of significance, however, is the difference in vapour pressure between different isotopes, which is greatest for the heaviest ($^2H_2{}^{18}O$) and lightest ($^1H_2{}^{16}O$) isotopes, the lighter molecule having a higher vapour pressure due to its elevated reaction rate. Upon evaporation, a relative increase in the concentration of molecules containing ^2H and ^{18}O occurs within the remaining water due to the removal of $H_2{}^{16}O$ with vapour, the term "Rayleigh fractionation" used to explain such progressive removal of a given isotope.

It should be appreciated that ^{2}H and ^{18}O abundances are very low, contributing just 0.015 and 0.2% of the total elemental abundance, respectively (^{1}H and ^{16}O comprise 99.985 and 99.762%; Faure, 1998), and thus the determination and use of absolute isotopic ratios is problematic. This can be overcome by comparing the isotopic concentration of a given sample to that of a common standard i.e.

$$\delta^{18}O = 1000.\{(^{18}O/^{16}O)_{sample} - (^{18}O/^{16}O)_{standard}\}/(^{18}O/^{16}O)_{standard}$$ **Equation 39**

Where $\delta^{18}O$ = the relative difference in concentration between the sample and the standard in parts per thousand (or per mill; ‰), Vienna Standard Mean Ocean Water (V-SMOW) being the reference standard. Note that $\delta^{2}H$ can be similarly calculated.

2.3.2.2 Use in recharge studies

Work undertaken by Craig (1961) found that $\delta^{18}O$ and $\delta^{2}H$ in continental precipitation tended to have the linear relationship:

$$\delta^{2}H = 8\delta^{18}O + 10$$ **Equation 40**

This relationship is known as the Global Meteoric Water Line (GMWL). However, for a given rainfall event, precipitation becomes less abundant in $\delta^{18}O$ and $\delta^{2}H$ over time due to Rayleigh fractionation processes. External influences on fractionation also cause rain to have lower $\delta^{18}O$ and $\delta^{2}H$ abundances towards the Earth's poles, from the coast inland, and from lower to higher elevations (Drever, 1997). Indeed, Dansgaard (1964) identified that precipitation is influenced by an "amount effect", the isotopic characteristics of site rainfall varying with the amount of precipitation received (i.e. the relative abundance of $\delta^{18}O$ in sampled rainwater is lower in a 50 mm, as opposed to 5 mm, rainfall event). When all these factors are considered together, there is a potential for precipitation to plot along a Local Meteoric Water Line (LMWL) that is unique to a given area (White and Chuma, 1987; Mayo et al., 1992), the isotopic characteristics of that rainfall influenced by amount effect processes.

Given that residual water becomes progressively enriched in $\delta^{18}O$ and $\delta^{2}H$ during evaporation, these isotopes can potentially be used to determine whether groundwater is derived from rainfall, or seepage from a surface water body. Such discrimination between potential recharge sources is made easier given that $\delta^{2}H$ and $\delta^{18}O$ for evaporated waters plot along a line of lesser slope (herein called the Local Evaporated Water Line, or LEWL) relative to the LMWL, the slope determined by the temperature and relative humidity at the time of evaporation (Gonfiantini, 1986). Thus, an understanding of $\delta^{18}O$ and $\delta^{2}H$ abundances in rain, surface, and groundwater can not only provide significant insight into site recharge processes, but also identify variations in these processes on a catchment scale (Vogel and van Urk, 1975; Leaney and Herczeg, 1995; Datta et al., 1996; Herczeg et al., 1997; Jørgensen and Banoeng-Yakubo, 2000; Harrington et al., 2002).

The use of $\delta^{18}O$ and $\delta^{2}H$ in geohydrological investigations is not without complications however, as recharge water derived from rainfall may still be evaporated within the ETM zone. Indeed, the vertical percolation of $\delta^{2}H$ through a soil profile undergoing evaporation was shown to occur only once the downward diffusive flux exceeded the upward vertical movement of water induced by evaporation (Zimmerman et al., 1967). Further, where evaporation of the unsaturated zone is excessive, the ratio $\delta^{2}H:\delta^{18}O$ can be as low as 2 (Dinçer et al., 1974), significantly lower than ± 5, the value typically expected for open water bodies (Fontes and Gonfiantini, 1967). On this basis, Allison (1982) argued that, in actively recharged areas, low $\delta^{2}H:\delta^{18}O$ ratios should be represented in arid zone groundwater. He also suggested that an increase in the kinetic, or non-equilibrium fractionation (Clark and Fritz, 1997), the process whereby a sudden change in temperature or reactant concentration accelerates the forward reaction rate, was responsible for the lower slopes observed in soil moisture. This increase was attributed to differences in the thickness of the layer through which water vapour migrates following evaporation, the layer much thinner on an open water body (measured in microns; Clark and Fritz, 1997) as compared to the ETM (2 to 3 m; Wood, 1999) at a given site. Subsequent work by Sonntag et al. (1985) went further, finding that the ratio $\delta^{2}H:\delta^{18}O$ in unsaturated zone moisture samples increased with both humidity and grain size, the ratio the same as that determined for an evaporated open water body for grain sizes above 1 mm in diameter.

Allison et al. (1984) further developed the concept of ETM moisture mobilization during episodic recharge events, suggesting an empirical method for estimating site recharge on the basis of the observed displacement between ^{2}H in unsaturated zone moisture and the LMWL (refer **Figure 4**) i.e.

$$\Delta\delta^{2}H = C/\sqrt{R} \qquad \textbf{Equation 41}$$

Where $\Delta\delta^2H = \delta^2H_{LMWL} - \delta^2H_{uzm}$, and C is a constant (determined to be 20 for thick sands). It should be appreciated, however, that:

1. $\delta^{18}O$ can similarly be used to estimate recharge by assuming $C = 3$ (Allison et al., 1984);

2. The ratio $\delta^2H:\delta^{18}O$ in unsaturated zone moisture below the ETM zone, where stable isotope concentrations should have stabilised due to diffusion processes, must be equal to the slope of the LMWL;

3. The technique was developed on the basis of observations made in arid areas of Southern Australia in a winter-dominant rainfall zone;

4. Fractionation does not occur during transpiration (Zimmerman et al., 1967). This is significant because vegetation intercepts water that could potentially be recharging site aquifers so as to survive. Thus, δ^2H and $\delta^{18}O$ techniques have the potential to over-estimate recharge in vegetated areas unless site-specific values of C are determined, which potentially limits their application to arid areas. Indeed, site-specific values of C should be determined even if a site is un-vegetated;

5. The method should only be applied in those areas where recharge < 10 mm MAP.

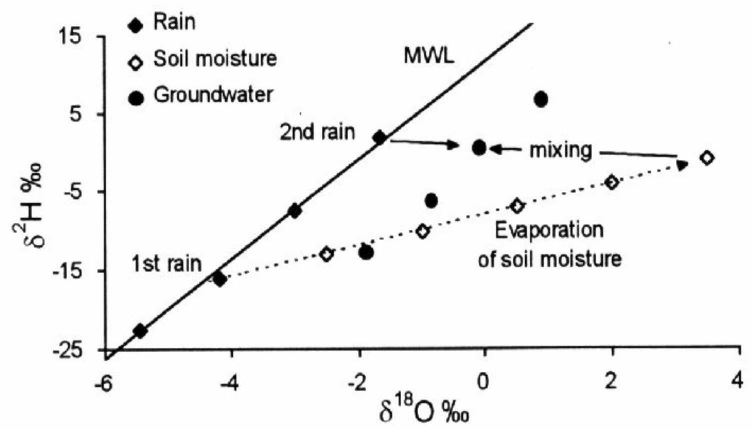


Figure 4 *Relationship between soil moisture and LMWL (from Allison et al., 1984, as seen in Clark and Fritz, 1997). Note that in uniform soils; a) soil moisture is offset from, but parallel to the LMWL, following evaporation, and; b) evaporated soil moisture falls along a line of lesser slope to the LMWL.*

The Stable Isotope (SI) Method for estimating site recharge (Allison et al., 1984) was developed by comparing concentrations of chloride, δ^2H, and $\delta^{18}O$ obtained from unsaturated zone samples. While it is not surprising that there was excellent agreement between the CMB and SI Methods at their initial study site, recharge estimates obtained using the two techniques at a site in the drier part of the Botswana Kalahari are also comparable (assuming $C = 20$; Beekman et al., 1997b). However, the applicability of the SI Method for use in wetter Eastern Botswana (Beekman et al., 1996a), more vegetated semi-arid areas, and those where a component of recharge is derived from a surface water source, is as yet unproven.

During an investigation undertaken in semi-arid USA, Wood et al. (1997) used stable isotopes to estimate the proportion of recharge derived from bypass flow. They assumed that the isotopic characteristics of site groundwater represented steady-state equilibrium between the isotopic composition of recharge derived directly from rainfall, and that from bypass flow i.e.

$$\delta^2 H_{gw} = X\delta^2 H_{pp} + Y\delta^2 H_{uzm} \qquad \textbf{Equation 42}$$

Where *X* and *Y* represent the proportion of δ^2H derived from bypass (*pp*) and matrix (*uzm*) flow, respectively. Wood et al. (1997) used the annual weighted average of δ^2H in precipitation to represent the bypass flow variable *pp*, and the average δ^2H concentration of unsaturated zone moisture (*rw*) within their study area as equation inputs. While their resulting estimate was within the range determined using other methods (65%, as compared to 60 to 80%), this should be regarded as a lower limit as the method assumes that recharge water entering the aquifer via preferred pathways has not been isotopically enriched in the ETM zone.

It should be appreciated that the use of stable isotopes for recharge estimation purposes is not restricted to arid zones. Given that recharge water molecules are comprised of ^{2}H and ^{18}O, it follows that these isotopes can be used to trace the movement of a particular recharge event through the unsaturated zone, thereby allowing the recharge flux to be estimated i.e.

$$R = n_{uz}.\Delta d / t \qquad \textbf{Equation 43}$$

Where n_{uz} = the effective water-filled porosity of the investigated profile (%), and *Δd* represents the difference in the depth of the recharge front for the period of time (*t*) that elapsed since recharge occurred. Several studies indicate that seasonal variations in ^{2}H and ^{18}O are preserved in the unsaturated zone of temperate areas (Bath et al., 1982; Saxena and Dressie, 1984; Darling and Bath, 1988; McConville et al., 2001). However, Allison (1988) noted that the recharge history was not as well preserved in drier areas, which he suggested was a consequence of diffusion of isotope concentrations associated with specific recharge events due to low recharge rates. Further, it seems likely that episodic recharge processes may have encouraged diffusion processes, the time between recharge events allowing stable isotope concentrations to stabilize throughout the profile.

A subsequent study undertaken in Northern Island by McConville et al. (2001) demonstrated the use of stable isotope tracers to estimate recharge flux through the unsaturated zone in a temperate area. Their work suggested that seasonal rainfall characteristics, represented by alternating winter-depleted and summer-enriched ^{18}O, were preserved in the unsaturated zone to a depth of approximately 1 m, before stabilizing as a result of dispersion processes. Of significance, however, was that resulting recharge calculations were consistent with those made using other methods (6.1 to 7.8% MAP; MAP approximately 900 mm). Given that calculations were based on relatively thin ETM zone thickness (about 1 m) in an area of significant recharge, investigation timing and sampling interval selection must be considered when using the technique for recharge estimation purposes.

2.3.3 Dating methods using radioactive isotopes

2.3.3.1 Tritium (^{3}H)

It was during the 1950's that researchers first suggested atmospheric thermonuclear bomb-derived tritium (^{3}H), a radioactive isotope, could potentially be used as a geohydrological investigation tool (Libby, 1953; Kaufman and Libby, 1954). Under natural conditions, ^{3}H is produced as follows (Clark and Fritz, 1997):

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{12}_{6}C + ^{3}_{1}H \qquad \textbf{Equation 44}$$

$$^{3}H + O_2 \rightarrow ^{3}HO_2 \rightarrow ^{1}H^{3}HO \qquad \textbf{Equation 45}$$

Note the incorporation of ^{3}H into the molecular structure of water, a process that was encouraged during atmospheric thermonuclear testing undertaken between 1951 and 1980, concentrations peaking in 1963 (Clark and Fritz, 1997). This is of significance to geohydrologists as it allows the age of post-thermonuclear testing-derived water to be determined if the initial concentration of bomb-derived ^{3}H is known at a given site. However, except under certain conditions, dating of water using this technique currently has limited application as atmospheric ^{3}H concentrations have essentially returned to background values due to radioactive decay (Clark and Fritz, 1997) i.e.

$$^{3}H \rightarrow ^{3}He + \beta \qquad \textbf{Equation 46}$$

The rate of decay calculated using

$$a_t\,^{3}H = a_o\,^{3}H.e^{-\lambda t} \qquad \textbf{Equation 47}$$

Where $a_t{}^3H$ = the residual ^3H activity {i.e. concentration in Tritium Units (TU, where 1 TU = 1 ^3H per 10^{18} atoms, or 0.118 Bq/kg; International Atomic Energy Agency-IAEA, 1983)} measured in the sample, $a_o{}^3H$ is the initial ^3H activity (TU), and $\lambda = \ln 2 / t_{\frac{1}{2}}$, $t_{½}$ representing the ^3H half-life of 12.43 years (Unterweger et al., 1980). True ages can still be determined using ^3H though, by comparing ^3H values with those of its daughter isotope ^3He, an advantage being that $a_o{}^3H$ does not have to be estimated (Geyh and de Vries, 2000) i.e.

$$a_t{}^3He = a_o{}^3H(1 - e^{-\lambda t})$$ **Equation 48**

Where $a_t{}^3He$ = the residual activity measured in the sample. Thus, when Equations 46 and 47 are combined:

$$a_t{}^3H = a_t{}^3H(e^{-\lambda t} - 1)$$ **Equation 49**

Vogel et al. (1974) used ^3H as a tracer to estimate the recharge flux through the unsaturated zone at Lobatse, Central Botswana, and Elandsfontein, Gauteng Province, South Africa. By comparing ^3H soil moisture profiles with an assumed $a_o{}^3H$ peak associated with thermonuclear testing, they were able to trace the downward movement of the recharge pulse associated with the bomb-derived peak at the respective test sites over time. Recharge to site aquifers could therefore be calculated using Equation 43, *t* representing the time that has elapsed since 1963. Recharge estimated on the basis of the Lobatse profile amounted to 2% MAP, although it was acknowledged that effective recharge to the aquifer may actually be less due to the interception of recharge water below the profile interval sampled. At the Elandsfontein test site, recharge between 5 and 13% MAP was suggested. Of significance at both sites was that, after approximately 15 years, the recharge pulse had not yet reached the aquifer, a confirmation that recharge is episodic, at least in part, in semi-arid regions of Southern Africa.

Although not stated by Vogel et al. (1974), it is apparent that, as with the use of the CMB Method, any recharge estimates must be based on unsaturated zone measurements taken below the ETM zone. They do note though, that reliable recharge estimates can only be obtained if collected profiles are representative of all the different unsaturated zone types that can occur within a given study, which in some instances, could result in significant spatial variations in estimated recharge. Later work by Phillips et al. (1988) and Scanlon (1992) also suggests that ^3H could be transported with vapour through the unsaturated zone, potentially comprising tracer-derived recharge estimates. However, Wood and Sanford (1995) propose that this will only be problematic at those sites with a high, unsaturated zone vapour-to-moisture ratio.

While atmospheric ^3H activity has essentially returned to background levels, recharge flux through the unsaturated zone can be estimated in those areas where the 1963 bomb peak is still represented within the unsaturated zone. Conditions favourable for the preservation of the bomb peak include a semi-arid to arid climate, episodically recharged aquifers, and sites with a significant unsaturated zone thickness and low infiltration rates. For example, work undertaken by Wood and Sanford (1995) indicates it has taken 30 years for circa 1963 recharge to reach a depth of 6.6 m in aeolian sediments beneath a pan in semi-arid USA. This equated to a recharge rate of 77 mm/year when the average effective water-filled porosity of profile material was considered.

2.3.3.2 Helium (^3He and $^3He/^4He$)

Selaolo et al. (2000) applied a variation of the ^3He dating technique to estimate recharge in Botswana Kalahari by comparing $^3He/^4He$ ratios, a potential benefit being that groundwater ages in excess of 50000 years, and therefore beyond the limit of the ^{14}C Method, can be determined. While current ^3He concentrations are a result of thermonuclear explosions and natural decay processes, ^4He, the dominant atmospheric helium isotope (Clark and Fritz, 1997), is produced via the natural decay of uranium and thorium, and their daughter isotopes. Therefore, providing any ^4He in a given groundwater sample is derived solely from the decay of the surrounding aquifer materials, $^3He{:}^4He$ values will decrease along a given flow path due to the:

- Past introduction of bomb-derived ^3H and its subsequent decay;
- In situ production of ^4He in response to radioactive decay of aquifer materials; or,
- Introduction of the ^4He into the aquifer, most likely in response to crustal degassing (Torgerson and Clarke, 1995).

The solution rate of ^4He resulting from radioactive decay can be expressed as (Andrews and Lee, 1979):

$$He_s = \rho {n_{aq}}^{-1}\{(1.19x10^{-13}[U]) + (2.88x10^{-14}[Th])\}$$ **Equation 50**

Where He_s = the solution rate of ^4He (as ccSTPg/H_2O/yr), ρ = the bulk density of the aquifer rock (g/cm^3), n_{aq} = the fractional effective porosity of the aquifer, and U and Th represent the concentration of uranium and thorium (ppm). However, in order to date a given groundwater sample, it is first necessary to account for any ^4He, which can be achieved by considering the different air to water ratios of He and Ne resulting from variations in solubility i.e. (as seen in Selaolo et al., 2000)

$$He_c = He_m.(X-1)/X$$ **Equation 51**

Where He_c = air-corrected ^4He concentrations (ccSTPg/H_2O), $X = [(He/Ne)_m/(He/Ne)_{air}].(\beta Ne/\beta He)$, where $\beta Ne/\beta He = 1.165$ (with β representing the Bunsen solubility co-efficient), and He_m the measured He isotope concentrations in groundwater (ccSTPg/H_2O). The apparent groundwater age therefore becomes:

$$t = He_c/He_s$$ **Equation 52**

Where t = apparent groundwater age in years. Once a reasonable groundwater residence time has been calculated, the long-term average areal recharge to an aquifer (mm/yr) can be estimated as follows (adapted from Beekman et al., 1996b):

$$R_{ave} = 1000.\{(n_{uz}.A_r.d_{uz}) + (n_{aq}.A_{aq}.d_{aq})\}/(A_r.t_{total})$$ **Equation 53**

Where d_{uz} = average thickness of the unsaturated zone (m), d_{aq} = the average thickness of the aquifer (m), A_r = the area through which recharge occurs (m^2), A_{aq} = the total aquifer area (m^2), and t_{total} = the sum of the average transit times through the unsaturated zone (t_{uz}), and confined (t_{ac}) and unconfined (t_{au}) parts of the aquifer, where $t_{total} = t_{uz} + t_{ac} + t_{au}$ (in years). Of concern though, is the observation that groundwater ages derived using the $^3He/^4He$ ratio method could, in some instances, be several orders of magnitude older than results obtained from ^{14}C dating methods (Heaton, 1984), which Selaolo et al (2000) attributed to; a) spatial variation in aquifer parameters as outlined in Equation 53, or; b) the introduction of ^4He from an adjoining lithologies. In these cases, alternative dating-techniques should be considered.

2.3.3.3 Carbon (^{14}C)

^{14}C has been widely used to date groundwater up to 60000 years in age (Leaney and Allison, 1986; Kotze et al., 2000; Verhagen et al., 2001; Harrington et al., 2002), although care is required when interpreting residence times calculated using Equation 47 ($t_{½}$ = 5730 years; Clark and Fritz, 1997) due to difficulties associated with accounting for $a_o{}^{14}C$ dilution by alternative carbon sources. For example, Plummer and Sprinkle (2001) showed that age estimates for a single groundwater sample varied between 8000 and 400 years depending on the technique used to determine $a_o{}^{14}C$, a condition not conducive to obtaining reliable estimates of recharge. Such findings are particularly concerning in a Southern African context due to the high proportion of carbonate-bearing aquifers that occur in semi-arid and arid parts of the region.

The determination of an appropriate $a_o{}^{14}C$ correction factor (q) for a given aquifer is a cause for much debate (Zhu and Murphy, 2000), its determination largely dependent on the physico-chemical characteristics of the aquifer in question. However, the current trend, and indeed most advanced approach, is to inverse-model those geochemical reactions that have occurred along the groundwater flow path to the point where the sample was taken, using specially developed software packages such as Netpath (Plummer et al., 1994). For this to be performed, chemical inputs for solid, dissolved, and vapour phases, and a thorough understanding of unsaturated and saturated zone processes, is required, data that is not always available, particularly in older flow systems.

Once q has been determined, Equation 47 can be adapted to allow more realistic aquifer residence times to be calculated (Clark and Fritz, 1997) i.e.

$$a_t{}^{14}C = q.a_o{}^{14}C.e^{-\lambda t}$$ **Equation 54**

Which can be re-arranged to:

$$t = -8267.\ln\left(\frac{a_t{}^{14}C}{q.a_o{}^{14}C}\right)$$ **Equation 55**

As a guide, Vogel (1970) suggested q should vary between; a) 0.65 to 0.75 for karst systems; b) 0.75 to 0.9 for sediments with fine-grained carbonate such as loess; and, c) 0.9 to 1 for crystalline rocks.

Work undertaken by Vogel (1967), and Bredenkamp and Vogel (1970), confirms that a good conceptual understanding of groundwater flow process is required when estimating recharge using the ^{14}C isotope. By adapting the Dupuit-Forcheimer approximation of groundwater flow that is constant with depth, Vogel (1967) noted that, for an isotropic and homogeneous unconfined aquifer of constant thickness that overlies an impermeable basement, and receives constant recharge over the entire aquifer surface:

$$t_z = \frac{n_{aq}d_{aq}}{R_{ave}}\ln\frac{d_{aq}}{h}$$ **Equation 56**

Where *h* is the height of the sampling point *z* above the base of the aquifer (i.e. $z = d_{aq} - h$; all distances in metres), and t is calculated using Equation 55. In many cases, however, there is insufficient data to be able to confirm Dupuit-Forcheimer conditions, and indeed, given the anisotropic and heterogeneous site conditions associated with most fractured rock aquifers, it would be wrong to assume they are represented. In these instances, average recharge (mm/yr) can be estimated using:

$$R_{ave} = 1000.(n_{aq} d_{aq} A_{aq} / MRT) \quad \textbf{Equation 57}$$

MRT representing the Mean Residence Time for groundwater within the aquifer in years, the assumption being that constant recharge over the entire area has occurred over time. Note that Equation 57 is a simplification of Equation 53, to be used in those areas where preferred recharge zones have not yet been identified, and the physical characteristics of the unsaturated zone on a catchment scale are unknown.

2.3.4 Indicators of modern recharge

Regardless of the environmental tracer technique used at a site, the common assumption is that the processes observed at the time of investigation represent past conditions, often covering a period of thousands of years depending on aquifer storage characteristics. In terms of aquifer management, it is therefore important to know whether the suggested recharge is actually occurring, and if so, the recharge threshold, particularly in semi-arid and arid environments where recharge is episodic in character. In the absence of long-term site rainfall or water level data, an understanding of environmental tracers present in recharge waters can be of some benefit, particularly when investigating aquifers containing young groundwater, and receiving significant recharge (Cook et al., 2001)

Anthropogenic changes in the atmospheric concentrations of ^{3}H and ^{14}C have been significant in recent time. For example, work undertaken by Friedli et al. (1986) indicates that atmospheric ^{14}C concentrations have decreased by 25% in the last 100 years due to the release of fossil fuel-derived carbon following combustion, the relative abundance of ^{13}C also changing since the pre-industrial age. ^{3}H and ^{14}C abundances have also increased following thermonuclear testing, the concentration of ^{14}C reaching about 200 pmC and 160 pmC (pmC - percent modern carbon; pre-bomb atmospheric concentration approximately 100 pmC) in the northern and southern hemispheres, respectively (Clark and Fritz, 1997; Verhagen et al., 2001). Thus, relatively high ^{3}H (refer **Table 1**) and ^{14}C (i.e. > 100 pmC) concentrations in groundwater would indicate that at least some post-1950's recharge has occurred, an assumption made by numerous researchers worldwide (Mazor et al., 1977; Mazor, 1982; Leaney and Herczeg, 1995; O'Brien et al., 1996; Talma et al., 2000).

Table 1 Range of ^3H concentrations in groundwater for different recharge conditions, as adapted from Clark and Fritz (1997).

Continental regions (TU)	Coastal and low latitude regions (TU)	Recharge conditions
<0.8	<0.8	Sub-modern – recharged prior to 1952
0.8 to ~4	0.8 to ~2	Mixture between sub-modern and recent recharge
5 to 15	2 to 8	Modern (<5 to 10 years)
15 to 30	10 to 20	Some bomb-derived ^3H present
>30	>20	Considerable component of recharge from 1960's or 1970's
>50	-	Dominantly 1960's recharge

Chlorofluorocarbons (CFC's) have also been used as indicators of modern recharge due to pollution-induced increases in atmospheric concentrations that have occurred since the 1950's (refer **Figure 5**). Indeed, the technique has significantly improved the understanding of recharge processes at various South African sites (Weaver and Talma, 1999; Talma et al., 2000). For example, at a site in Dewetsdorp, Free State, Weaver and Talma (1999) were able to show that a shallow weathered shale aquifer had received modern recharge, whereas groundwater derived from higher yielding dolerite dyke/Karoo Basin contact aquifer had not. In terms of resource management, this represents a significant finding, as it suggests that the strategically important contact aquifers in the area are recharged episodically, and are potentially being mined (i.e. they are not being recharged at all). However, the influence of aquifer characteristics on observed results was not discussed in any significant detail, other than to say that; a) flow was being retarded within the sampled contact aquifer, and; b) water level response during recharge events was lower in the contact aquifers.

Given their potential to influence resource management decisions, it is suggested here that aquifer characteristics must be considered when using environmental tracers to assess whether modern recharge has occurred, particularly:

1. Aquifer storage. It is not surprising that groundwater from a significant aquifer with relatively high storage would have a relatively high MRT given the low recharge rates characteristics of semi-arid to arid areas (refer Equation 57). However, the derivation of SVF and CRD recharge estimation methods shows that water level responses should be less in an aquifer with greater, as opposed to lesser, storage. Further, given that the volume of modern recharge is relatively insignificant compared to the volume of groundwater contained within the aquifer as a whole, it is not surprising that low environmental tracer concentrations would be measured, particularly if groundwater within the aquifer mixes thoroughly;

2. *Groundwater flow rates and permeability*. These parameters will dictate how quickly groundwater contained within a given aquifer will mix;

3. *Preferential recharge areas*. At sites where piezometric levels do respond to rainfall, at least some recharge implied. However, if an environmental tracer is not detected within groundwater samples, it may not mean that recharge has not occurred, but rather that flow from an area of preferential recharge has not yet reached the groundwater sampling point. This condition will be particularly true in semi-confined or confined aquifer systems.

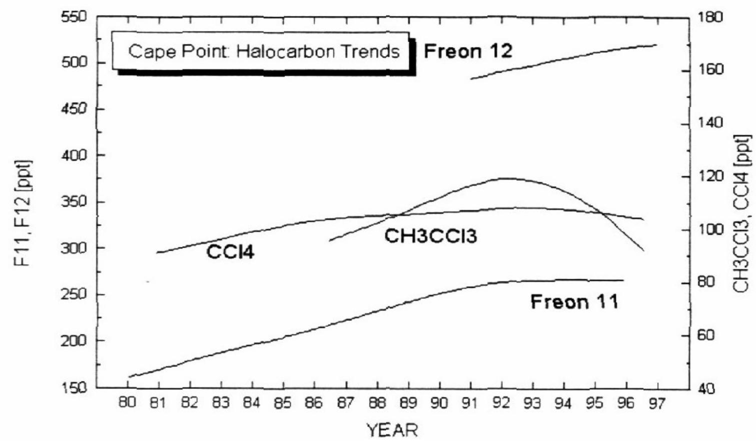


Figure 5 *Atmospheric chlorofluorocarbon concentrations measured a Cape Point, South Africa (from Weaver and Talma, 1999).*

2.4 Summary

As outlined in Section 1, the summary shown in **Table 2** and **Table 3** is intended as a means of rapidly identifying those methods with potential for application in a given study area. It is important to note, however, that all of the methods reviewed as part of this study have limitations. As such, it is recommended that any selected technique be thoroughly understood before proceeding to the recharge estimation stage. Further, multiple estimation techniques should be applied and the obtained results compared wherever possible.

Table 2 Summary of physical mass balance-type recharge estimation methods reviewed as part of this investigation.

Method	MDR	Limitations	Comments
SVF	1. Long-term monitoring data for all components of the hydrological cycle (i.e. inflows, outflows, etc) and SWL must be known; 2. Storativity.	1. Can be difficult to identify areas of preferred recharge from available monitoring data; 2. Often difficult to define aquifer or model boundary conditions; 3. Spatial variations in aquifer storage across the study area, and vertically within the aquifer itself, must be known; 4. Heterogeneity, such as preferred groundwater flow in a given direction, can be difficult to represent; 5. Unsuited for use in confined aquifer systems unless a significant body of monitoring data is available; 6. Difficult to obtain input parameters, particularly in unregulated catchments; 7. Can be problems modelling recharge thresholds.	1. Quantitative flow modelling required; 2. Calibration of developed models using other techniques is important; 3. May be unsuited for use in some fractured rock aquifers due to the significant variations in storativity that occur over relatively short distances; 4. Long-term monitoring data is required, preferably covering at least two El Nińo cycles. Based on a five to eight year return cycle observed at Hotazel (refer Section 5), at least 20 years of data is required to model continuous aquifer behaviour; 5. The technique can be used to estimate storativity if aquifer recharge is already known; 6. Application cost varies from low in areas where existing data and models are available (i.e. only re-modelling and calibration is required) to very high in those where all data must be collected, interpreted, modelled and calibrated. Some experience is required in order to identify when model outputs do not represent site conditions.
CRD	1. Long-term rainfall, extraction / artificial recharge data; 2. Storativity.	1. As per SVF limitations; 2. Represents average aquifer behaviour in its original form, although it can be used to model preferential pathway / matrix components of recharge, and determine the respective recharge thresholds, providing the stable isotopic characteristics of site groundwater are known (refer Sections 6, 7 and 8).	1. As per SVF Method Points 2, 3, 4 and 5; 2. Can be used to generate SWL data for use in SVF modelling providing input parameters are known. Note that this data will be most representative in those aquifers where 100% recharge occurs via the matrix; 3. Consideration must be given to the lag between rainfall and CRD-generated water table response when undertaking SVF modelling; 4. Cheap technique to apply although generated estimates often reflect this.
Unsaturated zone moisture balance	1. Long-term rainfall data; 2. Unsaturated zone moisture monitoring data; 3. Site specific data such as soil retention capacity, moisture content / permeability relationships, vegetation type, rooting depth, etc	1. Moisture monitoring data must be available for all profiles in the study area; 2. No guarantee that in situ samples taken for laboratory testing have not been disturbed during sampling; 3. Remoulded samples may not represent field conditions; 4. Laboratory test results may not be indicative of the study area as a whole; 5. In situ measuring devices, such as lysimeters, can be sited incorrectly; 6. Installation of monitoring equipment may influence the hydraulic behaviour of site materials.	1. Developed models must be complex and account for seasonal variations (i.e. hydraulic conductivity, rooting depth, etc), preferential pathway versus matrix derived flow, etc; 2. Unsuited for sites where unsaturated zone characteristics vary significantly across a study area; 3. As per SVF Method Points 2 and 4; 4. If long-term data collected during a focussed research investigation is available, lumped parameter-type models of an aquifer system can be developed by integrating SVF and moisture balance models; 5. An expensive and time-consuming method when applied correctly, with generated results often unrepresentative of the catchment as a whole
Lumped parameter	1. As per SVF and unsaturated zone moisture balance methods.	1. As per SVF and unsaturated zone moisture balance methods.	1. As per SVF and unsaturated zone moisture balance methods; 2. Should only be attempted by experienced geohydrologists if sufficient data is available; 3. Very expensive and time-consuming method to apply correctly, although resulting estimates are generally accurate.

Table 3 Summary of the environmental tracer-type CMB and SI recharge estimation methods.

Method	MDR	Limitations	Comments
CMB	1. $Cl_d + Cl_p$; 2. Cl_{rw} or Cl_{gw}.	1. Unsuited for use in terrains where chloride is not derived from precipitation or dry fallout (i.e. marine rocks still containing connate water); 2. Limited long-term $Cl_d + Cl_p$ data available for Southern Africa; 3. Climate and land use changes may influence $Cl_d + Cl_p$ (refer Section 3); 4. $Cl_d + Cl_p$ concentrations must be accurate and precise to 0.1 mg/L; 5. $Cl_d + Cl_p$ is prone to pollution; 6. Climate and land use changes may cause Cl_{rw} to vary from the long-term average; 7. Cl_{rw} determined during unsaturated zone studies should be treated with caution (refer Sections 7 and 8); 8. Site geology can influence Cl_{gw} (refer Section 5); 9. Effects of infiltrating surface water on derived recharge estimates must be considered.	1. Care must be taken to ensure that the estimate is a reflection of long-term average recharge and not the most recent recharge event; 2. Samples should be taken at the end of the dry season. Allowing for a lag between rainfall and the arrival of the recharge front of up to 60 days, this would be between September and November in summer-dominant rainfall areas of Southern Africa; 3. It is recommended that, in Southern Africa, recharge estimates be based on saturated (i.e. groundwater) samples only; 4. The distribution of chloride across a catchment and its concentration in all components of the water cycle (i.e. chloride concentrations of all surface and groundwater bodies in a study area, etc) must be known; 5. Can have most confidence in results in areas where recharge does not bypass the unsaturated zone; 6. Many of the problems associated with using other methods in fractured rock aquifers (i.e. difficulties in determining spatial variations in storativity) can, under certain conditions, be overcome using this technique; 7. Generally the most cost-effective and easiest technique to apply when sufficient data is available.
SI	1. MWL characteristics; 2. Stable isotopic composition of unsaturated zone moisture or groundwater.	1. There are few laboratories in the region where testing can be undertaken; 2. Climate changes could influence the stable isotopic composition of rainfall over time; 3. As per CMB Method Point 9.	1. As per CMB Method Points 1 to 6; 2. Provides insight into the source of recharge water (refer Sections 5, 7 and 8) and recharge processes in general (refer Section 6). As such, the technique generally compliments other recharge estimation methods, the CMB Method in particular; 3. Low to moderate application cost, with some familiarity in the isotope characteristics of the water cycle required by investigating geohydrologists.

Table 4 Summary of other environmental tracer-type recharge estimation methods reviewed as part of this investigation.

Method	MDR	Limitations	Comments
^3H	1. ^3H concentration of unsaturated zone moisture or groundwater; 2. Temporal atmospheric ^3H concentration data for a given area is preferable.	1. There are few laboratories in the region where testing can be undertaken; 2. ^3H can be transported with vapour in the unsaturated zone; 3. Atmospheric ^3H has now returned to background levels.	1. Still a good indicator of modern recharge in drier areas or those covered by a relatively thick unsaturated zone; 2. Care must be taken to ensure that the estimate is a reflection of long-term average recharge and not the most recent recharge event, particularly when calculations are based on unsaturated zone data; 3. Expensive technique to apply; 4. Technique can be applied by relatively inexperienced geohydrologists.
$^3He/^4He$	1. ^3He and ^4He composition of groundwater samples; 2. As per ^3H Method Point 2.	1. As per ^3H Method; 2. Relatively complicated method; 3. Assumes ^3H (and its subsequent decay to ^3He) is bomb-derived; 4. Assumes all ^4He in groundwater is derived from decay of aquifer materials (i.e. there is no input from external sources); 5. Significant dating errors can occur, even when all sampling, testing and assessment work has been undertaken by skilled geohydrologists.	1. Can be used to date groundwater with ages in excess of 50000 years; 2. Probably used more to understand aquifer flow processes as opposed to a primary recharge estimation tool; 3. Should only be attempted by experienced geohydrologists if sufficient data is available; 4. As per ^3H Method Point 3.
^{14}C	3. ^{14}C concentration of groundwater samples.	1. As per ^3H Method Point 1; 2. Difficult to determine q in areas where alternative sources of carbon exist (i.e. carbonate aquifers); 3. Significant sample volumes are required when dating fresh groundwater; 4. Cannot generally be used to date groundwaters with a pH < 4.5; 5. Cannot be used to date groundwaters with ages in excess of 50000 years.	1. Method has proven application in the assessment of flow processes in confined aquifers; 2. During recharge studies, the method is generally used to check existing estimates as opposed to being used as a primary assessment tool; 3. Primarily used to indicate whether modern recharge has occurred; 4. As per ^3H Method Point 3; 5. As per ^3H Method Point 4, although caution is required.
CFC's	1. CFC concentration of groundwater samples; 2. Temporal atmospheric CFC concentration data for a given area is preferable.	1. Specialized sampling equipment is required; 2. Testing on groundwater samples must be undertaken outside of Southern Africa (there do not appear to be any laboratories in the region with the required analytical equipment).	1. As per ^3H Method Points 1, 3 and 4; 2. As per ^{14}C Method Points 3 and 5.

3 Chemical and isotopic characteristics of precipitation

3.1 Introduction

The chemical and isotopic characteristics of precipitation have been shown to be of importance when undertaking geohydrological investigations, particularly when using environmental tracer methods to estimate site recharge. Fortunately, long-term data for various climatic parameters, including stable isotope abundances measured in precipitation samples taken at various Southern African sites, is available for interpretation, and indeed some interpretative work has been undertaken already. This section summarizes these earlier findings, and introduces and discusses new data collected as part of this study from a recharge estimation perspective.

3.2 Previous investigations

3.2.1 Stable isotopes (^2H and ^{18}O)

Diamond and Harris (1997) considered the isotopic characteristics of rainwater collected at various sites in the Western Cape Province of South Africa, data from two Cape Town sites, the University of Cape Town (UCT; June 1995 to May 1997) and the Cape Town International Airport (CTIA; 1962 to 1974), having the most continuous records. They concluded that a unique LMWL could be constructed for both UCT and CTIA, with Western Cape precipitation in general falling along the line $\delta^2H = 6.1\delta^{18}O + 8.6$, amount or temperature effects not apparent throughout a given year. With a view to determining whether elevation influenced isotopic abundances in precipitation, seepage from a sea level-Table Mountain summit transect (elevation range 0 to 1000 m) was also sampled in the days following a major rainfall event. While acknowledging that their sampling strategy was somewhat crude, Diamond and Harris (1997) nevertheless concluded that no altitude effect was represented in their data. An altitude effect of $-0.55\delta^{18}O$‰ per 100 m increase in elevation was identified in a subsequent study, however, this interpretation based on the relative abundance of stable isotopes in spring water that seeps from the flanks of Table Mountain (Harris et al., 1997). Sampled spring elevations varied from 35 to 310 m in this latter study, Harris et al. (1997) acknowledging that correlation between altitude and ^{18}O abundance was not good (r^2=0.61).

The assessment of potential altitude effects using stable isotope abundances in spring water is not a new concept, although in other studies the trend has been to first confirm that the effect is present in precipitation sampled at various elevations. Lee et al. (1999) calculated an altitude effect of $-0.15\delta^{18}O$‰ from spring water samples taken on Cheju Island, Korea, while Scholl et al. (1996) reported varying altitude effects (between $\delta^{18}O$ -0.15 and -0.32‰ per 100 m) for precipitation samples taken on the flanks of the island of Mauna Loa, Hawaii. This later work is particularly significant as it demonstrates that localised climates not only influence the isotopic composition of precipitation, but also any resulting altitude effects.

While temperature effects were not represented in their data, Lee et al. (1999) did note that the "d-excess", as determined from the LMWL equation $\delta^2H = m\delta^{18}O + d$, varied between wet and dry seasons, and thus constructed wet and dry season LMWL's for their study area. They went further, calculating the amount of wet and dry season precipitation in groundwater using the mass balance:

$$d_{gw} = Xd_{wet} + (1 - X)d_{dry} \qquad \textbf{Equation 58}$$

Where d_{gw}, d_{wet}, and d_{dry} represent the d-excess for groundwater, wet season precipitation, and dry season precipitation, respectively, for the fractional components X and (X-1). However, for such a mass balance to represent site conditions, no evaporation can occur during recharge, which Lee et al. (1999) believed likely given the islands thin soil cover and the highly permeable character of the underlying volcanic lithologies.

When the findings of Harris et al. (1999), Lee et al. (1999), and Scholl et al. (1996) are considered together, it is apparent that site climate, geology, and geomorphology, must considered when interpreting altitude effects from spring sample data. Indeed, several assumptions must be made i.e.

- No evaporation occurs prior to recharge either in the unsaturated zone or standing water bodies prior to recharge (i.e. recharge is derived entirely from precipitation);
- The recharge area for the spring has the same elevation as the spring itself. This is unlikely given that there would be no flow from the spring if this were the case. However, in very steep terrains where springs are ephemeral, this is probably an acceptable assumption given that springs in these settings only flow immediately after rainfall and for short periods of time. In those areas where annual springs occur, there flow increasing in response to rainfall, greater storage is implied, and thus there is a potential for some recharge to be sourced from more elevated sites;
- Sampled water represents a specific recharge event, and not an average of several recharge events. This implies that aquifer storage is minimal;

- Precipitation is not remobilised to sites further down-slope prior to recharge. Indeed, in sites where throughflow processes are of significance, recharge water must not comprise mobilised unsaturated zone moisture.

Care must therefore be taken when interpreting altitude effects from spring or groundwater data, particular in semi-arid or arid areas where evaporation can significantly influence stable isotope concentrations. As an example of how site conditions can distort stable isotope interpretations, reference is made to the work of Adams et al. (2001). During their assessment of groundwater chemistry at a site in the southwest of South Africa, they observed a relationship between water quality and site geomorphology. They suggested that groundwater of poorer quality generally (but not always) occurred in less elevated, flatter, points in the landscape in response to the recharge of standing water containing elevated, evaporation-induced salt concentrations. Stable isotopic evidence was also provided, which indeed indicated that some groundwater had an evaporative signature. Of concern though, was their further interpretation of the available isotope data. They claimed that an altitude effect could be observed in the data set, such that ^{18}O abundance generally increased with decreasing elevation. However, given the conceptual model they had already presented, the observed ^{18}O behaviour could easily represent variations in site recharge processes across the study area.

Work undertaken by Sungaro et al. (2000) suggests a LMWL for Harare of $\delta^2H = 7.2\delta^{18}O + 10$ based on precipitation data for the years 1960 to 1976. This varies somewhat from those developed by Beekman et al. (1997b) for Central and Southeastern Botswana, based on data collected at Lobatse (1991 to 1992, and 1995 to 1996; $\delta^2H = 6.8\delta^{18}O + 8.8$) and in the Letlhakeng-Botlhapatlou area (1993 to 1995; $\delta^2H = 6.1\delta^{18}O + 6.9$), respectively. In both countries, however, precipitation data does appear to be influenced by an amount effect, with ^{18}O typically more depleted in composite samples taken in months of heavier rainfall. Indeed, Froehlich et al. (in preparation; as seen in Sungaro et al., 2000) suggest that Harare precipitation displays a “hysteresis effect”, whereby the isotopic composition not only varies with the amount of rainfall received but also the month of the year, which they attribute to the movement of the Inter-Tropical Convergence Zone (ITCZ).

3.2.2 Chemistry

In terms of systematically assessing the chloride concentration of precipitation on a regional scale, the most significant work to date has been undertaken in Botswana. Sampling initially commenced in the eastern part of the country in 1983, and by 1988 monitoring was undertaken on a country scale. Beekman et al. (1997) note that significant variations in $Cl_d + Cl_p$ occur across the country and throughout the year, between different types of rain gauges, and rain gauges of the same type, such that no clear trend could be observed in the data. Indeed, between successive sampling years, $Cl_d + Cl_p$ values in nearby Zimbabwe could vary by a factor of two, with a long-term countrywide average of about 1 mg/L suggested (Beekman and Sungaro, 2002).

One of the significant findings of Beekman and Sungaro (2002) was that precipitation collected using composite rainfall samplers had significantly higher chloride concentrations than either commonly available PVC gauges, or more expensive copper gauges. While they could not attribute a reason for this, they nevertheless recommended that such composite samplers not be used for determining $Cl_d + Cl_p$. Additionally, recommendations were:

i. PVC gauges not be used as they were more susceptible to both spilling (due to limited capacity) and evaporation, although they provided no evidence that evaporation had occurred;
ii. Copper gauges should be used due to the low chloride concentrations of obtained samples, and the limited variation between chloride concentrations of samples taken on different dates.

Weaver and Talma (2002) designed and tested a composite rainfall sampler for use under South African conditions, the basis of their design being a 15 mm thick layer of silicon oil ($SG_{oil} < SG_{water}$ so as to float) to prevent evaporation from the collected sample. They were able to demonstrate that control samples had been exposed to minimal evaporation over a 12-month period, with chloride concentrations relatively unchanged during the course of testing. In comparison, significant changes in ^{18}O and chloride concentrations were observed in a composite sampler containing no oil.

Weaver and Talma (2002) summarized the average chloride concentrations of rainfall along transects extending from coastal to elevated inland regions in the Western Cape Province of South Africa. In many instances, they note that rainout (progressive decrease in precipitation concentration for a given parameter with decreasing rainfall) and continental effects (progressive decrease in precipitation concentration for a given parameter from the coast inland) were present in their data, consistent with observations made elsewhere (Cook et al., 2001). Chloride concentrations in these areas therefore varied with proximity to the coast, values of 22 mg/L reported at the coast near Langebaan.

While elevated chloride concentrations are to be expected in coastal precipitation, chloride sources have also been inferred in inland areas. Work undertaken by Hingston and Gailitis (1976) in the Western Australian Wheatbelt suggested $Cl_d + Cl_p$ concentrations of between 4 to 8 mg/L, the higher values occurring as dry fallout from nearby playas. Equally significant was the suggestion by Mazor and George (1992) that chloride in groundwater in these areas had an oceanic source, the ion mobilized into inland areas as aerosols. If true, this later finding highlights the conservative character of chloride, and its use as a tracer in hydrological studies.

3.3 Characteristics of precipitation at selected Southern African Sites

3.3.1 Introduction

Precipitation was routinely sampled at two South African sites during the course of this investigation, Bloemfontein and Hotazel, in Free State and Northern Cape Provinces, respectively. At each site, a PVC rain gauge was measured twice daily between 6h30 and 8h00, and 15h30 and 17h00, and a composite monthly sample taken, whereby all rainwater contained in the gauge at the time of measurement was added to a single container. These containers were stored in a refrigerator adjacent to the respective sampling sites so as to limit the potential for evaporation. On rare occasions where rainfall occurred, but twice daily sampling was not undertaken, rainwater contained in the gauge was discarded. Testing undertaken on the obtained precipitation samples varied with sampling site (refer **Table 5**), with chemical testing undertaken at the Institute for Groundwater Studies (IGS) laboratory, University of the Free State, Bloemfontein. Stable isotope (^2H and ^{18}O) concentrations in precipitation samples were obtained by the Quaternary Dating Research Unit (QUADRU) laboratory, Centre for Scientific and Industrial Research (CSIR), Pretoria, from local and international laboratories.

Table 5 Parameter concentrations determined during laboratory testing on precipitation samples. Chloride, ^2H and ^{18}O results shown in this report are accurate to within 0.1 mg/L, and δ1 and δ0.1‰, respectively (Cruywagen, 2002; Talma, 2003).

Site	**Tested anion**	**Tested stable isotopes**
Bloemfontein	Cl	^2H and ^{18}O
Hotazel	Cl, NO_2, NO_3, PO_4, SO_4	^2H and ^{18}O

3.3.2 Stable isotopes

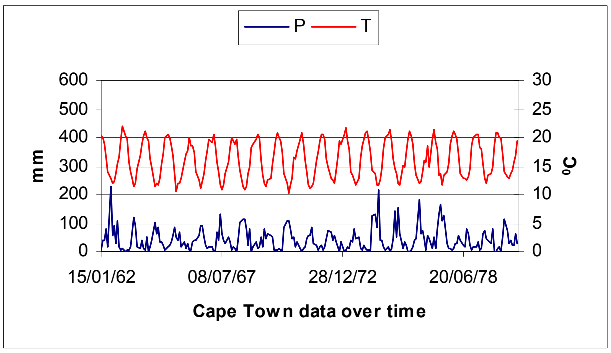
Stable isotope concentrations of monthly composite precipitation samples have been measured sporadically in Southern Africa for more than 40 years, although data of most relevance to South

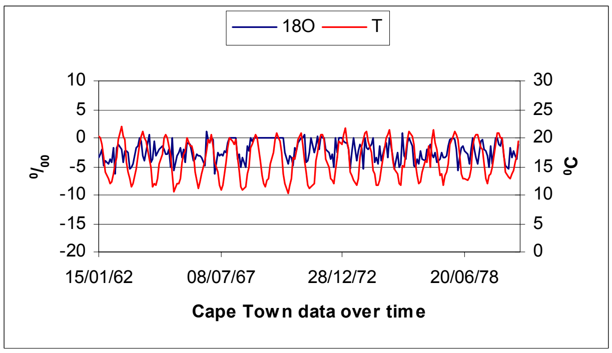
Africa is that available for Cape Town, Pretoria, and Windhoek. Long-term data considered during this report was obtained from the IAEA/ World Meteorological Organization (IAEA/WMO, 2001) online database, the data considered for analysis varying with application. For example, LWML and amount effect characteristics were assessed on stable isotope and precipitation data for those years where continuous data was available (i.e. composite monthly samples had been taken in all months of a given year, and tested to determine ^{2}H and ^{18}O abundances; refer **Table 6**), an exception being when a sample of 10 mm or less was not tested. In comparison, temporal graphs of stable isotope concentrations, temperature, and precipitation that are included within this report considered all available data for the period represented.

Table 6 Years that continuous, composite monthly, ^{2}H and ^{18}O precipitation data was available. The record was assumed to be continuous in those years where 10 mm or less of rainfall was not tested in a given month.

Site	Years (January to December)
Cape Town	1962, 1964, 1966-1967, 1996, 1998-2000
Pretoria	1962-1963, 1967-1969, 1970-1971, 1997-2000
Windhoek	1962-1966, 1968-1969, 1971, 1973

A temperature effect is represented in precipitation data for all three sites, with rainfall in Cape Town clearly winter dominant, as opposed to most rainfall occurring in the summer months at Pretoria and Windhoek (refer **Figure 6**). This temperate, Mediterranean-type climate influences the LMWL of Cape Town, the range of stable isotope data (i.e. interval between upper and lower isotope concentrations) much less than that observed in both other centres as a result (refer **Figure 7**).





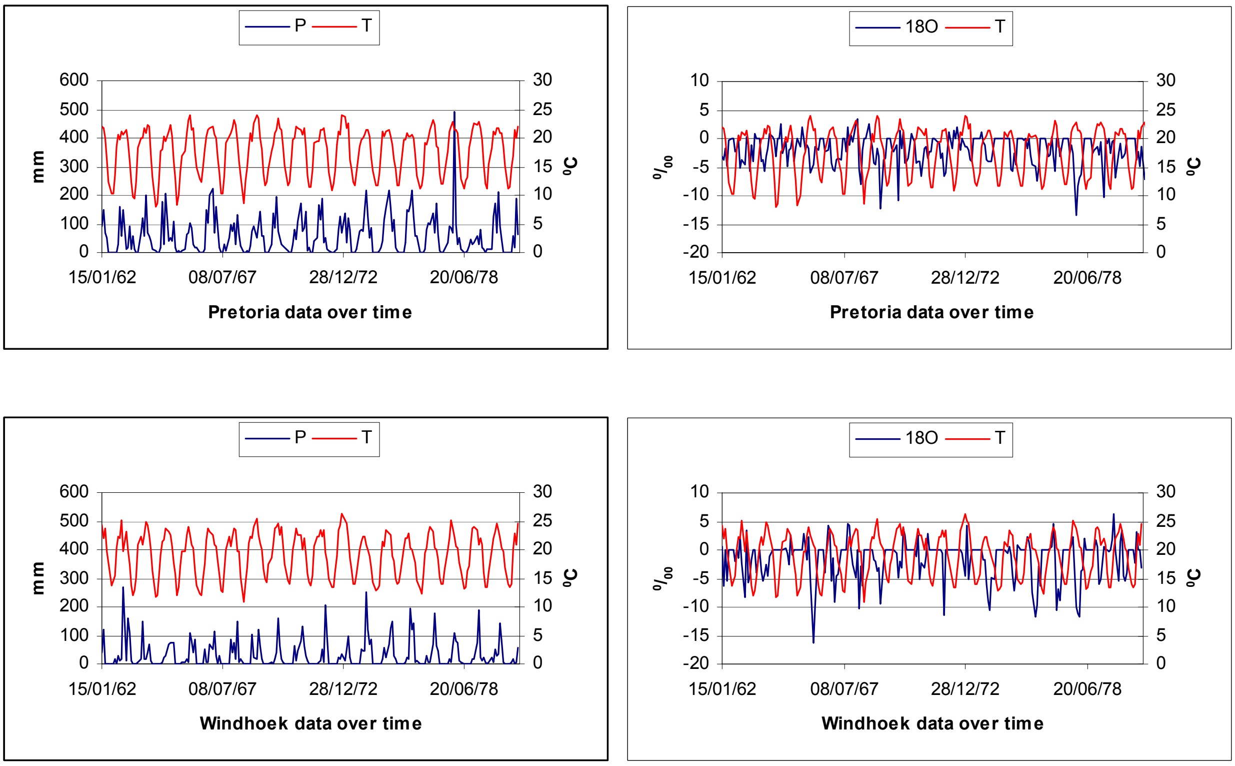


Figure 6 *Time graphs of precipitation (P), temperature (T), and ^{18}O concentration (18O) data for Cape Town, Pretoria, and Windhoek. Note that ^{18}O abundances in rainfall generally follow the trend of temperature in the Mediterranean-type climate of Cape Town. However, in the summer-dominant rainfall of Pretoria and Windhoek, ^{18}O becomes more depleted as temperature and rainfall increase.*

An amount effect was identified in each of the long-term data sets when the weighted average stable isotope concentration of precipitation for a given 50 mm interval was considered (refer **Figure 8**). However, the effect was better represented at those sites receiving most rainfall in summer months as opposed to more temperate Cape Town.

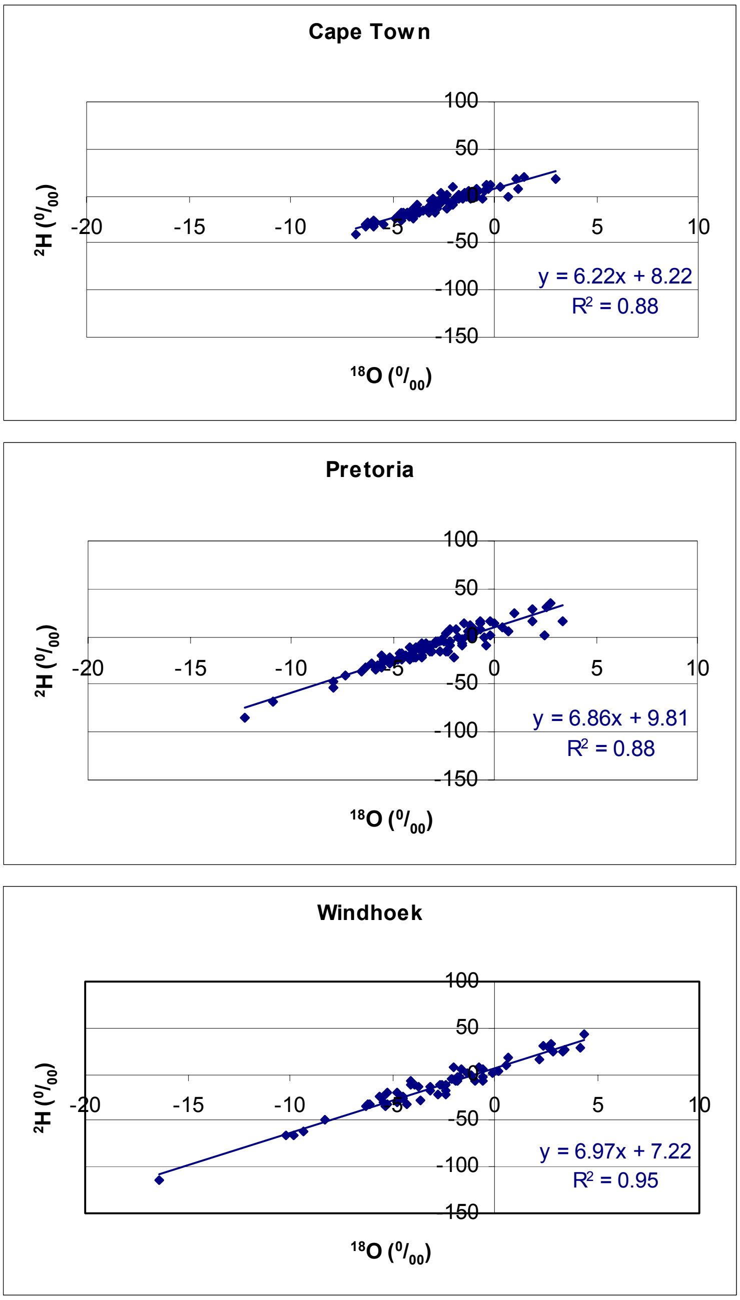


Figure 7 *LMWL's for Cape Town, Pretoria, and Windhoek.*

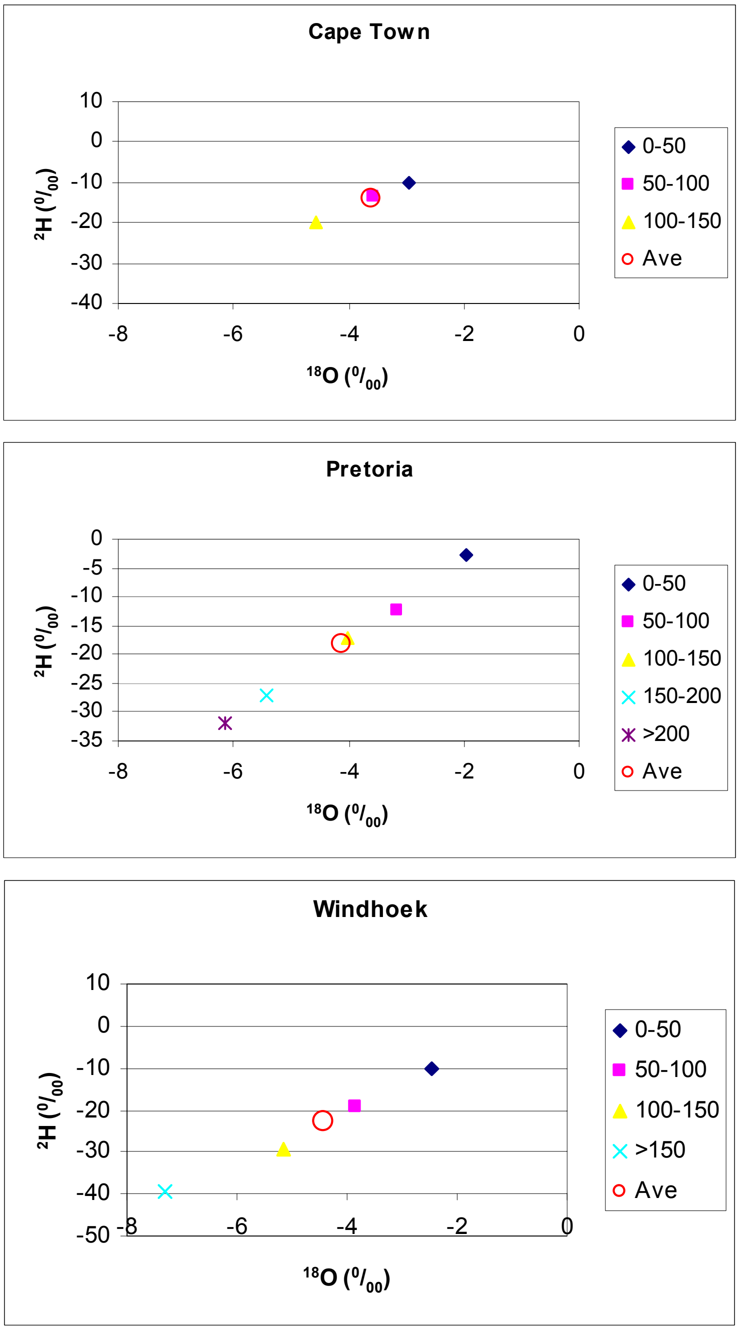


Figure 8 *Comparison of weighted average stable isotope amount effects present in precipitation data for Cape Town, Pretoria, and Windhoek. Note that the spread of data (i.e. Cape Town has the lowest data range, followed by Pretoria, then Windhoek) increases with increasing average temperature (refer* ***Figure*** *7). Calculated weighted average $\delta^{2}H$ and $\delta^{18}O$ values in Cape Town, Pretoria, and Windhoek precipitation, were –3.6 and –14‰, -4.1 and –18‰, and –4.4 and –23‰, respectively.*

LMWL's for the respective datasets confirm that precipitation characteristics are different between the three centres. The range of data, and the significant depletion of ^{2}H and ^{18}O in precipitation, suggests that event-related and seasonal rainout processes are particularly important in the warmer, summer-dominant rainfall climates of Pretoria and Windhoek. Lower R^2 values for Cape Town and Pretoria also imply that evaporation-induced enrichment of ^{18}O has occurred in some instances, although probably for different reasons. In Cape Town, the limited precipitation that does fall in summer is exposed to drier, less humid conditions compared to Pretoria, these conditions encouraging evaporation prior to sampling, either as it falls through the atmosphere, or in the gauge itself. In Pretoria, however, evaporation of precipitation associated with lighter rainfall events appears less seasonal, and is more likely a response to localized weather conditions. Perhaps of most significance, however, is the similarity in the orientation of the respective LMWL's. Indeed, when compared with those determined for Bloemfontein and Hotazel during this study (refer **Table 7** and **Figure 9**), and sites elsewhere by other workers, there is little apparent variation across much of Southern Africa (refer **Table 8**). What is of more importance in this region in terms of distinguishing between the isotopic signature of precipitation for a given site is the:

- Range of data, which is climatically controlled;
- Amount effect characteristics of site rainfall.

Table 7 Stable isotopic characteristics of composite monthly precipitation samples taken for the period 2002-2003 at Bloemfontein and Hotazel. Note that significant evaporation is suggested for the Hotazel sample taken in January 2003, as indicated by the enriched $\delta^{18}O$ concentration.

Month	**Bloemfontein**		**Hotazel**	
	$\delta^{18}O$ (‰)	**$\delta^{2}H$ (‰)**	**$\delta^{18}O$ (‰)**	**$\delta^{2}H$ (‰)**
February	-0.8	8	-2.8	-6
March	-3.3	-12	-1.8	-3
April	-3.1	-5	-1.8	8
May	-3.8	-14	-1.3	7
June	-	-	0.4	30
July	-	-	-	-
August	-2.6	1	-1.7	7
September	0.2	23	-1.7	-3
October	-1.8	-4	1.9	30
November	0.3	8	-0.3	2
December	-3.0	-21	-1.0	-13
January	-0.9	-1	6	36

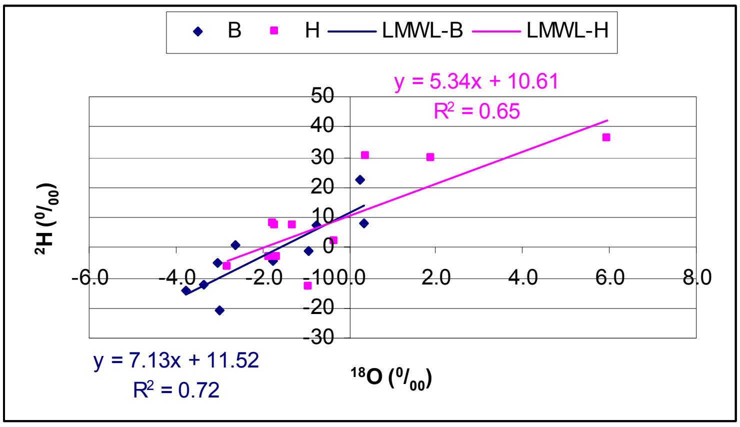


***Figure 9** LMWL characteristics for Bloemfontein (B) and Hotazel (H). Note the influence of the Hotazel sample taken in January 2003 on the slope of the line here. If this point is ignored, the Hotazel LMWL satisfies the equation* $\delta^2\mathrm{H} = 8.1\delta^{18}\mathrm{O} + 14.0(\mathrm{R}^2 = 0.58)$.

Table 8 LMWL orientations for various Southern African sites. Elevations marked "*" have been assumed. Note that there is little apparent variation in the characteristics of the LMWL for the respective sampling sites. Indeed, in inland areas, LMWL's generally appear to satisfy the equation $\delta^2\mathrm{H} = 7\delta^{18}\mathrm{O} + 10$. This estimate is qualitative, however, as statistical comparisons between the different sites are difficult given the potential for climatic variations to be represented in the respective datasets (i.e. rainout could potentially be more pronounced if sampling was undertaken in wetter as opposed to drier years).

Site	Elevation (mamsl)	LMWL orientation	R^2 value for LMWL	Determined by:
Bloemfontein	1400*	δ^2H = 7.1δ^{18}O + 11.5	0.72	Bean (current study)
Botswana (Eastern)	1000*	δ^2H = 6.8δ^{18}O + 8.8	0.94	Beekman et al. (1997b)
Botswana (Central)	1000*	δ2H = 6.1δ^{18}O + 6.9	0.97	Beekman et al. (1997)
Cape Town	-	δ^2H = 6.1δ18O + 8.6	Not stated	Diamond and Harris (1997)
Cape Town	44	δ^2H = 6.2δ18O + 8.2	0.88	Bean (current study)
Harare	1471	δ^2H = 7.2δ^{18}O + 10.0	Not stated	Sungaro et al. (2000)
Hotazel	1063	δ^2H = 8.0δ^{18}O + 14.0	0.58	Bean (current study)
Pretoria	1330	δ2H = 6.9δ^{18}O + 9.8	0.88	Bean (current study)
Windhoek	1728	δ^2H = 7.0δ^{18}O + 7.2	0.95	Bean (current study)

3.3.3 Chemistry

While no distinct seasonal trend is apparent in Hotazel data (**Figure 10**), the proportions of the respective anions appear to stay relatively constant throughout (refer **Figure 11**). In comparison, the chloride concentrations in Bloemfontein precipitation increase significantly during the dry season. No amount effect was observed when the datasets were combined, however, although sample chloride concentrations appeared to fall into two categories, those with values above, or below, 5 mg/L (refer **Figure 12**). Given their distance from the coast, it seems unlikely that rainout and continental effects would have influenced chloride concentrations at the two sites. Further, the similarity in anion ratios within the Hotazel dataset suggests that the observed variations have occurred in response to natural, as opposed to anthropogenic, processes. Thus, an alternative natural source of chloride is implied, one being unsaturated zone chloride mobilized during dust storms that occur in the region. These storms are particularly widespread in areas where there ETM zone is dry and vegetation has been disturbed, a seasonal process in semi-arid and arid Southern Africa. The distribution of unsaturated zone chloride may therefore be influenced by climatic and land use patterns, with chloride concentrations greater in:

i. Drier areas;

ii. Drought years;

iii. Areas where agriculture is more intensively practiced. This could explain why $Cl_d + Cl_p$ values in Botswana rise with increasing rainfall, as it is in these areas where land use from grazing and crop farming is more intensive, particularly given their higher population relative to other parts of the country.

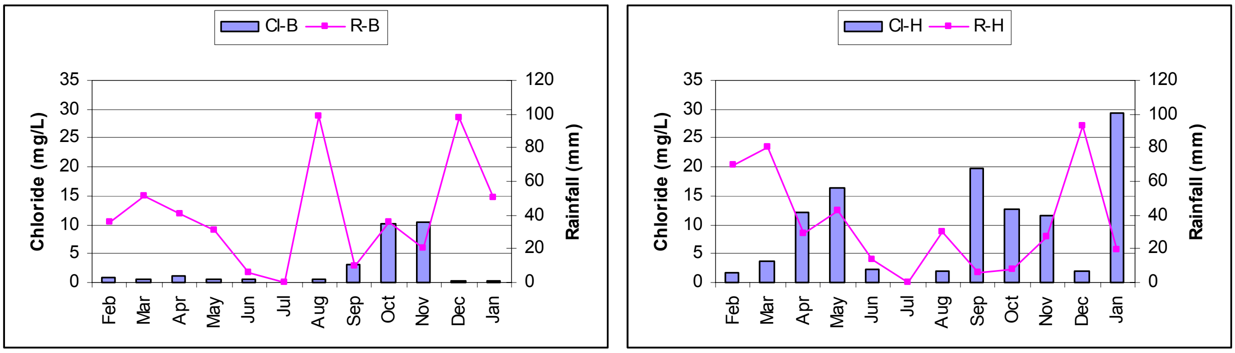


Figure 10 *Chloride concentration of precipitation, and measured rainfall at sites in Bloemfontein and Hotazel for the period between February 2002 and January 2003. Bloemfontein chloride concentrations and rainfall are denoted "Cl-B" and "R-B", respectively; Hotazel data is similarly identified (i.e. Cl-H and R-H).*

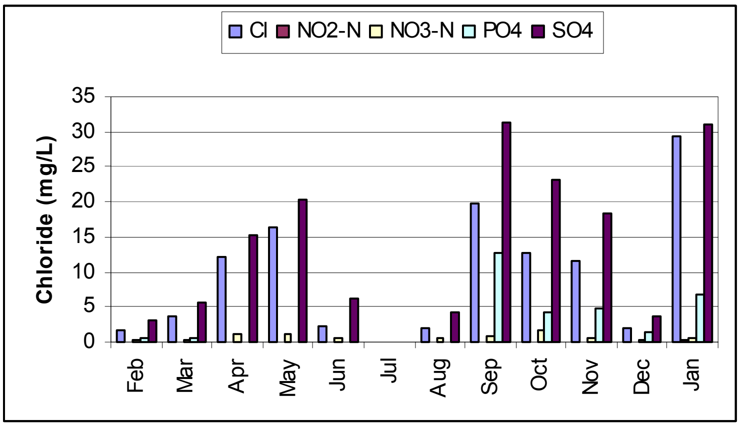


Figure 11 *Concentrations of selected anions in Hotazel precipitation samples taken between February 2002 and January 2003. Actual values are included within Appendix 1 of this report.*

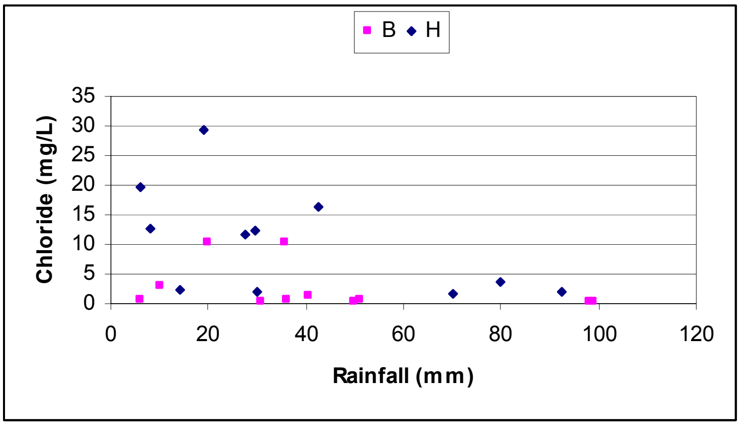


Figure 12 *Relationship between the chloride concentration of precipitation and rainfall at sites in Bloemfontein (B) and Hotazel (H).*

The significant spatial (from sampling site to catchment scale) and temporal variations observed in precipitation concentrations during other studies (Beekman et al., 1997b; Beekman and Sungaro, 2000), and the relationship between precipitation concentrations and landscape features (Hingston and Gailitis, 1976), support the presented chloride re-mobilization model. However, it is the observed partitioning of precipitation chloride concentration data that is of importance from a recharge estimation perspective. It is suggested here that those values > 5mg/L represent site-specific enrichment from one or more dust storm events within a given sampling period. Thus, while correct for the point of sampling, they do not represent $Cl_d + Cl_p$ on a catchment scale. Indeed, the inclusion of these values in weighted average calculations would result in a significant over-estimation of recharge (refer **Table 9**). In comparison, concentrations with values $\leq$ 5 mg/L are thought to represent background conditions, which is consistent with the assumption of Beekman et al. (1997b).

Table 9 Chloride concentration of precipitation, and rainfall at sites in Bloemfontein and Hotazel for the period 2002-2003. Values within brackets for May 2002 and January 2003 represent the total amount of rainfall measured at a site, the un-bracketed number the amount kept for sampling (i.e. some rainwater was discarded after a sampling event was missed). Weighted average calculations are based on the amount of rainwater that was sampled in a given month, and not the total amount of rainfall. Note that weighted averages calculated using the entire dataset as opposed to those months with a concentration of less than, or equal to, 5 mg/L, are almost three times higher (2.8 at both sites).

Month	Bloemfontein rainfall (mm)	Chloride concentration (mg/L)	Hotazel rainfall (mm)	Chloride concentration (mg/L)
February	36.1	0.8	70	1.72
March	51	0.53	80	3.55
April	40.4	1.23	29.5	12.22
May	31 (47)	0.49	42.5	16.26
June	6	0.58	14	2.21
July	0	0	0	0
August	99	0.49	30	1.98
September	10	3.12	6	19.78
October	35.5	10.22	8	12.76
November	20	10.37	27.5	11.63
December	98.1	0.24	92.5	1.97
January	50 (51.2)	0.22	19	29.23
Total rainfall (mm)	***494.3***		***419***	
Sampled rainfall (mm)	***477.1***		***419***	
Weighted average - All data (mg/L)	***1.7***		***6.7***	
Weighted average – Data < 5 mg/L (mg/L)	***0.6***		***2.4***	

3.4 Summary

Available stable isotope data indicates that an amount effect can be observed in Southern African precipitation. However, while the slope of the LMWL remains relatively constant (i.e. $\delta^2H = 7\delta^{18}O + 10$), the observed effect appears to vary throughout the region. Further, given the relationship between air temperature and the isotopic composition of rainfall, temporal changes in climate could alter the currently observed effect.

Chloride concentrations in precipitation samples also vary between sites, a possible response to the increased mobilization of unsaturated zone-derived chloride during dust storms in drier areas, drought years, and areas where agriculture is intensively practiced. The implication of these variations is that it is difficult to have confidence in CMB Method-based recharge estimates unless the $Cl_d + Cl_p$ value used during calculations is based on long-term monitoring data for the area under investigation. Further, it is possible that, even at sites where such data is available, past and current changes in land use and climate may potentially have altered the $Cl_d + Cl_p$ from the long-term background value.

4 Isotopic characteristics of evaporated water

Evapo-transpiration processes significantly influence recharge estimates obtained using the CMB and SI Methods. Some idea of the variation between evaporated water characteristics at various Southern African sites could therefore potentially improve the understanding of recharge processes in the region.

Table 10 Characteristics of surface water samples. Note that data was obtained in areas where naturally occurring surface water is seldom found by sampling man-made facilities. Samples were taken from a cluster of four power stations located approximately 200 km southeast of Pretoria in Mpumalanga Province, Matimba Power Station (Limpopo Province) and the Hotazel-centred Kalahari Manganese Field (Northern Cape Province; refer Figure 1).

Site	Sampling date	Sampling details
Eskom Hendrina Power Station, Mpumalanga Province	July 2000	Samples were taken from dams, drains, and marshy areas in the vicinity of the power station that contained both fresh and polluted water
Eskom Tutuka Power Station, Mpumalanga Province	September 2000	As above
Eskom Kriel and Matla Power Stations, Mpumalanga Province	February/March 2001	As above
Eskom Matimba Power Station, Limpopo Province	August 2001	As above
Kalahari Manganese Field, Northern Cape Province	April and October 2002	Samples were taken from in-pit dams, ponds at sewage treatment works, and return-water and slimes dams that generally contained polluted water

One-off evaporated water samples have been taken at various South African sites as part of resource assessment and pollution studies in the period between 2000 and 2002 (refer **Table 10** and Appendix 2). When shown graphically, it is apparent that there is a significant variation between the respective sites, with lower slopes observed in hotter, drier areas (refer **Figure 13**). This is not surprising when humidity and temperature influences on fractionation are considered.

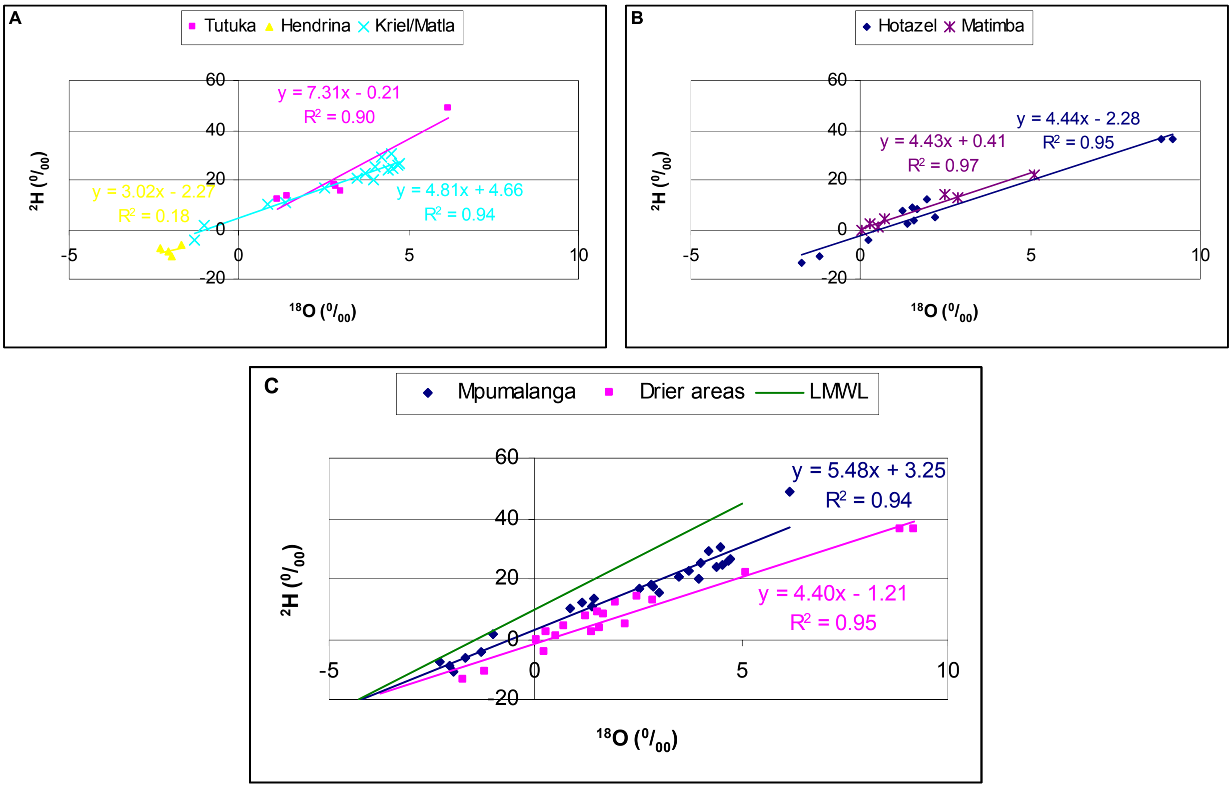


Figure 13 *Stable isotope concentrations in some South African surface water samples. When combined, the line of best fit through Mpumalanga Province data has the orientation* $\delta^2\text{H} = 5.48.\delta^{18}\text{O} + 3.25$ *(refer Plots A and C). In comparison, data collected at two hotter, drier South African sites generally plots below this, and along the line* $\delta^2\text{H} = 4.40.\delta^{18}\text{O} - 1.21$ *(refer Plots B and C). The line of best fit for all data sampled during this investigation has the relationship* $\delta^2\text{H} = 4.98.\delta^{18}\text{O} + 1.42$ *(R^2 = 0.88). Of significance are the enriched $\delta^{18}O$ (i.e. $\delta^{18}O$ > 2‰) values that have been measured at sampling sites such as slime and ash dams where surface water has been exposed to evaporation for extended periods, as this suggests stable isotopes can be used to distinguish between different recharge sources in these environments.*

The influence of bypass flow on the slope of the line constructed through unsaturated zone moisture samples that have been exposed to evaporation within the ETM zone, herein referred to as the Unsaturated Zone Evaporated Water line (EWL-U), has received limited attention during previous studies. Work undertaken by Beekman et al. (1997a) indicates that a significant variation was observed in EWL-U at sampling sites in the Botswana Kalahari. However, when the relationship between line slope and the estimated proportion of bypass flow are compared, a qualitative trend can be observed, whereby the lowest slope is associated with diffuse recharge, the highest with preferential pathway flow (refer **Table 11**). This is significant as is suggests that matrix-derived recharge water has a different isotopic signature to either preferential pathway-derived recharge water, or some mixture of the two.

Table 11 Relationship between EWL-U and the proportion of bypass flow (taken and adapted from Beekman et al., 1997b).

Profile	Depth (m)	EWL-U	R^2	Samples tested	Bypass flow (%)
LM-1	>2.00	$\delta^2H = 2.5.\delta^{18}O - 18.3$	0.43	19	0
LBA-3	>2.00	$\delta^2H = 5.8.\delta^{18}O - 8.8$	0.91	4	60-75
LBA-4	>1.84	$\delta^2H = 5.0.\delta^{18}O - 16.2$	0.77	5	75-85
LBA-7	>1.73	$\delta^2H = 5.9.\delta^{18}O - 7.6$	0.97	8	60-70

5 Geological influences on recharge processes

5.1 Introduction

Hotazel is a Northern Cape mining community centred within the Kalahari Manganese Field. SAMANCOR Hotazel Manganese Mines, a member of the BHP Billiton group, has numerous properties in the area, of which five have been developed:

1. *Mamatwan Mine*. This open cut mine has been continuously operating since 1962;
2. *Wessels Mine*. An underground operation, this mine has been producing high grade manganese ore since 1972;
3. *Hotazel Mine*. The highest known manganese ore grades were extracted from this open cut mine between 1961 and closure in 1988;
4. *Middelplaas Mine*. Initially an Anglo-American operation, production at this underground mine ceased in the early 1980's;
5. *Smartt Mine*. Ore was extracted from the open cut here between 1954 and sometime in the 1960's. However, recent exploration has identified sufficient additional reserves such that it is feasible to proceed with the development of several new open pit mines on the combined Smartt-Rissik properties.

Working in conjunction with Geo-Hydro Technologies (GHT) and SAMANCOR with a view to satisfying the Environmental Management Programme Report (EMPR) requirements for the respective properties, a baseline geohydrological study of the entire field was undertaken, and a comprehensive aquifer-monitoring network installed. This provided a unique opportunity to assess the applicability of the CMB and SI Method in a semi-arid area of Southern Africa, where a significant body of exploration-derived geological data was available for interpretation. While field testing was restricted to selected monitoring bore sites, all monitoring, and private bores located during the hydro-census, where sampled and their basic chemical and stable isotopic composition determined as outlined in later sections of this report.

Hotazel is centrally situated within the Kalahari Manganese Field approximately 60 km by bitumen road northwest of the regional centre of Kuruman, Northern Cape. The field itself, which measures about 40 x 20 km, occurs in a relatively low-lying area, and is bound by the topographically higher Asbestos Hills and Korannaberg on the east and west respectively. Indeed, a large proportion of the field can be geomorphologically described as a Proterozoic basin that has been infilled with sediments of Tertiary or younger age, the only pre-Tertiary outcrop occurring at the town of Blackrock in the northwest.

Economically, the region is dependent on mining and pastoral-based farming, the savannah-type vegetation and semi-arid climate ideal for producing good quality sheep and cattle in a relatively disease-free environment when managed correctly. Nevertheless, properties are generally large, with stocking capacities in the region of 1 Livestock Unit (LSU) per 18 ha (Hotazel Manganese Mines, 2000?a).

Topography across most of the field falls gently (1V: 200H to 1V: 50H) towards larger watercourses, the gradient only increasing in the immediate vicinity of these features. The Gamagara River dissects the field, joining the Kuruman River in the northeast, these being the main drainage features in the area. Smaller tributaries do enter these waterways, however, perhaps the most significant being the Witloop in the south of the field. No springs or permanent surface water bodies are known to occur within the study area though, the Gamagara and Kuruman Rivers flowing rarely and only after periods of prolonged wet weather during above average rainfall years.

To determine the location of pre-existing boreholes and springs in the vicinity of the respective SAMANCOR mines, surrounding properties were visited and landholders and tenants consulted. A total of 48 boreholes were located, none of which were within 1 km of current or proposed mine mining operations (refer **Figure 14**). While no logs or yield information was available for any of the located bores, the owner of Perth, a farm adjacent to the Smartt-Rissik prospect, was able to confirm that bores on his property tap weathered Ongeluk Lava aquifers. Perth BH3 is apparently a relatively high yielding borehole that was used as the sole water supply for the farms Botha, Perth, Rissik, and Smartt in the past, although this was stopped once bores were subsequently constructed on the respective properties. This approach is, however, still used to overcome water supply problems on other properties in the region.

Within the area of investigation, the bore from which most water has the potential to be extracted annually is M24, a production borehole located to the north of the abandoned Middelplaas Mine shaft. Constructed in 1977 as an emergency water supply bore for the nearby Mamatwan Mine (the main water supply is derived from the Vaal-Gamagara system; GHT, 1995), available usage data suggests that the bore was not used as a water supply source for most of 2002. Thus, in terms of the current mine water management strategy, the bore is not an operational necessity for the site.

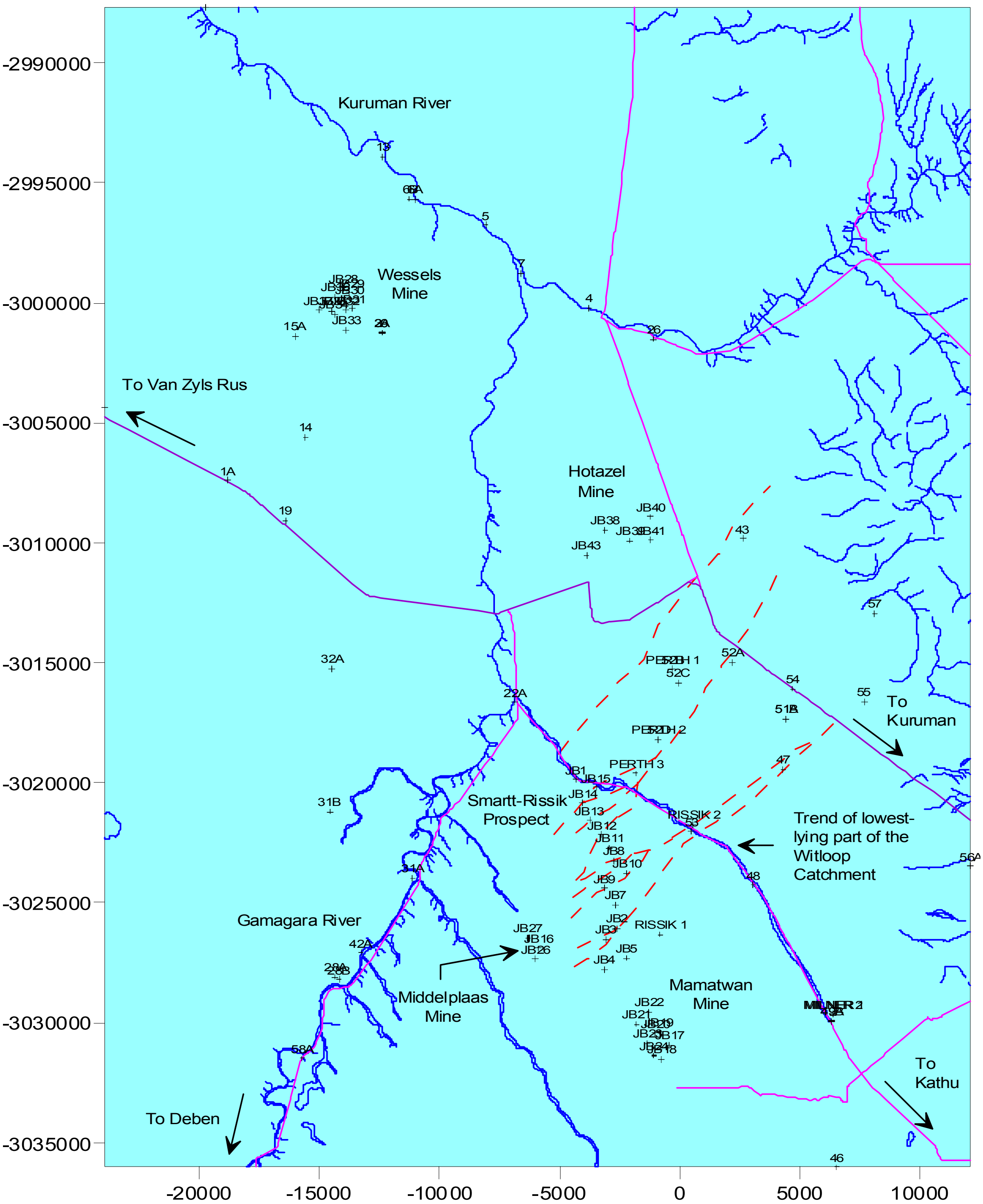


__Figure 14__ Boreholes located during hydro-census. It should be appreciated that, on a regional scale, many more dykes intercept pre-Dwyka Formation-aged lithologies than those shown for the Smartt-Rissik prospect (dashed red lines). Monitoring boreholes installed at indicated mine sites as part of this investigation are shown on __Figure 21__, __Figure 22__ and __Figure 23__.

At least three water quality investigations have been undertaken in the region, these conducted by:

- Ross (1996), who attempted to determine water quality characteristics for the area, seemingly concentrating on the areas surrounding existing SAMANCOR operations;
- Clarke (1997), who assessed the domestic supply potential of site aquifers, the economic viability of constructing a desalination plant at Hotazel, and proposed treatment strategies;
- HMM (2000?a), which was a desk top study based on site geology, and incorporating water quality findings made during earlier studies.

Each of the studies was essentially a summary of the chemical characteristics of site water, and did not attempt to determine geohydrological and geochemical controls on water quality.

5.2 Climate

Rainfall in the area, while summer dominant, is sporadic and varies significantly from year to year, with most rain falling in heavy downpours (refer **Figure 15**). Annual rainfall data for Hotazel does suggest, however, that droughts are cyclical (once every five to eight years), and probably a response to El Nino-La Nina weather patterns (refer **Figure 16**). Available Intensity Frequency Duration (IFD) data indicates that the most intense rainfall events occur in May, with 35.9 and 101 mm falling in 60 minute and 24-hour rainfall events, respectively. The MAP for Kuruman, the nearest official recording station to the site, is approximately 350 mm/year (refer **Figure 17**) although this figure is somewhat misleading given the significant variations that can occur from year to year.

The semi-arid conditions and the sites position on the fringes of the Kalahari Desert can result in extreme daily and seasonal temperature variations, with average daily temperatures ranging from 30 to 15^0C in January to about 17 and 0^0C in July. 70 to 80% of possible sunshine hours can be expected year round, which when considered with other climatic data, results in relatively high average monthly potential evaporation rates, 2276 mm of evaporation occurring on average annually. Of most significance, however, is the degree to which monthly evaporation exceeds monthly precipitation. Based on average monthly results, the ratio of evaporation to precipitation is about 2.7:1 in February, increasing to approximately 46:1 in July. Such significant evaporation excesses are not conducive for the direct recharge of site aquifers, particularly where site groundwater tables are deeper than about ±4m. Thus, any recharge that does occur is likely to be episodic and confined to those years where above average rainfall is received.

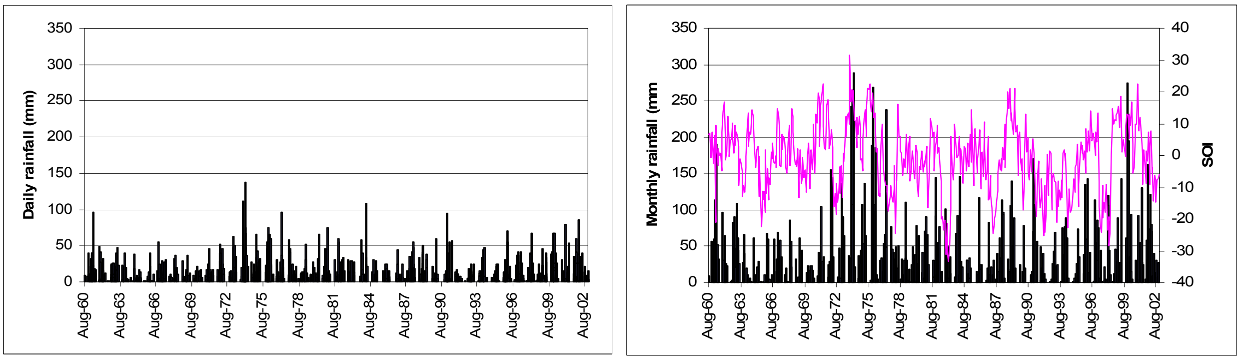


Figure 15 *Hotazel rainfall (daily and monthly) as measured by Kotzee (2003) for the years 1960 to 2002. Maintained privately, the data set is an important asset for local resource managers as measurements were taken continuously over this period (i.e. there are no breaks in the data set). Southern Oscillation Index (SOI) data compiled by the Commonwealth Bureau of Meteorology (CBOM; 2003), which is a measure of the variation in air pressure between Northern Australia (Darwin) and Tahiti, is also shown on the monthly rainfall plot for comparison purposes.*

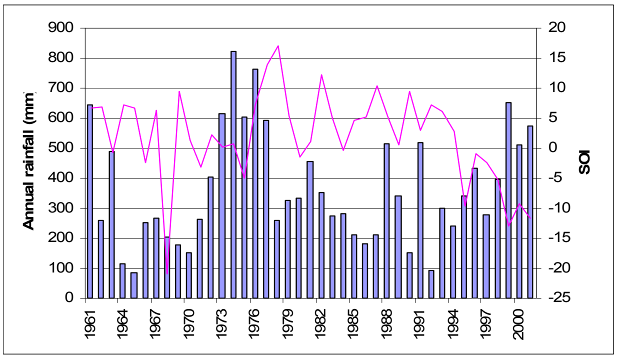


Figure 16 *Annual Hotazel rainfall for the years 1960 to 2002. Accompanying SOI data suggests a reasonable agreement between the El Ninŏ-related droughts that affected Eastern and Southern Australia in 1965, 1972, 1977, 1982, 1987, 1991, 1993-94 and 1997, and below-average Hotazel rainfall (MAP about 365 mm/yr) in all years except 1991.*

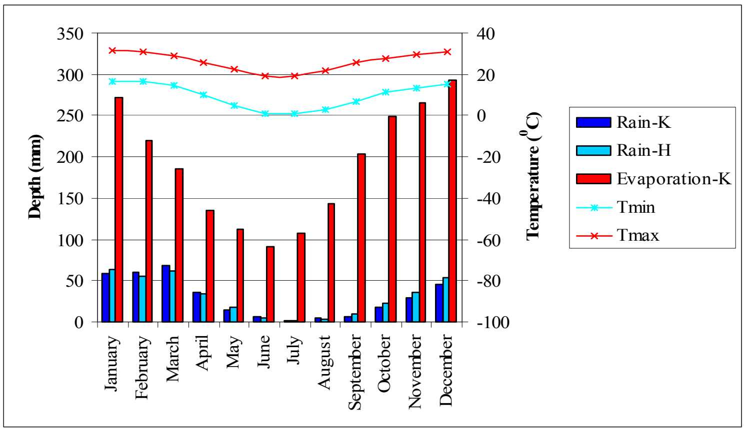


Figure 17 *Climatic data for Kuruman. Rainfall, evaporation, and temperature (T) records were available for the years 1931 to 1990, 1960 to 1987, and 1980 to 2001, respectively, with discussed IFD data collected between 1957 and 1972. Average monthly rainfall for Hotazel (denoted "Rain-H") has also been included for comparison purposes.*

5.3 Geology and geochemistry

5.3.1 Ongeluk Formation

The oldest rocks in the immediate vicinity of the proposed development form part of the Transvaal Super Group, a Proterozoic aged marine sequence deposited in an intra continental (Kaapvaal Craton) back arc basin environment approximately 2600 million years ago (Cairncross et al., 1997; refer **Figure 18** and **Figure 19**). Of these, the generally jasper-iron-magnesium rich lavas of the Ongeluk Formation are the oldest, the presence of pillow lava structures elsewhere in the region suggesting deposition in a shallow sea. Drilling undertaken using rotary air percussion rigs suggests that the material is often un-weathered, hard, and relatively massive, with available diamond drilled core suggesting that any fractures are usually infilled with epidote and calcite.

5.3.2 Hotazel Formation

In terms of economic exploitation potential, the Hotazel Formation is the most important lithological unit in the area due to the presence of manganese bearing beds within it. Deposited between 2200 and 2300 million years ago, the formation is structurally confined within the Dimoten Syncline, a northwesterly plunging (8^0 regionally) basin containing more than 80% of global land-based manganese reserves within an area of approximately 525km^2 (Cairncross et al., 1997). It is this basin that defines the extent of the Kalahari Manganese Field.

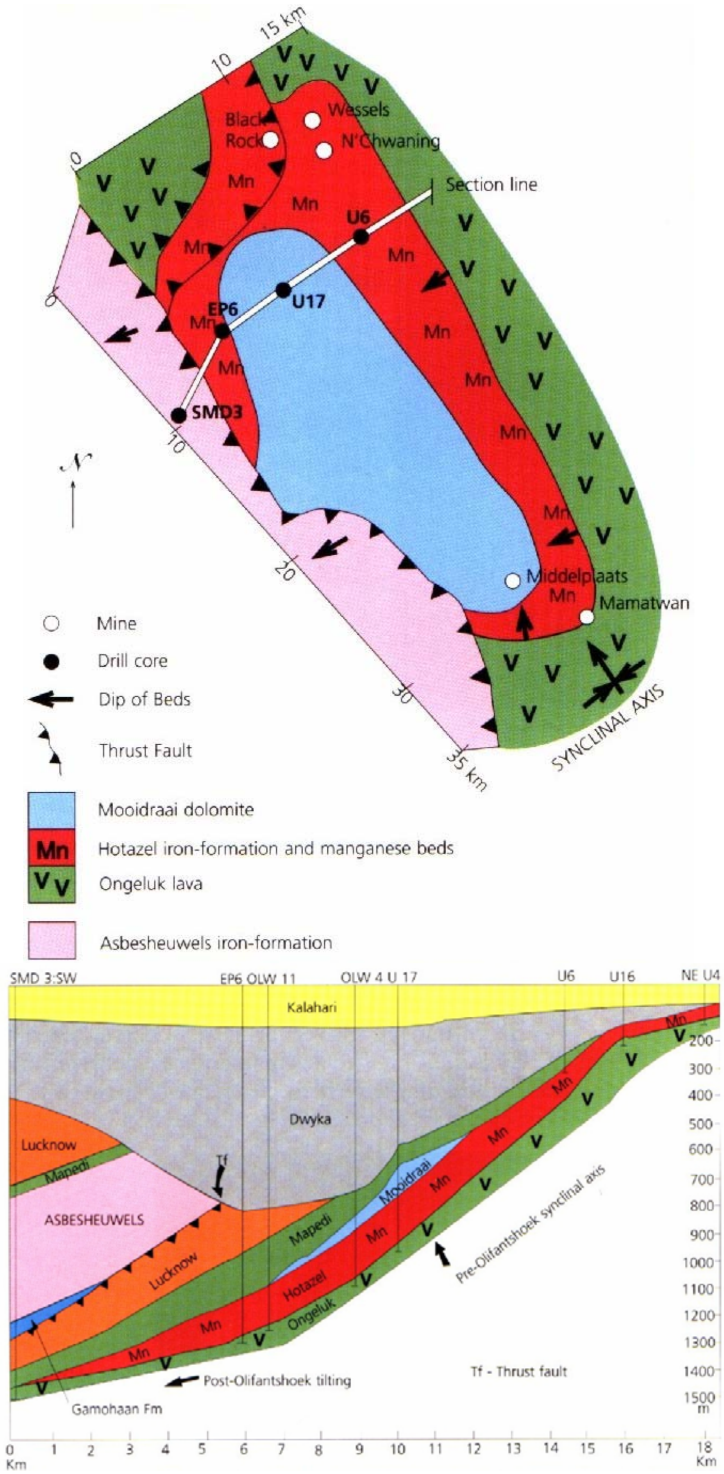


***Figure 18** Kalahari Manganese Field geology (from Cairncross et al., 1997).*

In some instances, the base of the Hotazel Formation comprises what is colloquially referred to as debrite, a lithology that appears to comprise lenticular, and in some cases brecciated, chert deposits within a dolerite-type matrix. Various explanations have been offered for the formation of the material, perhaps the most popular being that pre-existing chert beds were fractured following the post-depositional emplacement of dolerite-type material (van der Merwe, 2002a).

However, the remarkably similar chemical characteristics of debrite and Ongeluk Lava sampled during this investigation suggest a transitional model of formation may be more applicable (refer Appendix 3).

Three manganese-bearing sequences are of importance throughout the basin, the lower, middle, and upper bodies. Of these, the lower body is of most significance, with virtually all reserves in the field derived from here. At Mamatwan Mine and across the Smartt-Rissik prospect, ore dips in a south to southwesterly direction at approximately 6^0, and is of the low grade Mamatwan type, characterized by laminated, carbonate bearing, braunite rich mudstone, although supergene enrichment is thought to have occurred adjacent to dykes in the area (Cairncross et al., 1997; van der Merwe, 2002a; 2002b; Hotazel Manganese Mines, 2000?b). In the more structurally complex area around Wessels Mine in the north of the basin, however, ore of the higher grade Wessels type dips west at 8^0. Work undertaken to date across the field suggests that 11 texturally distinct ore zones are represented in primary ore of this type (Cairncross et al., 1997).

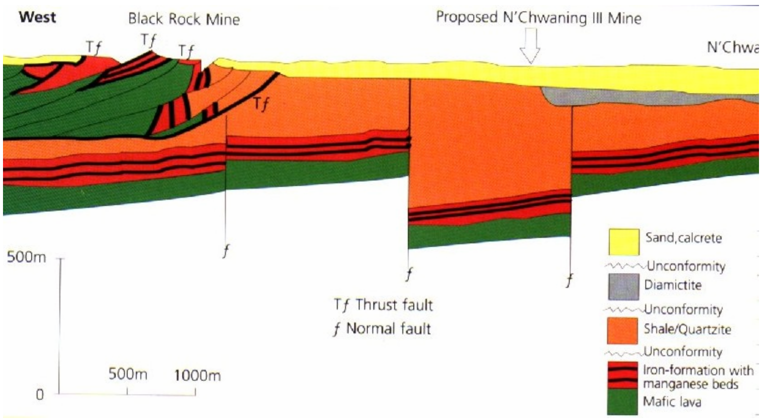


Figure 19 *Section through the northern part of the Kalahari Manganese Field (from Cairncross et al., 1997). Note the extensive thrust faulting that has occurred in the vicinity of the Assmang-owned Black Rock Mine, which is located just west of SAMANCOR's Wessels Mine.*

Ore exposed in the still operating Mamatwan mine and abandoned Perth, Smartt, and Hotazel pits is typically massive in character, with minor vertical fracturing and bedding parting observed. However, inspection of drill core and drill cuttings suggests that many of these fractures are filled with carbonate minerals at depth.

Iron rich beds, colloquially referred to as Banded Iron Formations (BIF's), also form part of the Hotazel Formation, those containing significant carbonates in the south of the field in the vicinity of Mamatwan Mine, the Smartt-Rissik prospect, and the now derelict Middelplaas operations.

Indeed, BIF's here are perhaps best described as laminated, carbonate bearing, haematite rich mudstones. Work undertaken on the Smartt-Rissik prospect suggests that manganese ore beds are always enveloped within a red coloured BIF, with greenalite-magnetire-carbonate micro-to-meso banded rythymites separating subsequent envelopes (van der Merwe, 2002b). Black coloured, magnetite rich BIF's are also observed adjacent to a sill that has intruded BIF's below the base of the lower manganese body, an apparent result of localized contact metamorphism and associated oxidation of Fe^{2+} to Fe^{3+}.

BIF's exposed in the vicinity of the Smartt-Rissik prospect appear to be more fractured than associated manganese ore beds, particularly with regards to parting along bedding planes. This tends to suggest that site BIF's are somewhat brittle in character, a finding supported during rotary air percussion drilling when platy, angular particles of BIF up to 75 mm in diameter were observed among cuttings.

Results of XRF studies undertaken by Beukes and van der Westhuizen (2002; 2003) confirm that units comprising the Hotazel Formation at the site contain appreciable silica (as quartz), iron, manganese, and calcium. High Loss-On-Ignition (LOI) figures suggesting the presence of calcareous minerals in the samples, a finding confirmed following X-Ray Diffraction (XRD) analysis (Beukes and van der Westhuizen, 2002; 2003).

Acid-Base Accounting (ABA) undertaken on representative Hotazel Formation samples indicates that constituents are not readily soluble in water, even when completely oxidized (refer Appendix 3). Nevertheless, testing did suggest that trace to minor amounts of crushed ore derived aluminium, calcium, iron, potassium, magnesium, manganese, sodium, zinc, and sulphate could dissolve under ideal conditions, which suggests that these parameters also have potential for application as pollution indicators during routine monitoring.

ABA was also undertaken on slimes and discard samples from the respective mine sites, and given their source, can be considered to represent a mixture of site lithologies, with Hotazel Formation derived material predominant (refer Appendix 3). Aluminium, calcium, iron, potassium, magnesium, manganese, sodium, zinc, and sulphate were again released during testing, albeit in greater amounts when compared to the tested background Hotazel Formation samples.

5.3.3 Mooidraai Formation

The dolomites of the Mooidraai Formation that gradationally overlie the Hotazel Formation are thought to represent a carbonate succession deposited in a shallow sea along the western margin of the Kaapvaal Craton (Hotazel Manganese Mines, 2000?b). The formation sub-crop in the project area is essentially restricted to a small section extending westwards from the western edge of the Mamatwan and Smartt-Rissik prospects to the Gamagara River, and is comprised of grey-blue coloured dolomite interbedded with minor chert. The only known mine workings to have intercepted the Mooidraai Formation within this section were associated with the now abandoned underground Middelplaas Mine.

Being of similar age (albeit gradationally younger), it is not surprising that the Mooidraai Formation in the vicinity of Middelplaas Mine has a similar structural history to the Hotazel Formation that it overlies, as characterized by the presence of at least one northeast-to-southwesterly trending dyke within the unit.

5.3.4 Intrusive units

The sill intercepted during exploration drilling on the Smartt-Rissik prospect has a similar attitude to the sediments it occurs within, and typically resembles a coarse grained dolerite under field conditions. In hand specimen, it appears to have similar characteristics to the older Ongeluk Formation, although it can sometimes be distinguished on the basis of colour, feldspar shape, and the apparent absence of augite. When drilled using rotary air percussion equipment, the sill was generally found to be resistant to drilling, and in most instances, fresh throughout. Observed core obtained from diamond drilling was typically un-fractured, with those rare fractures typically filled with secondary minerals. While the proven extent of the Smartt-Rissik sill is limited to those areas where exploration drilling has been undertaken, it is known to also sub-crop, presumably continuously and with relative constant thickness, on the Mamatwan and Middelplaas mine properties.

A sill was also encountered during mining at the Hotazel Pit further to the north, and was easily distinguished from adjacent sub-crops of sub-vertical to vertical dykes and Ongeluk Lavas due to its fibrous appearance, a consequence of the predominance of plagioclase lathes. Whether or not this sill is equivalent to that encountered on Smartt-Rissik remains unknown, however.

Regional aeromagnetic data indicates that the Smartt-Rissik prospect is intercepted by several regional scale linear structures trending northeast to southwest that extend into the Middelplaas mine area, most of which were proven to be dykes following exploration drilling (refer **Figure 14**). Under field conditions, these dykes appear doleritic in character, although bostonite dykes are known to occur elsewhere in the basin (i.e. Wessels and Hotazel Mines; Cairncross et al., 1997). Subsequent interpretation of borehole data suggests that vertical displacement of the Hotazel Formation and the sill that intrudes it has occurred along the trend of many of these structures, with the northwestern side typically block faulted downwards (van der Merwe, 2002b). Of importance, however, is that there is no evidence for the fracturing of site dykes, as would be expected if faulting post-dated dyke emplacement. Thus, many of the permeable voids that developed in response to faulting would have been filled during a later magmatic phase.

Aerial photographs, regional aeromagnetics and drilling data, and sub-crops intercepted during mining indicate that similarly orientated northeast-to-southwest bostonite dykes also occur in the central and northern parts of the basin around Hotazel and Wessels Mine, respectively. Dykes intercepted here vary in thickness from <1 to 70 m, the average apparently ranging between 20 and 30 m (Hotazel Manganese Mines, 2000?c). Given their common orientation and mineralogical similarities, it seems likely that both fault development and subsequent dyke emplacement across the basin was associated with distinct structural and magmatic events.

5.3.5 Structural deformation

Structural deformation varies across the field, with available data suggesting that it was more intense in the vicinity of Wessels Mine in the north. Here, fault orientations are typically orientated northeast-to-southwest, north-to-south, and west/northwest-to-east/southeast. The north-south orientated normal structures are thought to have developed during the initial deposition of the Olifantshoek Group sediments some 1800 to 2150 million years ago in response to extensional stresses, these post-dating the northeast-to-southwesterly orientated structures that have, in part, been infilled with bostonite (Cairncross et al., 1997). While the timing of the west/northwesterly-to-east/southeasterly shear events appears unknown, it seems plausible that associated structures are conjugate features that developed in response to the extensional episode.

Nappe and recumbent fold structures that developed along the strike of the regionally-extensive Black Ridge Thrust Fault in response to thrusting approximately 1800 million years ago are represented at Wessels Mine, and the western boundary of the Smartt-Rissik prospect. The suggestion has also been made that small-scale thrust-related structures occur in the old Hotazel

Mine pit (refer **Figure 20**), although given their sporadic distribution it seems likely that these represent either,

- The most easterly expression of thrusting; or,
- Localized deformation in response to sill and dyke emplacement.

Localized structures are also of significance in the Hotazel area, as these appear to control the highest-grade manganese deposits yet discovered at this, and any other for that matter, mineral field. There, ore mined from the now abandoned Hotazel, and adjacent Assmang-owned Devon, and Langdon Annex Mines, is thought to have been restricted to structurally isolated, north-south orientated, down-faulted grabens, although supporting evidence for the presence of these faults appears somewhat lacking.

Figure 20 *Structure in Hotazel Formation, Hotazel Mine pit. While resembling a parasitic nappe, the virtual absence of similar structures elsewhere in the pit suggests the structure represents either the most easterly expression of thrusting, or localized deformation due to sill and dyke emplacement.*

5.3.6 Olifansthoek Group

Sulphide-bearing Olifantshoek Group sediments, comprising Mapedi Formation shales and mudstones, and the Lucknow Formation quartzite horizons, are of significance at Wessels Mine, where they unconformably overlie Hotazel Formation sediments at depth (Hotazel Manganese Mines, 2000?c). Here, the Black Ridge Thrust Fault has truncated the sediments, resulting in the emplacement of a nappe comprising older Ongeluk and Hotazel Formation lithologies on top of the younger Olifantshoek Group beds. Being of no strategic importance, any Olifantshoek

Group sediments extracted as part of mining operations are immediately transferred to overburden and waste rock disposal sites on the site surface.

5.3.7 Hydrothermal alteration

Subsequent localized hydrothermal alteration has occurred across the basin, with the Wessels, Gloria, and Smartt Events of importance to this study. The high ore grades currently mined at Wessels Mine can be attributed to the removal of carbonates from primary sedimentary Mamatwan-type manganese ores during the Wessels Event approximately 1250 million years ago. This event also resulted in the release of significant quantities of silica, calcium, and magnesium from the system and the local redistribution of iron, manganese, barium, and boron (Cairncross et al., 1997). In comparison, the Gloria Event resulted in the sporadic emplacement of carbonate-sulphide-haematite mineral assemblages in joints and faults across the basin 550 to 600 million years ago (although no sulphide minerals have yet been identified on the Smartt-Rissik prospect), with the emplacement of fibrous minerals in brecciated fault rocks occurring later during the Smartt Event (approximately 90 million years ago; Cairncross et al., 1997). These events would have resulted in significant decreases in site porosity and permeability.

5.3.8 Dwyka Formation

The ±300 million year old tillites of the Dwyka Formation form the base of the Carboniferous to Jurassic-aged Karoo Basin. Unconformably overlying older lithologies at scattered sites generally located along the western margin of the Kalahari Manganese Field, these also post-date regional-scale structural and intrusive events. In terms of this investigation, the formation has relevance at only two sites, Wessels Mine and the abandoned Middelplaas prospect. At Wessels Mine, the Dwyka Formation is only preserved within erosional troughs in the northeast of the prospect, and thus is only of local significance. In the vicinity of Middelplaas Mine in the south, however, the formation is more extensively represented as basin in-fill, with a thickness of 100 m or more intercepted in some exploration boreholes. Dwyka Formation sediments there typically have sub-angular to sub-rounded particles of dolerite, Hotazel Formation sediments, and dolomite, within a brown clayey matrix, the finer grained material often washing badly when drilled.

5.3.9 Kalahari Formation

Five erosional surfaces (i.e. unconformities) can be identified across the basin (Cairncross et al., 1997), although in terms of the southernmost mines (Mamatwan, Smartt-Rissik, and

Middelplaas), the most important occurs at the base of the 90 million year old Cainozoic Kalahari Formation, which covers, and completely obscures, the Hotazel Formation at the site. While only a few metres thick in the vicinity of the old Smartt mine, it increases in thickness to the north, south, and west, approaching 80 m near the boundary of the Mamatwan Mine and Smartt-Rissik prospect. By considering regional geophysics, drill core, and bore log data for this area, a previously unidentified palaeochannel was discovered, the trend of the feature consequent with that of a regional scale, northeast-to-southwesterly trending dyke (i.e. dolerite infilled fault). It seems likely, therefore, that older, pre-existing structures can have a significant influence on the distribution of surficial deposits across the entire basin.

The thickness of the Kalahari Formation appears relatively consistent in the Hotazel area, typically measuring no more than 30 m. In the north of the basin, however, the formation thickness is typically between 80 and 100 m.

Sub-angular to well-rounded pebbles of doleritic material within a sand/calcrete matrix typically characterize aquifers within the Kalahari Formation across the field. Often occurring as steep-sided channel deposits when exposed in the Hotazel and Mamatwan Mine pits, it appears likely that pebble deposition followed, or was coincident with, an intense period of erosion during a climatically wetter period. These beds are typically underlain by, or on rare occasions interbedded with, red clay on the Wessels, Mamatwan, and Middelplaas Mine properties, the thickness of respective beds varying with location. Of significance, however, is the noticeable absence of this clay unit around the Hotazel Mine and across parts of the Smartt-Rissik prospect.

Closer to the surface, a distinctive white calcrete unit is apparent, often characterized by cemented sand sized particles, although pebble sized particles of doleritic-type composition are also represented at depth. Black, dendritic manganese staining is easily seen in this material, its occurrence suggesting the movement of water, and subsequent precipitation of manganese salts, along preferred pathways within the calcrete. Indeed, sections exposed in the Mamatwan mine and old Smartt pit suggest that the calcrete itself developed in a similar manner, with calcite precipitating from percolating bicarbonate rich water within the pores of pre-existing aeolian deposits.

A blanket of well sorted (in geological terms), quartz rich, aeolian sands up to 20 m thick (excluding the underlying calcrete layer) covers the entire site, their orange brown colour suggesting the presence of trace amounts of iron. These deposits typically become lighter in colour with depth, due to the increased prevalence of calcite and feldspar, and locally form a resistant layer of pink-brown coloured sandstone at the contact with the underlying calcrete. Given the characteristics of the adjacent lithologies, it seems likely that this sandstone could be both silicate and carbonate cemented, depending on local site characteristics.

A significant proportion of the overburden at the respective prospects is (or will be in the case of Smartt-Rissik) comprised of Kalahari Formation sediments. Results of XRF testing confirm the high quartz content of the surficial sand layer (JB8: 0-1 m and JB8: 5-8 m; SiO_2 > 90 wt%; refer Appendix 3), and although trace amounts of iron and aluminium minerals area present, sample inspection under a microscope suggests it forms part of the matrix of individual quartz grains. Thus, the upper aeolian sands can be regarded as chemically inert. In comparison, the high silica, calcium, and magnesium concentration measured in the calcrete layers (JB10: 14-18 m; 31.09, 25.2, and 10.7 wt%, for SiO_2, CaO, and MgO, respectively) confirms the presence of carbonate minerals here. This could result in the mobilization of minor amounts of calcium, magnesium, and bicarbonate ions during prolonged wet periods, although given regional climatic conditions the probability for this occurring will be low in most years.

The tested red clay sample (JB32: 66-67 m) was found to contain appreciable SiO_2, presumably in the form of quartz grains within the clay, dolomite, and minor amounts of the clay minerals montmorillonite (presumably Ca-type) and palygorskite. Both clays tend to develop in magnesium rich settings, with palygorskite a common mineral in arid environments. The structure of the respective clays varies, however, with palygorskite and montmorillonite having a chain and layered structure, respectively. Calcium-type montmorillonite clays can also have a significant potential to swell when wet, and unlike those of sodium-type, are usually non-dispersive.

Atterberg Limits, Linear Shrinkage, and Particle Size Distribution (PSD) testing was undertaken on a red clay and selected aeolian sand samples (refer Appendix 3). Results confirm that site aeolian profiles are comprised almost entirely of fine to medium grained sand, and thus have poor sealing properties. In comparison, the tested red clay sample (JB32: 66-67 m) contains minimal sand, is highly plastic, and has a high shrink-swell potential.

5.4 Construction of monitoring boreholes

Unlike other SAMANCOR leases in the area, old workings on the Smartt-Rissik prospect have limited size, and apart from the still open and relatively small mine pit and associated spoils dumps, no evidence of mining remains. Indeed, two of the four proposed pits are located in undisturbed areas.

11 bores, some containing multiple piezometers, were installed across the Smartt-Rissik prospect to allow water levels and site groundwater quality to be monitored over time. The following approach was taken to monitoring bore site selection:

- Discussions were held with SAMANCOR's contracted rotary air percussion driller, the exploration geologist, and the geological services manager to ascertain their perceptions of site geohydrology;
- Available geological and geophysical data was perused, and interpretations revised where deemed necessary;
- Interpreted dykes and faults bounding the proposed mine pits were targeted during the drilling programme because of the potential for these structures to act as preferential flow pathways;
- Borehole positions were refined following inspection of selected drill core obtained during exploration drilling. Features of importance included the degree of core fracturing or fracture infilling, and whether dyke material had been intercepted during drilling.

Initially, 300 mm diameter boreholes were drilled though the relatively un-cohesive surficial sands, and 265 mm diameter steel casing installed. Drilling was then continued to the sill/Hotazel Formation interface or the first water strike using a 250 mm diameter drill bit, with the bit diameters reduced to a minimum size of 165 mm with further drilling. In the event that several water strikes occurred, multiple 110 mm Outside Diameter (OD) uPVC casing strings were installed, with screened sections for a given casing string positioned adjacent to a selected strike. A screened (10 mm diameter or less) crushed dolerite filter pack was then progressively placed in the hole, with a bentonite seal not less than 3 m thick installed above respective screen sections. Drill cuttings were used as hole-support from the upper seal to the site surface, where a concrete plinth was constructed. A lockable steel bore cap incorporating a 2 m long marker post was then fitted to the steel casing installed initially to prevent hole collapse.

Following the installation of three piezometer nests, a single casing string was installed within a 165 mm diameter borehole at subsequent sites. This was justified for several reasons:

- The driller was reluctant to drill a 165 mm pilot hole at piezometer nest sites. Thus, 250 mm diameter holes were essentially being used for exploration purposes, making borehole construction slow and unnecessarily expensive;
- While several seepage zones were encountered in a given hole, often only one distinct water strike occurred. The installation of several piezometer pipes was therefore unwarranted from a geohydrological and cost-viewpoint; and,
- At any given monitoring site, the Static Water Level (SWL) in respective piezometers was found to be the same, suggesting hydraulic interconnection between different formations. Subsequent work suggests this could also be a response to the fracturing of brittle profiles during drilling, the bentonite seal unable to fill smaller fractures located furthest from the casing.

Following installation, the XYZ location of the monitoring bores and the pit water level in the derelict Perth Mine, an Assmang-owned lease adjoining the prospect to the north, was determined using GPS and conventional survey methods (refer Appendix 4).

A similar approach was taken to borehole construction at the remaining mine sites, although the rationale behind site selection varied depending on site geology i.e.

i. The absence of dykes on the Mamatwan prospect negated the need for trying to intercept preferred pathways within the Hotazel Formation with relatively deep boreholes;
ii. The occurrence of pebble bed aquifers above a thick layer of highly plastic silty sandy clay at Middelplaas and Wessels Mines indicated that relatively deep boreholes were not required for pollution monitoring purposes;
iii. The presence of dykes and faults at relatively shallow depth dictated that they be targeted when in the vicinity of potential pollution sources identified on Hotazel Mine property.

Pollution sources targeted during the monitoring bore construction phase are summarized in **Table 12**). At those sites where collapsing ground conditions were encountered during drilling, 165 mm OD steel casing was installed. As with all boreholes constructed at SAMANCOR sites in the region, XYZ co-ordinates for each of the boreholes was determined using a differential GPS (refer Appendix 4), and a cap/marker post assembly fitted.

Table 12 Pollution sources targeted at Hotazel, Mamatwan, Middelplaas, and Wessels Mines during monitoring bore installation. Those marked "*" were pre-existing boreholes that were incorporated into the monitoring system.

Site	Hotazel Mine	Mamatwan Mine	Middelplaas Mine	Wessels Mine
Slimes dam	-	JB18, JB19*, JB22, JB24	-	JB30, JB31
Waste rock dump	JB39, JB40, JB44*	JB20, JB21	JB16	JB36
Explosive magazine	JB41	JB21	-	JB28
Ore stockpile	JB38, JB42	-	JB25, JB26	JB33
Sewage plant	JB38	JB23	JB27	JB37
Store, workshop, wash-down areas, oil skimmers	JB43	JB17, JB19*, JB20	-	JB34, JB35
Return water dam	-	-	-	JB29
Solid waste site	JB39	JB24	-	JB32

5.5 Geohydrology

5.5.1 Groundwater flow characteristics

Given the proximity of installed monitoring bores to mining operations, there is a potential for the water table in the vicinity of Hotazel and Wessels Mines to represent local as opposed to regional flow conditions (refer **Figure 21** and **Figure 22**). In comparison, the Smartt-Rissik, Mamatwan, and Middelplaas prospects are adjoining properties that cover a significant proportion of the southern portion of the Kalahari Manganese field. Given the distribution of monitoring boreholes there, the relatively similar topography throughout, and that mining ceased more than 20 years ago at two of the three sites, is seems reasonable to assume that groundwater flow conditions in areas distant from Mamatwan Mine would be close to, or at, equilibrium conditions.

The water table across these southern prospects falls at an average gradient of 1V: 200H towards the northwest, and in the direction of, the Gamagara River, the water table rising into the sediments of the Kalahari Formation in the south and west (refer **Figure 23** and Appendix 4). However, in the northern half of the Smartt-Rissik prospect, groundwater is stored within the dyke-truncated Hotazel Formation. Here, the water table is locally elevated and relatively flat in response to a reduction in hydraulic conductivity adjacent to relatively impermeable dykes (i.e. dyke damming has occurred; refer **Figure 24**).

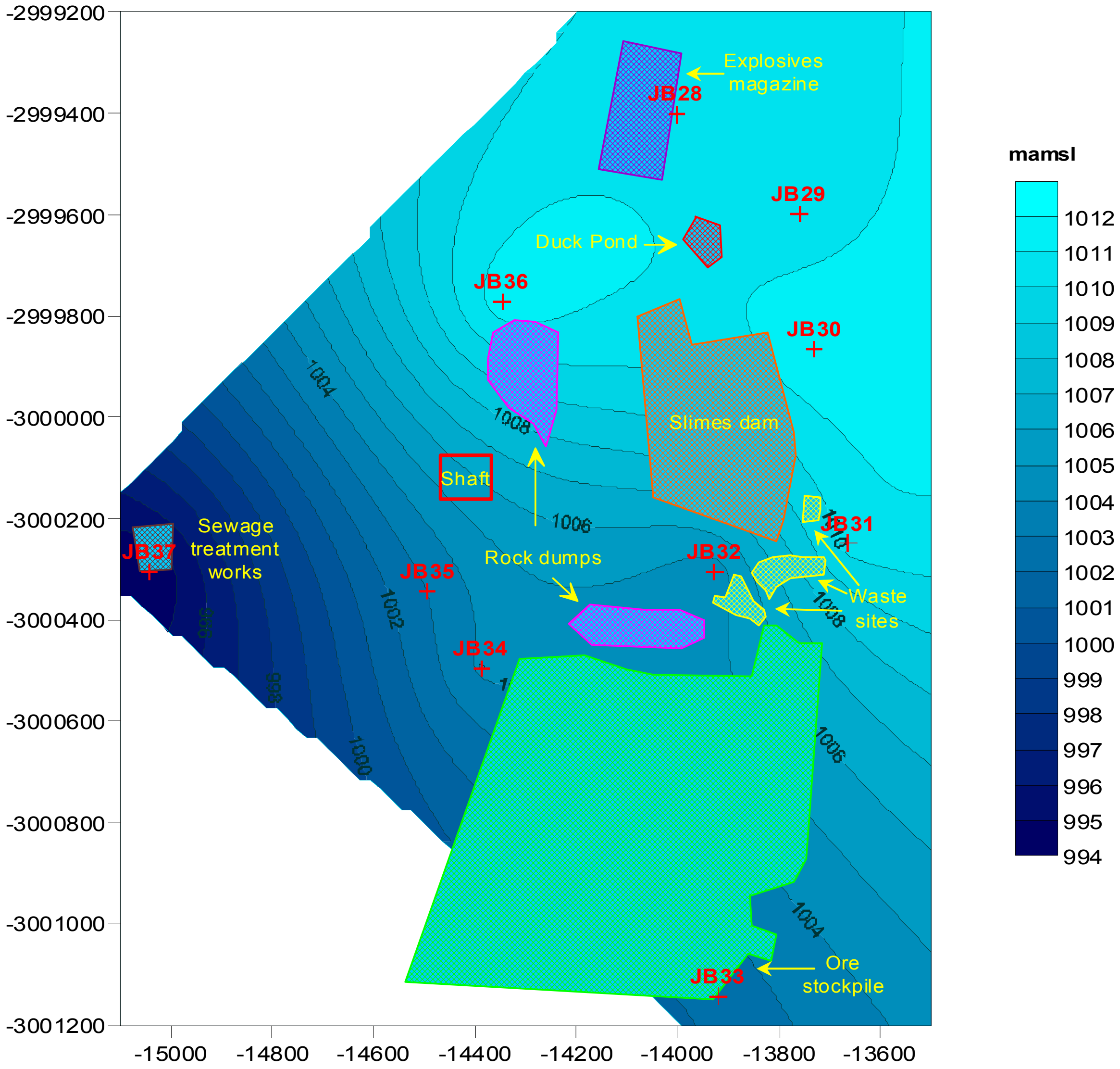


Figure 21 *Orientation of water table at Wessels Mine. Note the mound that has developed in the vicinity of the Duck Pond and slimes dam, which is increasing the hydraulic gradient in the direction of the mineshaft.*

The water table in the vicinity of Mamatwan Mine is highest adjacent to the now abandoned slimes dam at JB24, and decreases rapidly towards JB22, a borehole constructed through site spoils and into the underlying Hotazel Formation. If JB22 is ignored, however, it is apparent that the water table in the vicinity of the pit is also a reflection of topography, following the same trend as that observed in the un-mined areas of the Smartt-Rissik prospect to the north. This suggests that,

- On a mine scale, site aquifers have low permeability and storage characteristics;
- Groundwater ingress into the mine is minimal. While long term pumping data is not available, experienced mine staff have suggested that groundwater ingress was minimal until

a few years ago. This observed increase appears to coincide with several years of above average rainfall and the thickening of the Kalahari Formation sediments at the currently mined northern pit face.

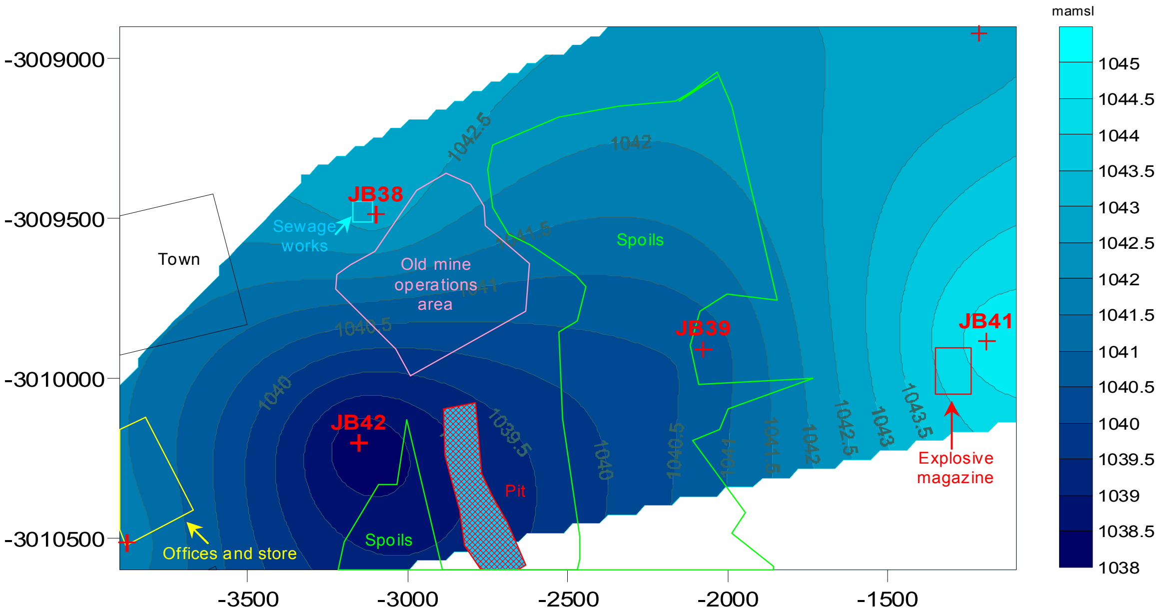


Figure 22 *SWL in vicinity of Hotazel Mine. The natural hydraulic gradient is towards the Gamagara River in the west at about 1V: 200H. Note that, on the basis of limited SWL data, mining has influenced the orientation of the water table in the vicinity of the abandoned pit (JB42).*

The elevated water level at JB24 can also be explained when the bore log for the site is considered. Here, relatively permeable, calcrete-cemented gravel beds were found to overlie impermeable red clay at shallow depth, conditions ideal for the development of a localized perched aquifer. The impermeable characteristics of this unit could also explain variations in piezometric conditions observed at M24 in the past. With a final blow yield of about 18L/s at a termination depth of 221.5 m, the bulk of the supply is derived from broken dolomites of the Mooidraai Formation at depth with lesser contributions from overlying Dwyka and Kalahari Formation aquifers. The similarity between the SWL in M24 and the abandoned underground Middelplaas Mine workings (167 and 160m, respectively; Rudolph, 1995) suggests:

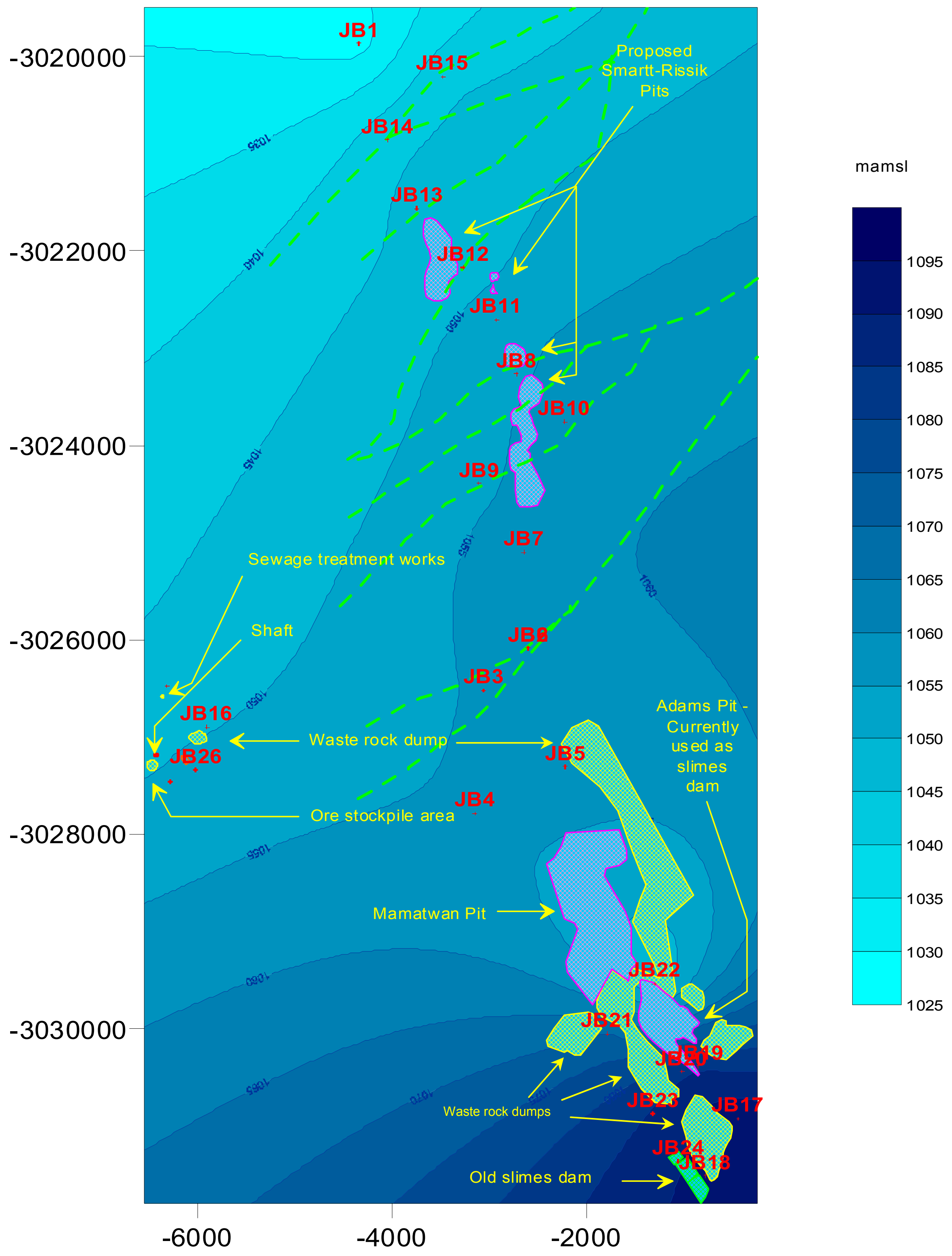


Figure 23 *Water table orientation across the Smartt-Rissik, Mamatwan, and Middelplaas prospects. Note the dykes (dashed green lines), the location of which was confirmed using regional aeromagnetics data and during exploration drilling, across the Smartt and Rissik properties.*

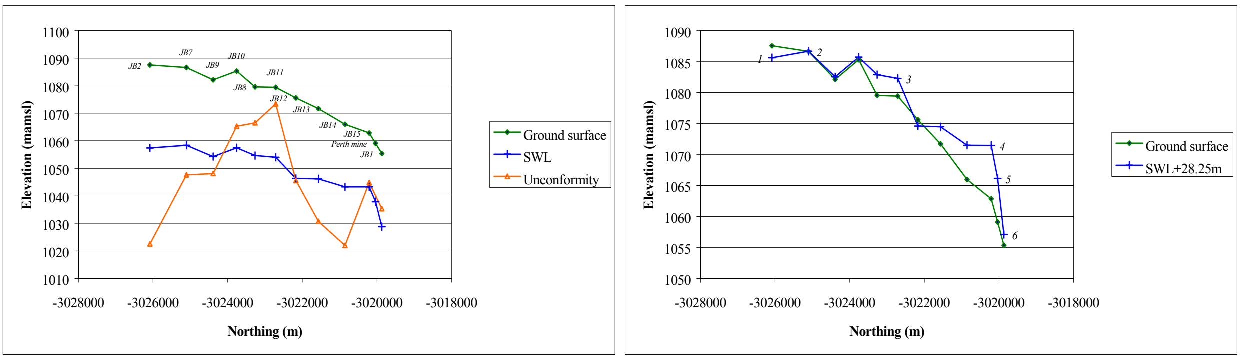


Figure 24 *Section (north-south) through Smartt-Rissik monitoring bores and the derelict Perth Mine (left plot). Note the relationship between site topography, the unconformity at the base of the Kalahari Formation, and SWL. The SWL profile has also been overlain on the topographic section by adding a value of 28.25 m to all monitoring bore SWL measurements (right plot). Points of significance along this section include; 1) Depression of water table due to groundwater extraction from exploration borehole REX158; 2) Groundwater is a reflection of topography due to the water table being above the Kalahari Formation unconformity; 3) First evidence of dyke damming (behind the dyke near JB12), as shown by the flattening and relative increase in the elevation the water table. Recharge through the floor of the existing Smartt pit may have contributed to the sudden increase in water table elevation here; 4) There is very strong evidence for dyke damming here. Both JB14 and JB15 intercept the same dyke structure. Although JB14 is 3.12m higher, and 900m distant from JB15, the difference in SWL is only 0.04m (SWL elevation 1043.28 and 1043.24 mamsl at JB14 and JB15, respectively); 5) Denotes the pit water level in the abandoned Perth mine. The SWL plot indicates that the mine intercepts site aquifers; 6) The SWL again appears to reflect site topography.*

- Kalahari Formation aquifers have been dewatered adjacent to M24 and the abandoned shaft;
- Hydraulic interconnection between the dolomites intercepted at the two sites;
- Surficial Kalahari Formation aquifers are not hydraulically connected to the dolomitic aquifers at depth, and must therefore be separated by a confining layer. Site geological conditions support the presence of a confining layer at the site, given the significant thickness (approximately 150 m) of Kalahari Formation clays, and clay matrix supported tillites (Dwyka Formation) intercepted during the construction of JB25. It is also of significance that, while the shaft has breached the confining layer, minimal water appears to be draining into Mooidraai Formation aquifers from younger, stratigraphically elevated aquifers, as evidenced by the absence of a cone of depression around the structure. Thus, since mining operations have only impacted upon site water levels in the immediate vicinity of the shaft, it

is reasonable to assume that Kalahari Formation aquifers surrounding the structure have low permeability.

Efforts to measure the water level in the shaft during this investigation proved unsuccessful, the shaft either empty (unlikely given the inferred hydraulic connection between the workings and M24) or blocked following a high level cave-in.

It should be appreciated that M24 is the only known production borehole to have been constructed into the dolomitic Mooidraai Formation. There are probably a few reasons for this:

i. The sub-crop extent of the Mooidraai Formation is relatively small, and restricted to the southwestern portion of the Kalahari Manganese Field;
ii. The depth at which the Mooidraai Formation is encountered, which in the vicinity of Middelplaas Mine is covered by a layer of Dwyka and Kalahari Formation sediments about 200 m thick. While occurring at shallower depth up dip to the east and northeast, the thickness of the Mooidraai Formation here is relatively thin (sometimes in the order of a few metres), thus reducing the potential to intercept high yielding aquifers;
iii. Farmers are not prepared to cover the additional cost associated with tapping Mooidraai Dolomite aquifers for stock water supplies.

In general, piezometer data and observations made during exploration drilling and monitoring bore installation indicate that the red clay layer is absent across the Smartt-Rissik prospect and the northern part of Mamatwan Mine. Indeed, vertical hydraulic connection between respective lithologies seems likely here, particularly when observations made during piezometer installation are considered, with intercepted aquifers unconfined to semi-confined in character.

Prior to construction, the highest known blow yield obtained during the drilling of hundreds of exploration boreholes across the Smartt-Rissik prospect with a rotary air percussion rig was 0.8 L/s, with the site average significantly lower. However, blow yields from some installed monitoring bores are significantly higher than this (one >10 L/s). Given that structural features were targeted during monitoring bore installation, this is of importance because it confirms that:

- Highly permeable secondary aquifers within the Hotazel Formation are associated with structural features such as dykes and faults; and,
- Groundwater occurrence is controlled by these structures. Away from these features, the permeability and storage potential of the Hotazel Formation is significantly reduced. Further, since some of the bores drilled into dykes intercepted only seepage, and groundwater

has been proven to dam behind dykes in the area, groundwater occurrence is not necessarily continuous along the trend of these structures. Instead, the bulk of the resource is restricted to more permeable zones, as confirmed following in situ determination of hydraulic conductivity (refer Appendix 4).

Primary aquifers intercepted at the site were generally restricted to calcrete-cemented pebble beds contained within Kalahari Formation sediments. While generally low yielding (<0.2 L/s), a blow yield of 5.6 L/s was measured at JB2, which suggests that these aquifers could be of importance locally.

Two boreholes, JB5 and JB6, were drilled within 4 m of boreholes known to intercept pebble beds with a thickness of more than 10m and a blow yield in excess of 3 L/s (unknown borehole and JB2, respectively). Blow yields were significantly less in both instances (<0.5 L/s at both), which suggests that these aquifers are heterogeneous. This is unsurprising given that the pebble beds were deposited on an undulating and sloping, rather than uniformly orientated, site surface.

Table 13 Results of constant discharge pump testing undertaken at JB2.

Site	**Transmissivity** ***m^2/d***	**Storativity**
JB2	20.6	-
JB6	11.4	2.11E-3
REX157	31.3	4.11E-4
REX158	8.3	1.23E-5
REX161	36.4	1.70E-3

With a view to determining whether Kalahari Formation aquifers were also anisotropic, a constant discharge pump test was conducted at JB2, with JB6, and exploration boreholes REX157, REX158, and REX161, used for observation purposes. Results indicate that transmissivity and storativity vary significantly from site to site (refer **Table 13**), with the pumping-induced cone of depression clearly orientated north-to-south and parallel to the strike of the sub-cropping Hotazel Formation–Ongeluk Lava Formation interface (refer **Figure 25**).

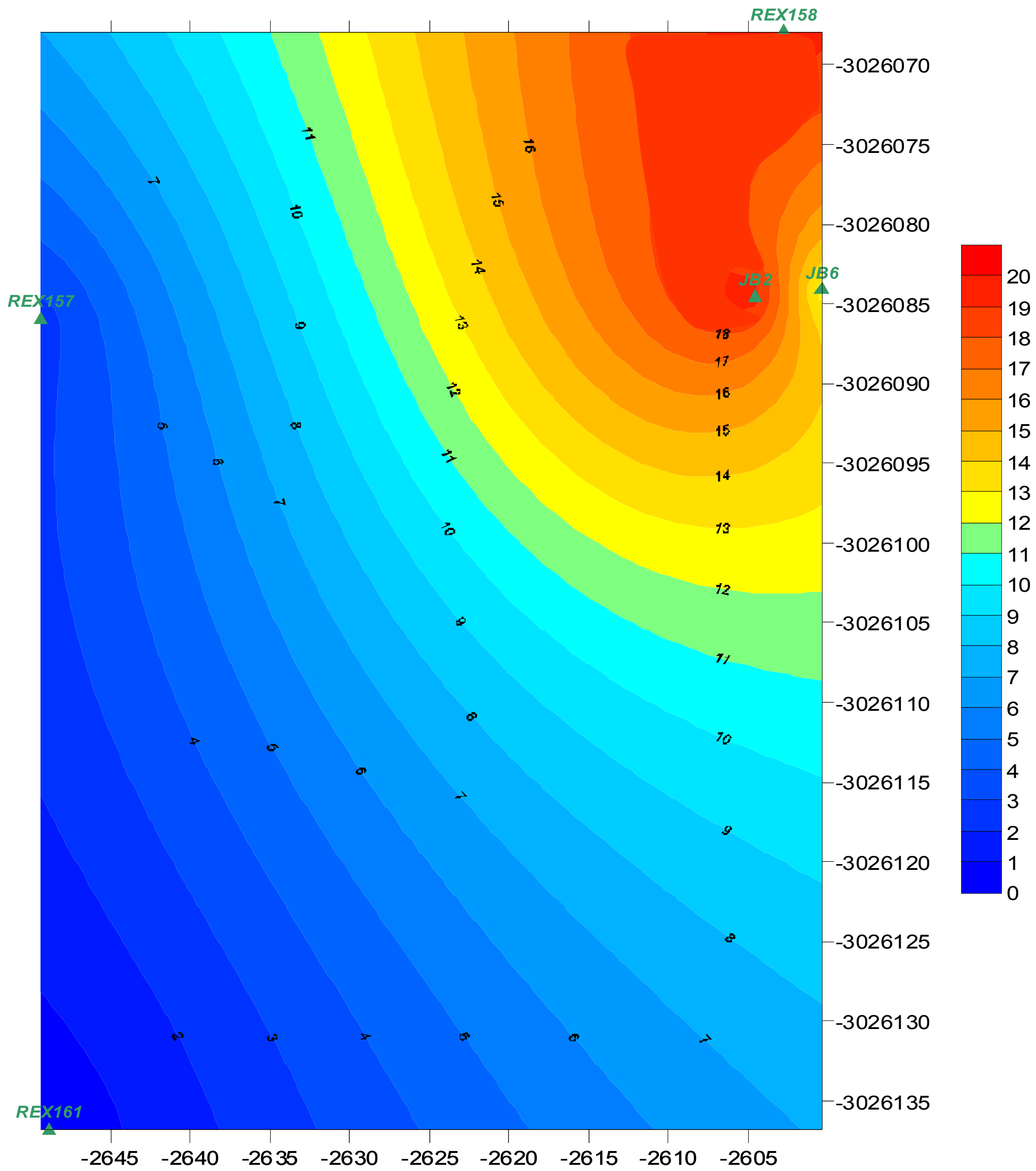


Figure 25 *Draw-down after pumping JB2 at a constant rate of 3 L/s for 72 hours (in metres). Note that the resulting cone of depression has an elliptical shape, which confirms that the tested aquifer in heterogeneous in character. The orientation of the cone parallel to the strike of the interface between the Hotazel and Ongeluk Lava Formations suggests that the palaeochannel tributary aquifers, as opposed to aquifers within the palaeochannel itself, are of significance locally.*

5.5.2 Water quality

Results indicate that water type is highly variable across the region, with calcium and magnesium the predominant cations typically (refer **Figure 26** and Appendix 5). Anion composition is more variable, however, varying between bicarbonate and chloride + nitrate end members in most instances, although sulphate is also of importance at some sites. Water classified as “Class 4” type according to Department of Water Affairs and Forestry (DWAF) guidelines does occur within the project area, and can in almost all instances be attributed to high nitrate concentrations (refer Appendix 5).

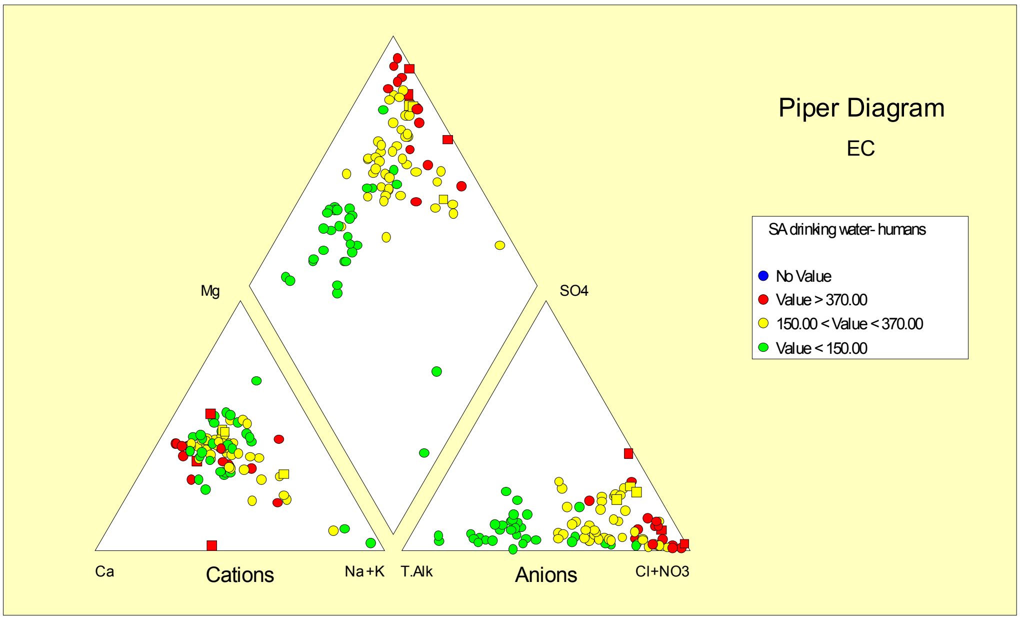


Figure 26 *Plot of major ion characteristics for groundwater samples on a Piper Diagram. Note that quality is generally better in those samples containing a lesser proportion of Cl+NO_3.*

The relationship between respective chemical parameters was also considered graphically. Plots indicate that there is a linear correlation between Electrical Conductivity (EC), Total Dissolved Solids (TDS), and chloride concentrations at the site, although the chloride correlation is not as well developed above an EC of 400 mS/m (refer **Figure 27**). Only at lower concentrations does chloride appear to be proportional to sodium, however (refer **Figure 28**), which suggests that; a) sodium exchange processes may be of significance at the site, and; b) alternative sources of sodium other than that associated with dissolved NaCl occur within the system.

Given the occurrence of dolomite mineralization throughout site lithologies, but particularly in the Kalahari Formation calcrete aquifers, the observed linear relationship between magnesium and calcium in sampled groundwater comes as no surprise (refer **Figure 29**). Of significance, however, is the non-linear relationship between calcium and Total Alkalinity (mg/L) within site aquifers, which suggests that alkalinity within the system is not merely a function of pH and dolomite dissolution – other geochemical processes may also be of significance (refer **Figure 30**).

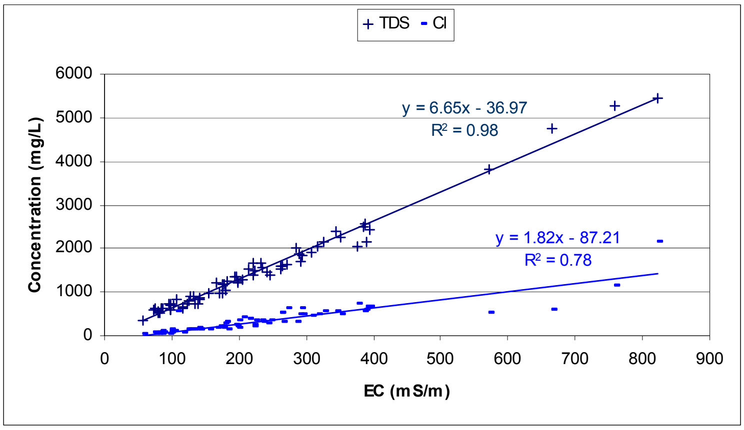


Figure 27 *Relationship between TDS and EC in groundwater samples.*

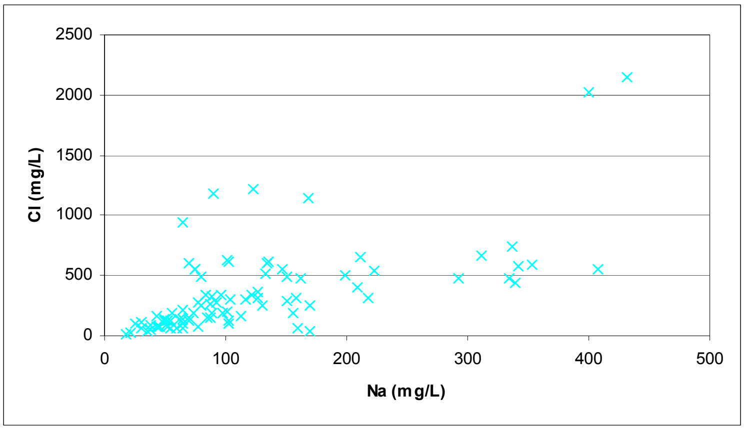


Figure 28 *Relationship between chloride and sodium ions in groundwater samples.*

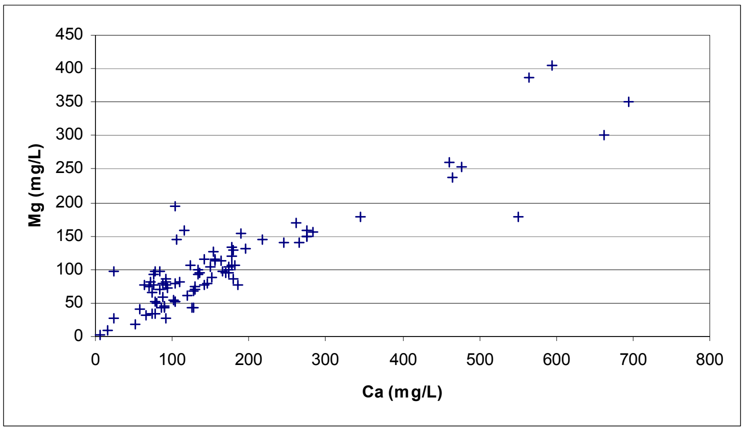


Figure 29 *Relationship between magnesium and calcium ions in groundwater samples.*

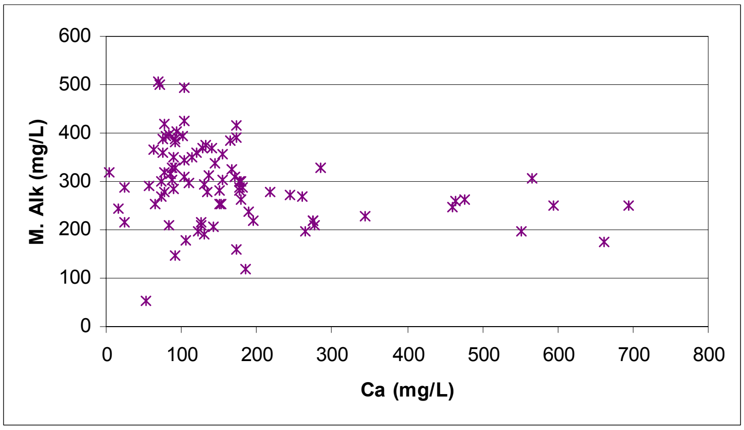


Figure 30 *Relationship between Total Alkalinity and calcium ions in groundwater samples.*

When considered spatially, however, it is apparent that groundwater of the poorest quality water is restricted to particular zones within the study area, notably those of lower pH in the ephemeral streambeds of the Witloop catchment and sampling sites around the derelict Hotazel Mine (refer **Figure 31**, **Figure 32**, **Figure 33**, and **Figure 34**). Sulphate concentrations are, however, also elevated in groundwater samples taken from above the red clay layer in the Wessels Mine decline and in the vicinity of the nearby slimes dam, discard dump, and return water pan, and the recently decommissioned Mamatwan slimes dam. This is unsurprising when ABA results for representative Hotazel Formation samples are considered. While XRD and XRF testing failed to identify any sulphide mineralization in these lithologies, ABA confirms that trace amounts must be present due to the observed increases in sulphate concentration following oxidation. This was particularly apparent in finer grained slimes dam material, presumably due to the increased surface area exposed to oxidation.

Where possible, one-off surface water samples were also taken at the respective mine sites. While variable, major ion concentrations were highest in samples taken at the Wessels slimes dam, and from pit water contained within the derelict Hotazel and Perth Pits (refer Appendix 5). In the case of the Hotazel and Perth Pits, this can be in part attributed to evaporation-induced concentration increases over time.

5.5.3 Isotopic characteristics

Isotopic data collected during the course of this investigation is summarized in Appendix 5. Plots of ^{18}O and ^{2}H groundwater data indicate that recharge water was partially exposed to evaporation prior to arrival in the aquifer as evidenced by the positioning of most groundwater samples along a line of lesser slope and d excess to the assumed regional LMWL (refer **Figure 35**). Of interest, however, is that some samples appear proportionally more evaporated, including:

1. Areas adjacent to abandoned mine pits on the Smartt-Rissik prospect. Samples JB1 and JB8, taken adjacent to the derelict Perth and Smartt pits, respectively, are definitely more evaporated than other groundwater samples taken during field investigations on the Smartt-Rissik prospect, one possible reason being the presence of standing water in open pits nearby. Sections suggest that, while the Perth pit may fill seasonally in response to rainfall events, for most of the year the pit water is derived from site aquifers. Given that Perth mine water is enriched both chemically and isotopically as a result of evaporation, the presence of evaporated water down-hydraulic gradient in JB1 merely confirms that the Perth mine truncates these aquifers. If site conditions at JB8 are also considered, standing water influences can again be inferred. While there is no available evidence to suggest that the derelict Smartt pit floor intercepts site aquifers, water is observed in the lower lying areas of the pit following heavier rainfall events, the presence of reeds in the southern corner suggesting an extended standing period. Available results therefore indicate that the abandoned Smartt pit is also hydraulically connected with site aquifers, essentially acting as recharge sump;

2. Samples taken from Mamatwan Mine monitoring bores adjacent to the coal stockyard and sinter plant (JB17), workshops (JB19), derelict slimes dam (JB23), and sewage treatment works (JB24). At each of these sites, recharge water is in part either derived from a surface water source (Vaal-Gamagara or pit water), exposed to evaporation prior to recharge, or both. In the case of groundwater at JB17 and JB23, elevated sulphate values confirm that, prior to recharge, evaporated water has percolated through coal and slimes, respectively;

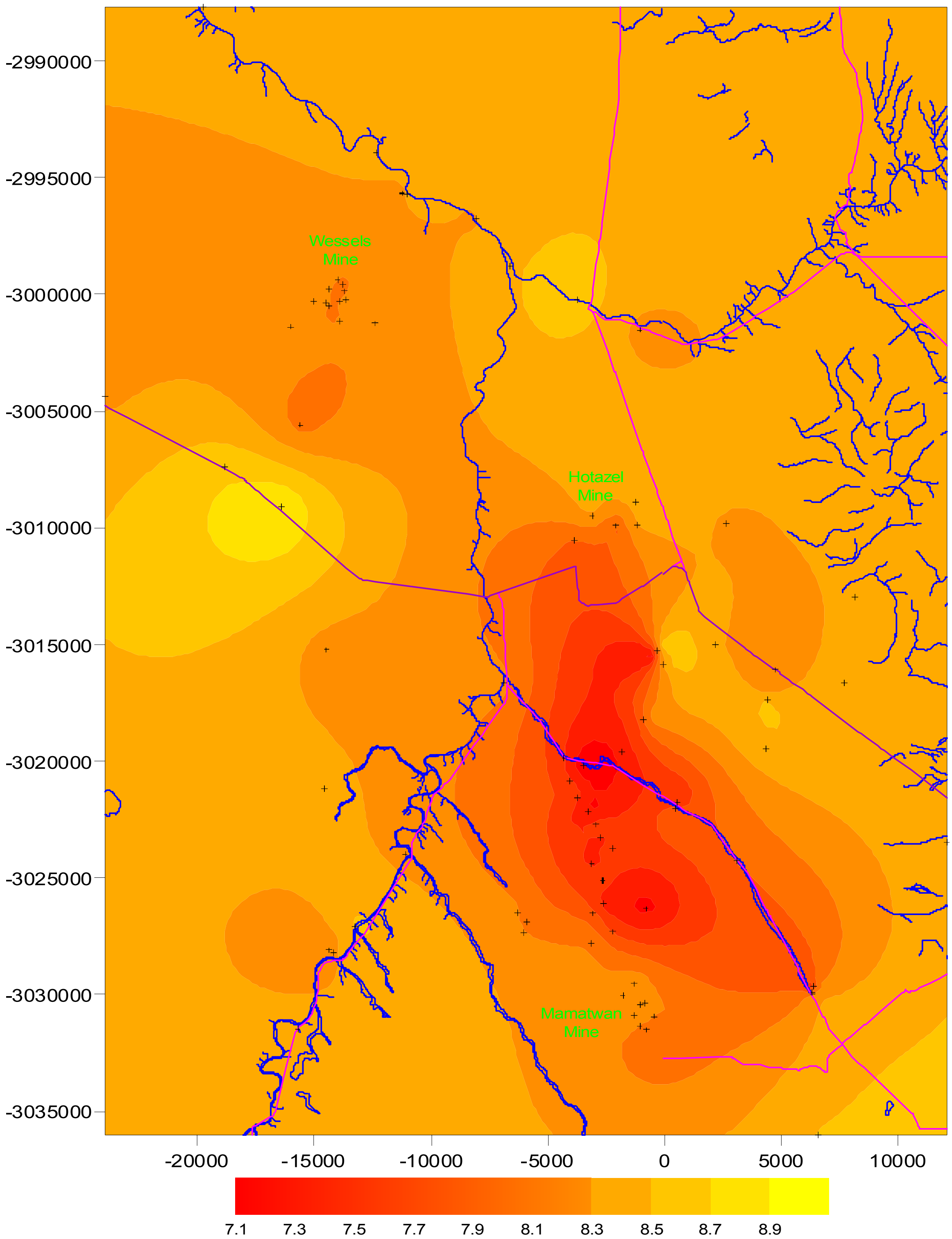


Figure 31 *Contoured laboratory pH values for groundwater samples taken across the Kalahari Manganese Field. The lower pH values occur in areas where groundwater is stored in Ongeluk or Hotazel Formation lithologies, as opposed to the overlying, carbonate rich, Kalahari Formation aquifers that occur elsewhere in the region.*

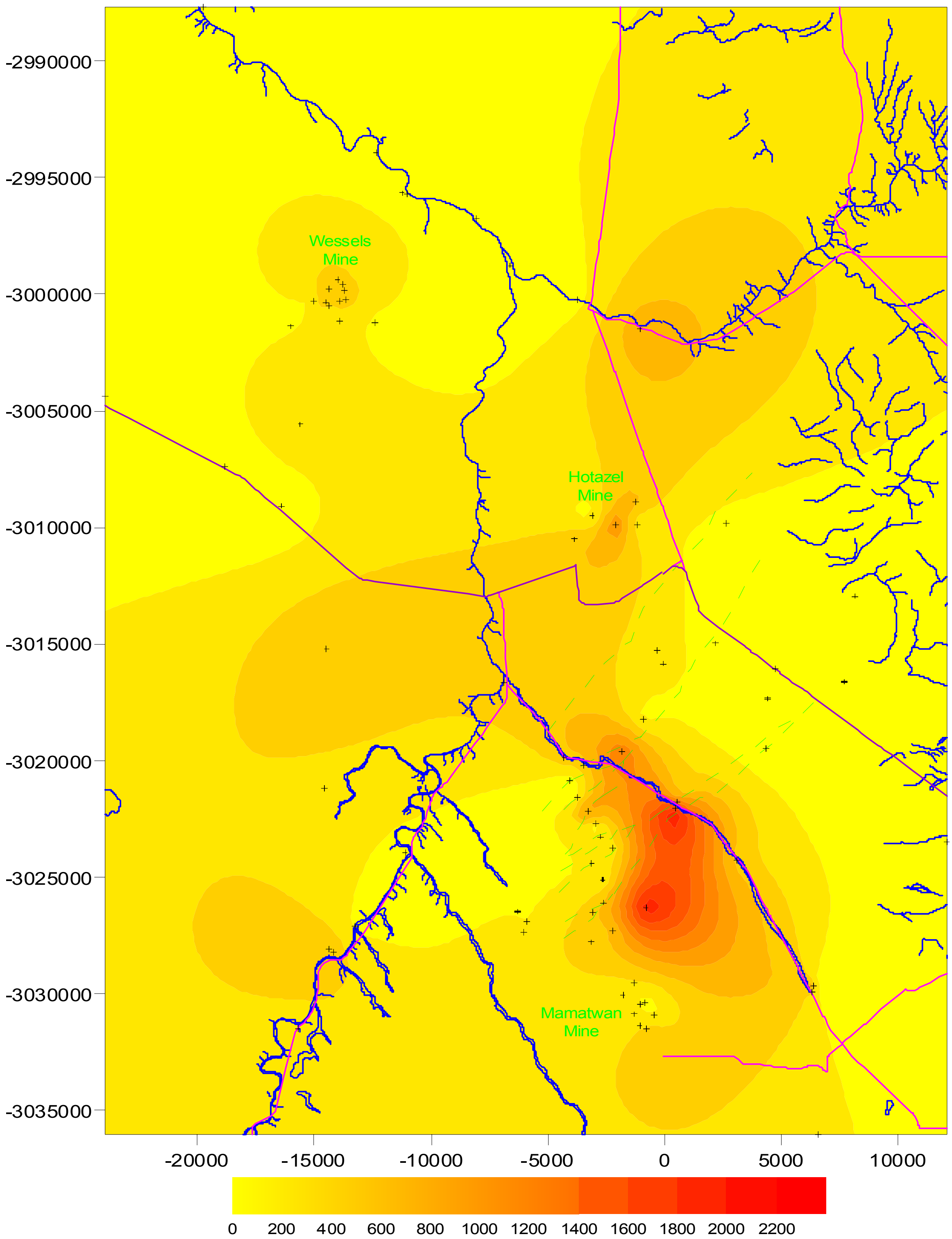


***Figure 32** Chloride concentrations for groundwater across the Kalahari Manganese Field. Note that the highest concentrations occur in the lower-lying areas of the Witloop catchment adjacent to confirmed dykes. This could be a response to the progressive dissolution of salts in the unsaturated zone there as the water level rises over time due to dyke damming effects.*

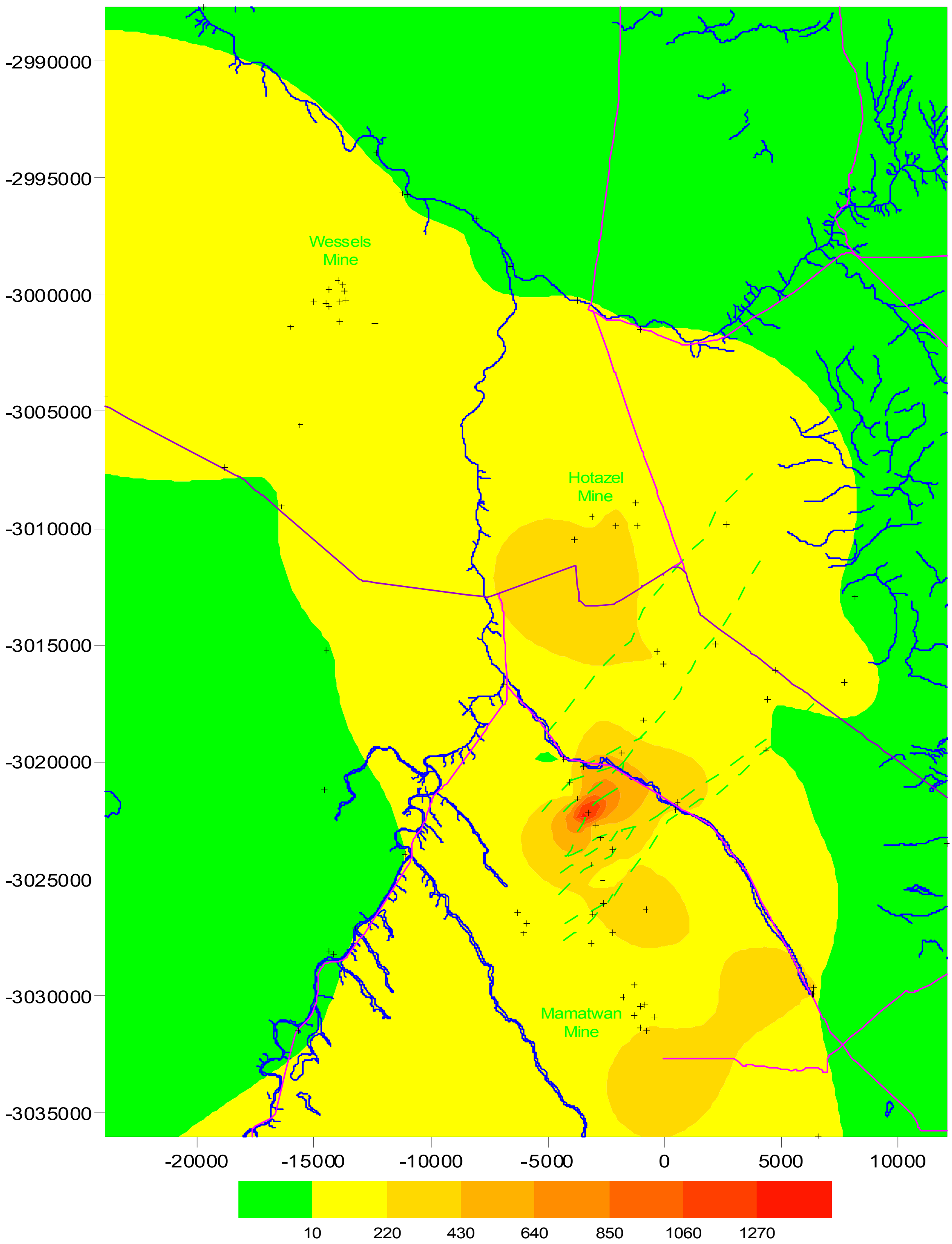


Figure 33 *Nitrate concentrations for groundwater across the Kalahari Manganese Field. Note that the highest concentrations occur within dyke bound compartments in the Witloop catchment, the lowest associated with Kuruman or Gamagara River, or Asbestos Hills, boreholes.*

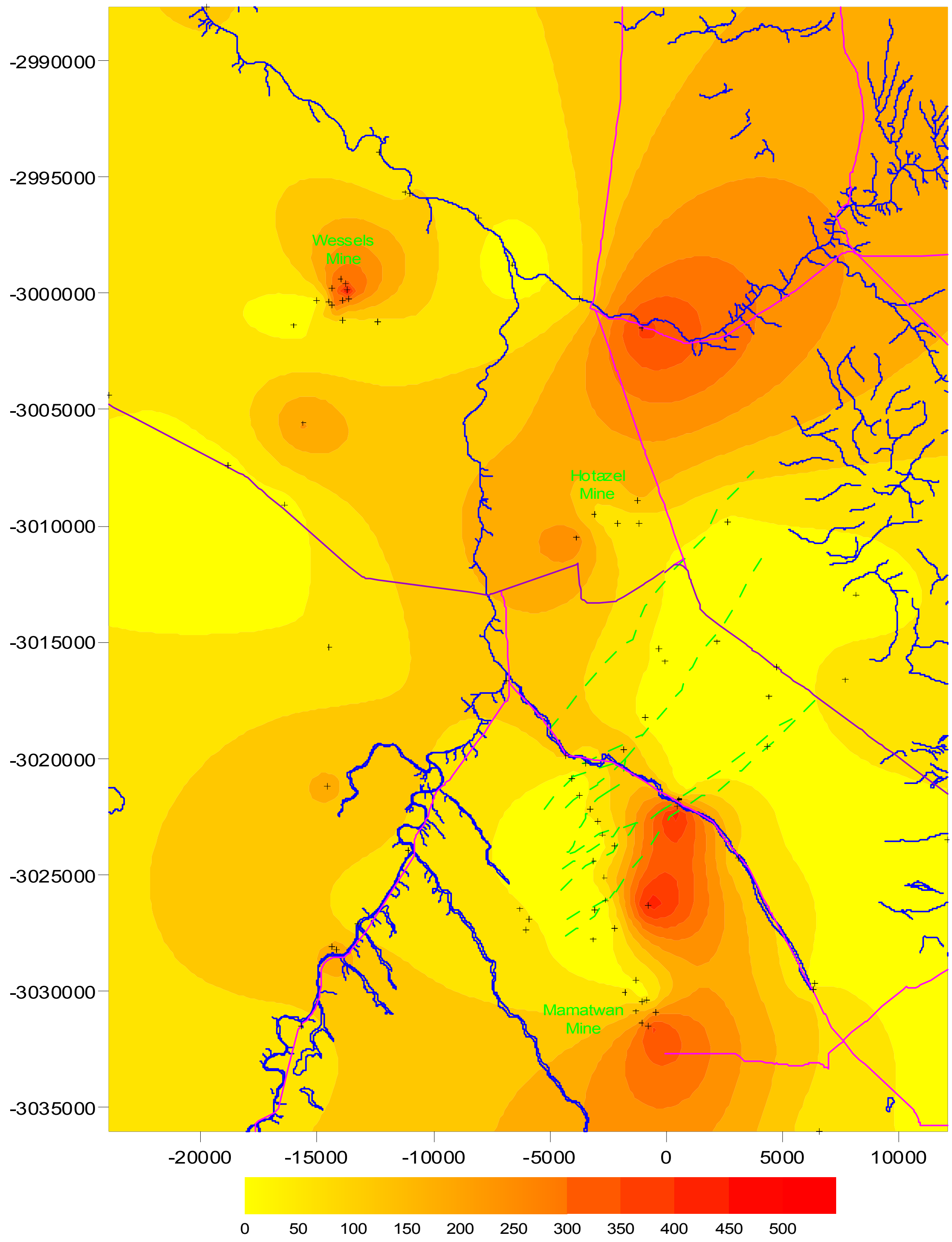


Figure 34 *Sulphate concentrations for groundwater across the Kalahari Manganese Field. Note that values are locally elevated in boreholes installed within dyke bound compartments in the Witloop catchment, and adjacent to slimes dams at Mamatwan and Wessels Mines.*

3. Samples taken across the Wessels Mine site. With the exception of JB33, the site furthest from a known surface water site or low-lying area where ponding could occur, all monitoring bores appear to intercept aquifers recharged at least in part, by evaporated water. While the waste rock dump, slimes dam, and Duck Pond are confirmed as recharge water sources when locally elevated water levels and SO_4 concentrations are considered, other sources of evaporated water also exist at the site, such as leakage and overflow from sewage treatment works;

4. Monitoring bores in the vicinity of the Hotazel sewage treatment works and store (JB38 and JB43, respectively). Water has been regularly used for wash down purposes in the areas adjacent to the store for more than 40 years, and as such, it is possible that run-off from hardstand areas has recharged underlying aquifers. In comparison, the sewage works is an obvious surface water source, particularly given that effluent is regularly pumped into unlined excavations constructed in aeolian sands for disposal.

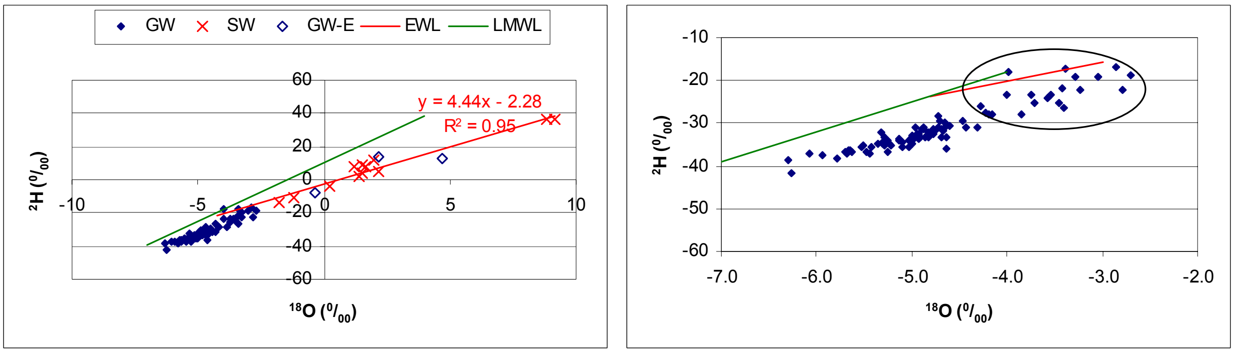


Figure 35 *Isotopic characteristics of site waters. The LMWL was assumed to have the characteristics* $\delta^2\mathrm{H} = 7\delta^{18}\mathrm{O} + 10$*, while the slope of the EWL was determined from site water samples. Note that three groundwater samples (denoted GW-E) lie on the EWL. Closer inspection of the remaining groundwater data (right hand graph) shows a tight cluster for samples where* $\delta^{18}O$ *is less than, or equal to, -4.3‰. Above this value and with proximity to the EWL (circled area), data is more scattered in character, possibly indicating that mixing with water from another source has occurred. When considered spatially, it is apparent that the circled samples were taken from sites adjacent to surface water bodies, elevated sulphates at some sites confirming that polluted waters have recharged site aquifers.*

Considered in conjunction with mine monitoring bore proximity to known surface water sources and EWL data, it is apparent that groundwater samples fall into three categories:

- Groundwater samples derived from aquifers almost completely recharged from an adjacent evaporated water source (i.e. JB24 and JB34). These samples plot along the EWL for the site, and typically have a relative ^{18}O abundance of >-3 ‰;

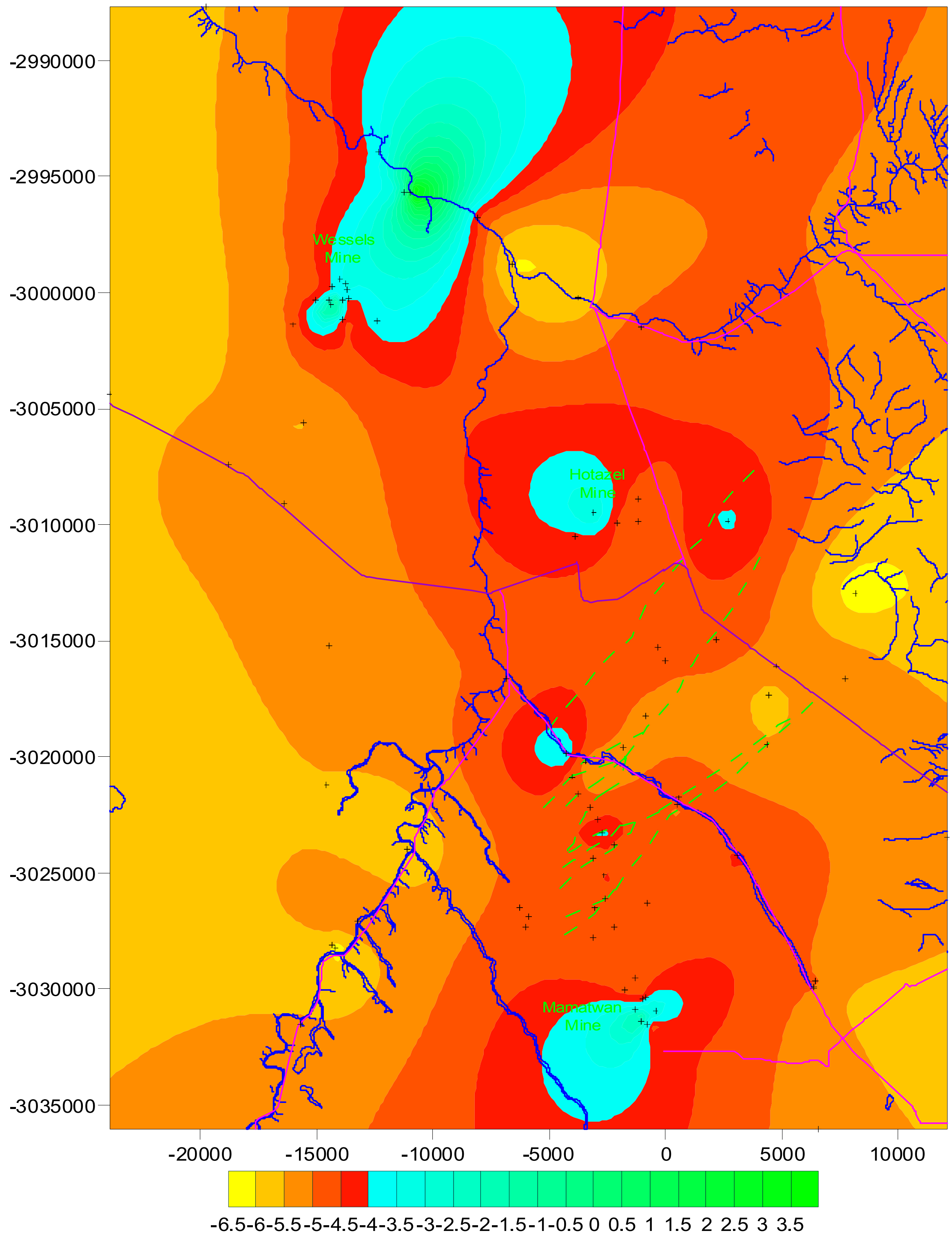


Figure 36 *Relative abundance of $\delta^{18}O$ in groundwater samples. Note that, with the exception of some aquifers in the vicinity of the Kuruman River, recharge derived from surface water sources (i.e. $\delta^{18}O > -4.3$ ‰) is only indicated in samples taken from the respective mine sites.*

- Groundwater samples derived from aquifers at least in part recharged from an adjacent artificial evaporated water source (i.e. slimes dam). These samples plot in a loose cluster between ^{18}O abundances of approximately –4.3 and –3 ‰;
- Groundwater samples derived from aquifers predominantly recharged directly from rainfall. While some infiltration of water resting in low lying areas may still occur, the infiltrating water has not been excessively evaporated as would be expected if the water had been continually recycled through a surface water body as typically occurs at a mine site. There is a good correlation between the ^{18}O and ^{2}H data, with values in this group not exceeding an ^{18}O abundance of –4.3 ‰.

When considered spatially, it is apparent that aquifers at the various mine sites have received significant recharge from surface water sources in the past (refer **Figure 36**). Of significance, however, is that aquifers adjacent to the Kuruman River to the northeast of Wessels Mine and a site to the east of Hotazel have been recharged by a significant component of evaporated water. Thus, recharge from surface water sources is not only of importance on a mine scale, but also a regional scale, particularly those lower-lying sites where surface water can pond following significant rainfall events.

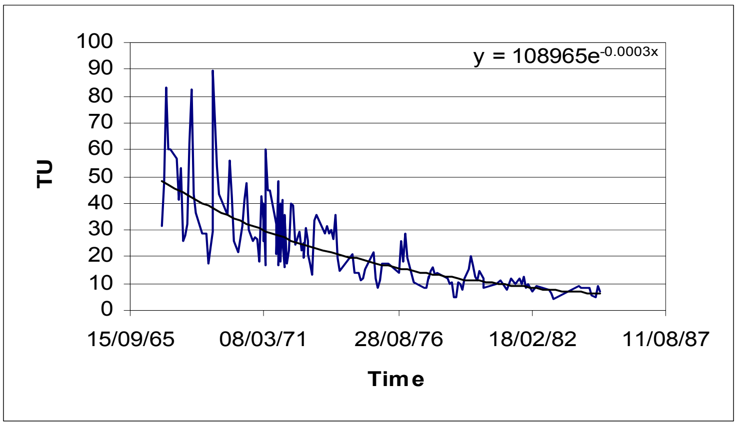


Figure 37 *Temporal variations in ^{3}H values for Johannesburg rainfall for the years 1967 to 1984 (IAEA, 2001). ^{3}H has a half-life of 12.43 years (Unterweger, 1980), with regression analysis of the presented data set suggesting that around 1.4 TU should be measurable in current rainfall, although subsequent measurements could refine this value further.*

In order to better understand recharge processes at the site, ^{3}H, ^{14}C, and ^{13}C concentrations were determined on eight groundwater samples taken from:

- Smartt-Rissik (JB2/REX158 and JB15);

- Mamatwan (JB17);
- Middelplaas (JB16 and M24);
- Wessels (JB33);
- Hotazel (JB40).

^{3}H data collected during this investigation suggests pre-1952 recharge when interpreted qualitatively as suggested by Clark and Fritz (1997; refer **Table 1** and **Figure 37**). ^{14}C values of tested groundwater samples show significant variation, with uncorrected ages of between approximately 400 and 30000 years suggested (refer **Figure 38**). However, the significant potential for carbon dilution due to the chemical composition of site lithologies required the determination of a correction factor q. Given that only eight samples were taken across the study area, the development of a detailed geochemical model was deemed impractical in this instance. Instead, available stable isotope and chemical data for the respective sites was perused with a view to identifying other tracers that may indicate modern recharge. Of the eight sites, tracers were only successfully identified at JB17, these being:

- Sulphate. This parameter is only found to be significantly elevated above background levels in the vicinity of slimes dams and discard dumps at the respective mine sites, and is thus an indicator of recent pollution. At JB17, a sulphate concentration of 244 mg/L was measured, a value significantly higher than background (in the vicinity of 50 mg/L);
- ^{18}O. ^{18}O data indicates that aquifers at JB17 have been, in part, recharged from an adjacent surface water source. Given that surface water sources and ephemeral waterways do not occur in the vicinity of JB17, an artificial source (i.e. slimes dam, sinter plant, etc) was inferred.

Given that groundwater at JB17, which has an uncorrected age of about 2600 years, has been recharged in recent time, it is reasonable to assume that similarly aged samples also represent recent recharge. Thus, groundwater samples with an uncorrected age of less than 3000 years (shown as a cluster on **Figure 38**) probably represent relatively modern water. Since undiluted modern recharge would have a ^{14}C value of 100 pmC, a dilution correction factor can be calculated as follows:

$$q = JB17\ pmC \,/\, Undiluted\ modern\ water = 73/100 = 0.73\ say\ 0.7$$

This is within the range of correction values for karst systems (0.65 to 0.75) suggested by Vogel (1970), and is thus acceptable given the dolomitic composition of site aquifer materials.

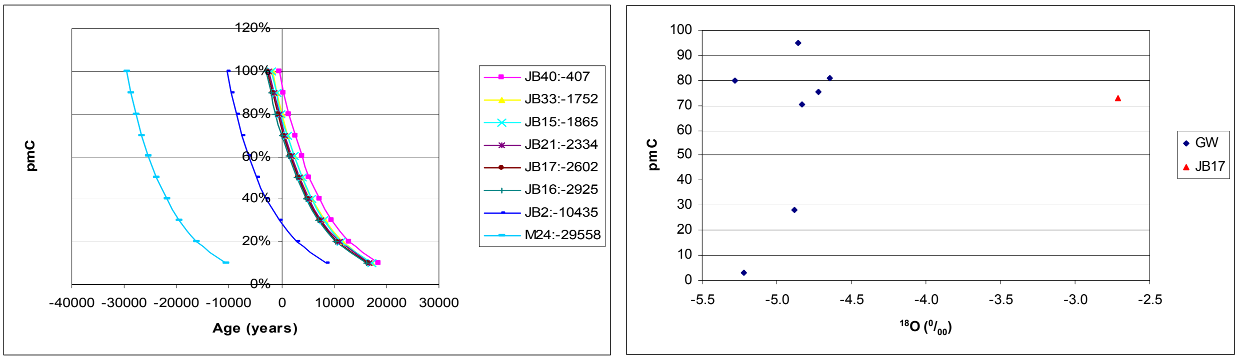


***Figure 38** Relationship between ^{14}C measured in groundwater, uncorrected groundwater age, and $\delta^{18}O$ abundance. Note that the dating results fall into three groups; a) A cluster of results with an age less than 3000 years; b) JB2, a sample taken from Kalahari Formation sediments adjacent to the Witloop catchment, which has an age of about 10000 years; and c) A significantly older (approximately 30000 years) groundwater sample taken from dolomitic aquifers intercepted at depth in M24. Of the dated samples, all represent background recharge with the exception of JB17, which is, in part, comprised of evaporated water.*

The calculated correction factor was also applied to samples taken at JB2 and M24, both of which have un-corrected ages in excess of 10000 years, resulting in corrected groundwater ages of approximately 7500 and 26500 years, respectively. This indicates:

- Older water is stored within some Witloop catchment aquifers. Given that dykes have been shown to retard groundwater flow in the region, it seems likely that older groundwater would have been prevented from draining from site aquifers in the vicinity of JB2. Indeed, the corrected age of groundwater at JB2 suggests recharge occurred during a period when the Kalahari had a significantly wetter climate 8000 to 5000 years ago (Partridge et al., 1990). It should be appreciated, however, that this may be a localized phenomenon, as modern recharge has been shown to occur elsewhere in the Witloop catchment (i.e. JB17);
- Mooidraai Formation aquifers have not been recharged in recent time. Dating suggests that the aquifer intercepted at M24 was recharged during a wetter climatic phase 30000 to 25000 years ago. This is unsurprising given the significant difference between the piezometric head in the Mooidraai Formation aquifer compared to that in the surficial Kalahari Formation sediments, and the thick covering layer of relatively impermeable clay interbeds within the overlying Dwyka and Kalahari Formations.

Although beyond the scope of this investigation, a short discussion on the origins of high nitrate groundwater sampled within the study area is required due to the potential that it is a response to either anthropogenic, or natural, recharge processes. High groundwater nitrate concentrations are found throughout the Kalahari, with the Hotazel area falling within an area of known concern (Tredoux et al., 2000). The relative proportion of ^{15}N contained within site groundwater has been used to identify the source of the high nitrate concentrations previously, studies undertaken elsewhere in South Africa (Vogel et al., 1981; Heaton et al., 1983; Heaton, 1984; Heaton, 1985; Heaton, 1986; Tredoux, 1993) confirming that these can occur both naturally, and as a result of pollution. A summary of the range of ^{15}N for given materials prepared by Clark and Fritz (1997), indicates that synthetic fertilizer, a major component of explosives at most open cast mine sites, typically varies between –5 and 5‰. Given that these values are well below those determined for samples taken during this study (5 to 36.8‰; refer Appendix 5), there is no evidence to suggest that blasting residues have contaminated site aquifers.

Heaton (1987) compared ^{15}N results for samples taken at sites throughout South Africa, his assessment suggesting that groundwater with ^{15}N > 10‰ had undergone de-nitrification, a process whereby bacteria convert nitrate to gaseous nitrogen under anaerobic conditions. For de-nitrification to occur, however, a source of organic carbon must be present, which Heaton (1987) credited to infiltrating animal and sewage waste. This appears to be based in part on earlier studies he conducted along the western fringes of the Kalahari, where values of ^{15}N > 8‰ were attributed to point source pollution from stock watering sites located adjacent to water supply bores. Heaton (1984) does note though, that soil-derived ^{15}N values of between 2 and 12‰ have been measured (Rennie et al., 1976; Shearer et al., 1978; Sweeney et al., 1978).

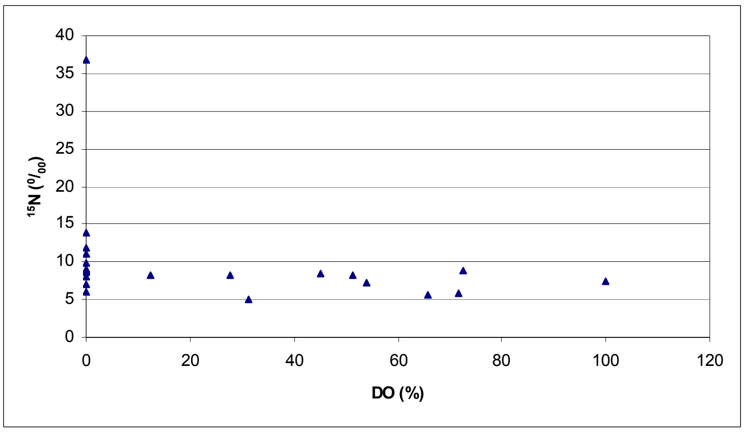


Figure 39 *Relationship between ^{15}N and DO in tested groundwater samples.*

When groundwater ^{15}N data collected during this investigation was plotted against the field Dissolved Oxygen (DO) concentration, ^{15}N values were typically between 5 and 8.8‰ at aerobic sites (i.e. sites containing measurable DO). At anaerobic sites (i.e. DO saturation = 0%), however, ^{15}N values were found to vary between 5 and 36.8‰, values > 10‰ confirming that de-nitrification has occurred at some sites in the region (refer **Figure 39**).

When groundwater age, recharge characteristics, and site factors are considered, the potential for animal waste to have polluted site aquifers across the entire extent of the study area is extremely low for the following reasons:

- There are relatively few groundwater bores within the study area, in part due to the poor quality of site water;
- Low site hydraulic gradients;
- Stocking rates are low because of the prevailing climatic conditions; and,
- A huge amount of waste would have to be generated to pollute an area on this scale;

It should also be remembered that ^{15}N data does not provide any indication of when de-nitrification occurred. Thus, de-nitrification may represent the infiltration of waste to site aquifers during a past, as opposed to recent, recharge event.

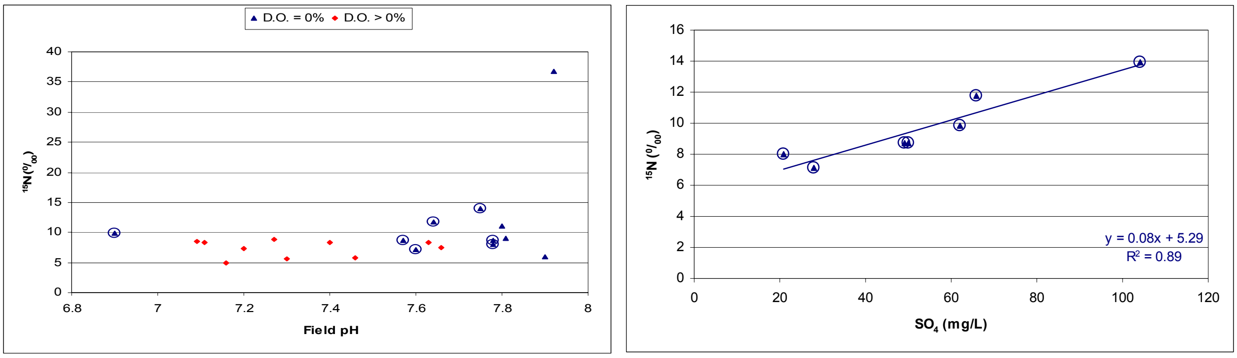


Figure 40 *Relationship between ^{15}N, Field pH, and sulphate concentration for tested groundwater samples. Note that Field pH is typically highest at anaerobic sites (i.e. DO = 0%), the sulphate concentration appearing to increase in response to bacterially induced fractionation at those anaerobic sites where rainfall-derived recharge has occurred (circled sites where $\delta^{18}O$ < -4.3‰).*

Available chemical and isotopic data indicates that, apart from decreasing the nitrate concentration of water contained in site aquifers, de-nitrification is also influencing groundwater quality in other ways. For example, those samples for which ^{15}N abundances were determined were found to have:

- In all but one case, higher Field pH values at sites where DO saturation = 0% (refer **Figure 40**);
- Sulphate concentrations that increase proportionally with ^{15}N abundance at sites where DO saturation = 0% (refer **Figure 40**). This is a particularly significant finding as it indicates that elevated groundwater sulphate concentrations can develop naturally in site aquifers, and thus are not always associated with the infiltration of polluted water at mine sites.

De-nitrification induced increases in pH and sulphate have also been observed within the Artesian Stampriet Basin of Namibia (Vogel et al., 1982; Stute and Talma, 1998). Here, pH changes were attributed to an increase in the concentration of dissolved carbonate species following the exchange of dissolved calcium with sodium contained in site aquifers, while sulphate increases were credited to dissolution and sulphide oxidation processes (Vogel et al., 1982). However, a decrease in pH would normally be expected upon sulphide mineral oxidation, which is not consistent with observations made in either the Stampriet Basin or Hotazel, where an increase in field pH occurred in response to de-nitrification processes. Thus, while beyond the scope of this investigation, more comprehensive geochemically orientated investigations and associated reaction modelling will be required before the impacts of de-nitrification on regional groundwater quality are fully understood.

While de-nitrification may have occurred at some sites in the study area, it is clear that elevated nitrate concentrations have developed in response to natural processes in most instances. Frood and Hall (1919) reported nitrate mineralization within the banded ferruginous slate and jasper beds of the Asbestos Hills Formation (Transvaal Super Group) near Prieska, although it is not known whether this extends into the younger Hotazel Formation sediments. The most likely source, however, would seem to be the soil horizon, the nitrates from here being flushed into site aquifers during episodic recharge events as suggested by Heaton (1984). This process is supported by isotope amount effect data, and the claim by local residents that water quality degraded significantly following the 1974 wet season, resulting in the sudden death of cattle, and water supplies being deemed unfit for human consumption by the residents themselves. Similar experiences have been reported in Namibia following heavy rain (Talma, personal communication, 2002b), which suggests water quality within site aquifers is being suddenly degraded as recharge occurs. If degradation is recharge related mobilization by this mechanism would probably be greater if recharge occurred after a period of prolonged dry weather and overstocking, when vegetative cover (and therefore nitrogen binding capacity) is at a minimum.

5.5.4 Recharge estimation

Wood (1999) noted that the CMB Method is seldom applied on a regional scale, presumably because of the influence that local variations can have on the resulting calculations. However, if the relevant controls on these variations are understood, there is no reason why the method cannot yield reasonable estimates. For example, in the Hotazel area, it is clear that groundwater chloride concentrations are highest in areas adjacent to dykes in the Witloop catchment, which can be attributed to:

1. Localized increases in groundwater level. Pre-Dwyka Formation dykes in the area are orientated perpendicular to the groundwater flow direction, their lower permeability relative to site aquifers causing the water level to rise until such time as groundwater overtops these structures, flows through the younger Kalahari Formation sediments, and enters the next dyke-dammed compartment;

2. Bypass flow processes. Bypass flow has been shown to occur in Kalahari Formation sediments previously, a characteristic feature being that $Cl_{uzm} > Cl_{gw}$ (Beekman et al., 1997b). Thus, as the water level rises, chloride anions stored in the unsaturated zone matrix are dissolved, with Cl_{gw} increasing as a result. It should be appreciated that other ions may be similarly mobilized, thereby explaining the observed increases in sulphate and nitrate adjacent to Witloop dykes. The bypass flow model is further supported when $\delta^{18}O$ and chloride concentrations are compared. If the higher chloride concentrations were evaporation related, a proportional increase in the chloride and $\delta^{18}O$ concentrations of site groundwater should be observed, which is not the case for the Hotazel dataset (refer **Figure 41**).

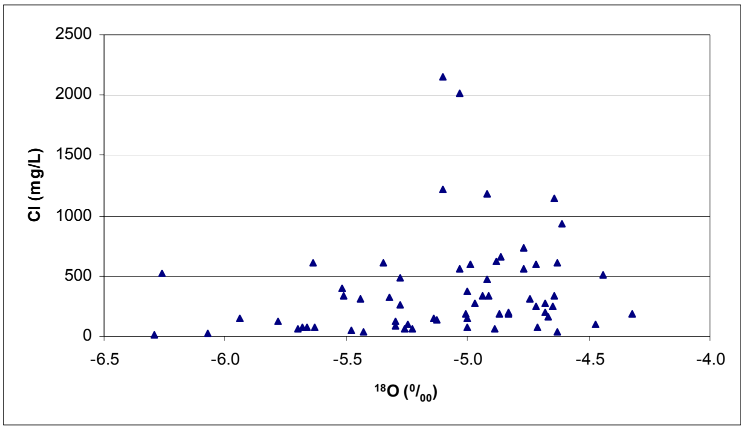


Figure 41 *Relationship between chloride and $\delta^{18}O$ concentration in directly recharged groundwater (i.e. $\delta^{18}O < -4.3‰$).*

With a view to obtaining a realistic estimate of regional recharge, chloride concentrations for groundwater samples were filtered using the following approach:

1. Groundwater sampling sites were ranked on the basis of chloride concentration;

2. The spatial distribution of groundwater chloride concentrations in the Witloop catchment was considered. Given that the highest concentrations (above 1000 mg/L at some sites) were distributed around the lowest-lying parts of an area intercepted by dykes, it was assumed that dyke-damming processes had impacted upon water quality here. As such, these sites were not included in averaging calculations;

3. Those sites with groundwater chloride concentrations within the range of the Witloop catchment samples were similarly ignored;

4. All sites where a significant component of recharge was derived from an adjacent surface water body ($\delta^{18}O$>-4.3‰) were ignored.

The remaining sites had virtually identical geographical characteristics in that they were all located on higher or gently sloping ground. Depending on the area of the Witloop assumed to be impacted upon by surface and dyke damming processes, the maximum groundwater chloride concentration included in averaging calculations was between 595 and 404 mg/L, the resulting average calculated to fall between 221 and 172 mg/L. Thus, assuming $Cl_d + Cl_p$ = 2.36 mg/L (refer Section 3), the CMB Method recharge estimate falls between $100.2.36/221 = 1.1\%MAP$ and $100.2.36/172 = 1.4\%MAP$, or an equivalent depth of 4 to 5.1 mm (MAP = 365 mm).

The SI Method was also used to estimate site recharge, with groundwater values used as an input variable in the absence of unsaturated zone moisture data. Assuming C = 20, and $\Delta\delta^2H = 10 - 1.9 = 8.1‰$ (refer **Figure 42** in Section 6), an equivalent average annual recharge depth of $R = (20/8.1)^2 = 6.1$ mm was estimated, or 1.7% MAP. Thus, in the Hotazel area, this technique provides comparable results to the CMB Method.

5.6 Summary

Recharge estimated using the SI and CMB Methods was found to be comparable in the Hotazel area. Observations made by local residents and collected stable isotope data indicates that recharge only occurs following significant rainfall events, often resulting in the degradation of groundwater quality. This degradation in quality is a response to the flushing of unsaturated zone-derived ions into underlying aquifers via preferential pathways and the matrix by recharge water.

An understanding of bypass flow processes is important when estimating recharge to dyke-dammed aquifers using the CMB Method. Findings made during this study indicate that dyke-induced increases in SWL mobilize chloride and other ions from the unsaturated matrix, a condition which would result in recharge being under-estimated if not considered when applying the technique. Indeed, given that other features (i.e. faults, lithological contacts, mobilization of chloride in run-off to low lying areas, etc) could cause similar behaviour, a thorough understanding of site geomorphology and geology should be considered a prerequisite to using the method for recharge estimation in any area.

Stable isotope data can also be used to distinguish between polluted and background water at industrial sites providing consideration is given to potential pollution sources and the influence these may have on water chemistry (i.e. water from mine slimes dams would be expected to have an evaporative signature). This of significance given that monitoring data collected at these sites to satisfy regulatory bodies could be used for recharge estimation purposes to the benefit of the community as a whole. Given that mining operations are located throughout Southern Africa, the opportunity exists for recharge data to be collected by, and at expense to, private enterprise, across much of the region.

6 The Modified Amount Effect (MAE) Method

Recent work undertaken in semi-arid Central Australia by Harrington et al. (2002) suggests that the recharge threshold can be predicted through an understanding of stable isotope abundances in rainfall and groundwater. Given that an amount effect was present in rainfall samples taken at a nearby monitoring site, they assumed that sampled groundwater was recharged only during heavier rainfall events due to its relatively depleted $\delta^2H/\delta^{18}O$ abundance. Further, they noted that the relationship between δ^2H and $\delta^{18}O$ in groundwater was approximately linear. Since the ratio $\delta^2H:\delta^{18}O$ in groundwater was less than that of rainfall, the recharge threshold could be determined by extrapolating the groundwater sample line-of-best-fit to the LMWL, and calculating the amount of rainfall required to cause the observed degree of depletion.

The findings of Harrington et al. (2002) are also significant with respect to the application of the SI Method of recharge estimation. Their work confirms that groundwater in semi-arid areas does not always plot parallel to, albeit with a lower y-axis intercept value, the LMWL, as would be expected if groundwater was comprised solely of uniformly evaporated unsaturated zone water. This suggests that:

- Alternative recharge mechanisms, or sources of recharge, may be of significance. While, Harrington et al. (2002) note that isotopically depleted samples were located next to rivers or areas where water could pond for extended periods, their depleted status suggests that evaporation prior to recharge was minimal. It is therefore suggested here that other processes, such as bypass flow, influenced the slope of the line-of-best-fit constructed through groundwater data;
- The SI Method is not applicable in some semi-arid environments. While intended as an unsaturated zone method for estimating recharge, the technique has been adapted locally such that $\Delta\delta^2H$ is determined by considering the relationship between site groundwater data and the LMWL. However, where the groundwater line-of-best-fit is not parallel to the LMWL, the assumption that groundwater is derived solely from moisture that has been resident in the unsaturated zone for the same period of time (i.e. has been exposed to the same amount of evapo-transpiration), is no longer valid.

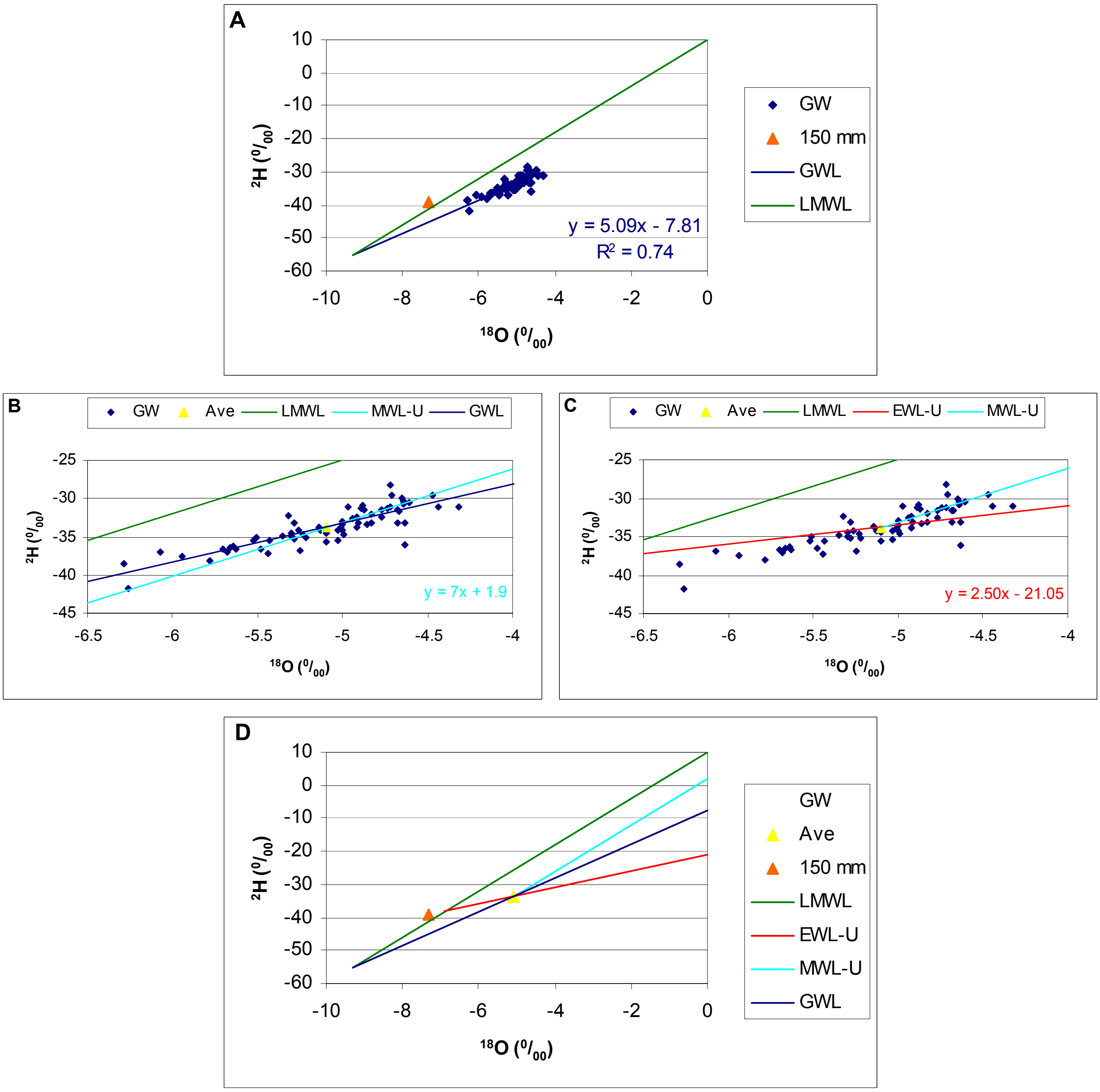


Figure 42 *Recharge threshold determined using amount effect data. Plot A shows the estimated recharge threshold determined using the technique of Harrington et al. (2002), their technique assuming GWL = EWL-U. The GWL with lesser slope and d-excess values compared to the MWL-U (Plot B) suggests that uniform matrix-derived recharge has not occurred; more recharge has occurred as the $\delta^{18}O$ and $\delta^{2}H$ concentration of precipitation has become more depleted, presumably because of increased flow along preferential pathways. Additional evidence for bypass flow is found when GWL and the assumed EWL-U are compared (Plot C; GWL does not equal EWL), which confirms that the method used by Harrington et al. (2002) will over-estimate the recharge threshold (Plot D. GWL and LMWL intersect at $\delta^{18}O = -9.3‰$, as opposed to EWL-U and LMWL at $\delta^{18}O = -6.9‰$).*

Unsaturated zone δ^2H profiles taken at the site by Harrington et al. (2002) do provide evidence for bypass flow at the site. Of the four profiles taken, δ^2H concentrations in three were relatively constant with depth below the ETM zone (i.e. $\delta^2 H_{rw} = \delta^2 H_{gw}$), and consistent with those in underlying groundwater. At the fourth site, however, where the lowest δ^2H concentration was measured, δ^2H abundance increased with depth from the base of the ETM zone ($\delta^2 H_{rw} \neq \delta^2 H_{gw}$), suggesting either bypass flow, or the downward migration of an isotopically depleted rainfall event through the unsaturated zone.

Given that amount effects are represented in Southern African rainfall, the technique of Harrington et al. (2002) was used to provide an estimate of the recharge threshold across the Hotazel study area (refer **Figure 42**). However, the method was modified to better represent the dataset and the findings of other workers. The problem with the technique in its current form is that it assumes variable site recharge such that the orientation of the unsaturated zone evaporated water line (EWL-U) equals line-of-best-fit through site groundwater data (GWL). In an area covered with a relatively homogeneous unsaturated zone, such as the surficial aeolian sands that occur in the Hotazel area, this only occurs when all recharge water enters site aquifers via preferential pathways once the recharge threshold has been exceeded. However, since matrix-derived flow can also influence the orientation of GWL, this may not always be the case (i.e. EWL-U does not equal GWL), and thus the isotopic composition of precipitation necessary to initiate recharge may be over-estimated.

By considering the characteristics of EWL-U, GWL, and matrix-derived recharge water, a new technique to assess the potential contribution of matrix versus preferential pathway-derived recharge has been developed (herein referred to as the Modified Amount Effect, or MAE, Method). As noted previously, recharge water is progressively enriched in $\delta^{18}O$ due to evaporation, which occurs with movement through the unsaturated zone, the slope of EWL-U generally around 5, but sometimes as low as 2. Given that the isotopic characteristics of unsaturated zone water were not determined at the site, the slope of EWL-U determined for 100% matrix flow in Botswana by Beekman et al. (1997b) was also assumed to represent EWL-U in Hotazel. The variable d was corrected to represent evaporation within the unsaturated zone by constructing a line through the ^2H and ^{18}O average for those samples representing background recharge (i.e. $\delta^{18}O < -4.3‰$), resulting in an EWL-U of $\delta^2 H = 2.5\delta^{18} O + {}^{-}21.05$.

Laboratory studies undertaken by Allison et al. (1984) confirm that if site recharge is constant, evaporation-induced enrichment within the unsaturated zone should also be constant, resulting in a line parallel to the LMWL, herein referred to as the Matrix Water Line (MWL-U). Thus, if exchange processes between aquifer materials and groundwater are ignored, preferential recharge areas can be inferred in cases where the LMWL and MWL-U are not parallel (i.e. the LMWL has a steeper slope and greater d excess than the MWL-U). A similar assumption can also be made if the line-of-best-fit through site groundwater data (GWL) is not parallel to the LMWL, as the isotopic characteristics of water stored in the aquifer represent a long-term average of recharge processes. An approximate estimate of the contribution of preferred pathways-derived recharge to aquifer storage can therefore be determined by constructing lines parallel to MWL-U, GWL, and EWL-U, through the average ^{2}H and ^{18}O composition of groundwater derived from direct recharge i.e.:

$$PP_{flow} = 1 - \left[\frac{(d_{GWL} - d_{EWL-U})}{(d_{MWL-U} - d_{EWL-U})}\right]$$ **Equation 59**

Where PP_{flow} = the proportion of recharge derived from preferential flow, and d_{GWL}, d_{EWL-U}, and d_{MWL-U} represent the d excess in $\delta^{2}H$ (‰) for GWL, EWL-U, and MWL-U, respectively. In this instance, PP_{flow} was estimated to be 42%, using d excess values shown on the respective plots of **Figure 42**. However, it should be appreciated the calculated value is sensitive to:

i. Variations in the orientation of the LMWL and EWL-U. However, the value suggested in this instance compares well with findings made during unsaturated zone studies in Botswana, where, on average, 50% of recharge entered the aquifer as bypass flow (Beekman et al., 1997);

ii. The recharge threshold. At low recharge thresholds (i.e. recharge occurs rapidly in most years), particularly in more temperate areas, evaporation effects may not be represented in the stable isotopic composition of groundwater data. In these areas, transpiration, and not evaporation, probably has a greater potential to reduce the recharge flux to site aquifers. This also has significance in terms of applying the SI Method as the coefficient C would have to be lower than that used in semi-arid and arid areas (i.e. $C<20$); and,

iii. The source of recharge water. The suggested method assumes that recharge water is derived solely from precipitation, with no contribution from an adjacent surface water body where pre-recharge evaporation has occurred. However, given the surficial drape of highly permeable aeolian sands across most of the Kalahari Manganese Field, this process is unlikely to have significantly influenced results in this instance.

Despite its deficiencies, the MAE Method does provide a means of estimating the bypass flow component in semi-arid and arid areas without unsaturated zone sample data, the collection of which can be an expensive and time-consuming exercise on a catchment scale.

7 Adapting the MAE Method

7.1 Determining EWL-U

The problem of determining representative catchment-scale values on the basis of testing undertaken on relatively small, unsaturated zone samples extends to the determination of EWL-U. With a view to overcoming this problem, groundwater samples were taken from the vicinity of Liebenberg's Pan near Petrusburg, Free State Province (refer **Figure 43**). Pans occur throughout the Western Free State, generally following the strike of the Ecca Series, which forms part of the Carboniferous to early Jurassic aged Karoo Basin sediments. Observations made during an earlier geohydrological investigation (Rudolph and de Lange, 2000), which included a hydro-census, reserve estimation, and water use calculations, notes that the Ecca Series here is comprised of mudstone, sandstone, and shale interbeds. Cretaceous-aged dolerite dykes and sills have intruded these sediments, with high yielding aquifers (>10 L/s) often occurring at the structure/sediment interface. These have been locally overlain by calcretes (presumably of Tertiary or younger age) to a maximum depth of about 15 m, these regarded as having limited aquifer potential.

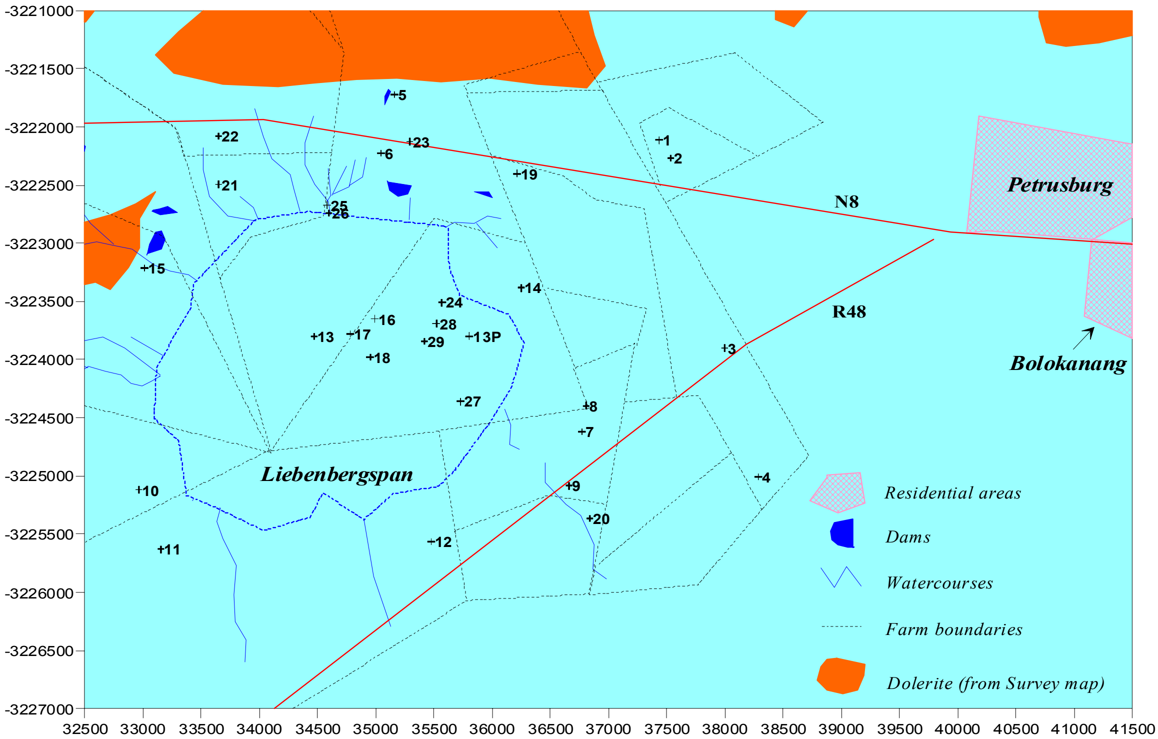


Figure 43 *Locality map for Liebenberg's Pan via Petrusburg. Sites sampled during this investigation (denoted "+") are also shown.*

Petrusburg has a semi-arid climate, with an evaporation excess of 1920 mm (2380 – 460 mm MAP) annually. Given that the water table is generally less than a metre below the pan surface, groundwater here is exposed to continuous evaporation in most years, the exception being those years where sufficient rainfall occurs to flood the entire pan for a few months of the wet season. Thus, the slope of EWL-U in these areas should be parallel to GWL because, while preferential pathway-derived water may not be as evaporated as matrix-derived during recharge events, it will eventually be evaporated to the same degree after entering the aquifer.

Liebenberg's Pan-derived brine with chloride concentrations in excess of 100 000 mg/L is further concentrated in evaporation ponds that have been constructed on site as part of a commercial salt-extraction enterprise operated by a local farmer. As such, numerous bores have been drilled into the pan for at least the last 20 years to enable the brine to be extracted, the production bore position changing if salt concentrations decrease.

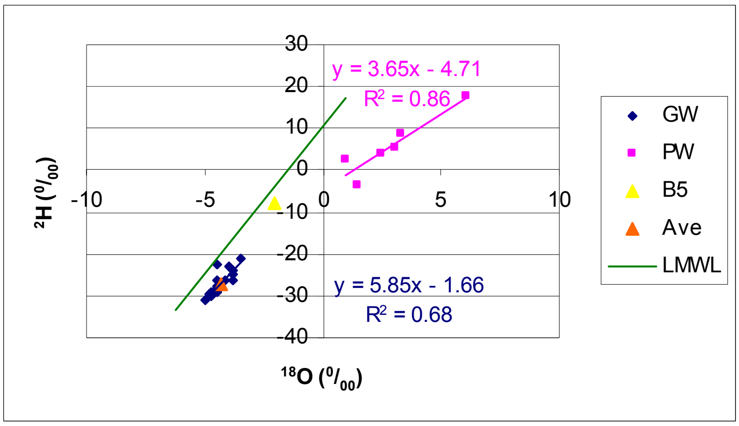


Figure 44 *Stable isotope characteristics of groundwater samples taken in the vicinity of Liebenberg's Pan, Petrusburg. "GW", "PW", and "Ave" denote groundwater samples taken from boreholes surrounding the pan, in the pan, and the background isotopic average, respectively. Respective site concentrations are summarized in Appendix 6.*

The pan itself is the lowest topographical feature in the landscape (i.e. all surrounding country falls towards the pan), and is surrounded by farms. Land use varies with soil type, topography, and access to irrigation water, with grazing and dairy farming predominant to the north and west of the pan in the steeper dolerite hills that occur there, and irrigated cropland located to the south and east on deeper soiled, gently sloping ground.

Unused and operating production bores were sampled in the vicinity of the pan, and on surrounding properties, the SWL measured wherever possible. Samples were then submitted to the TRI and CSIR laboratories in Bloemfontein and Pretoria for chemical and isotopic testing, respectively.

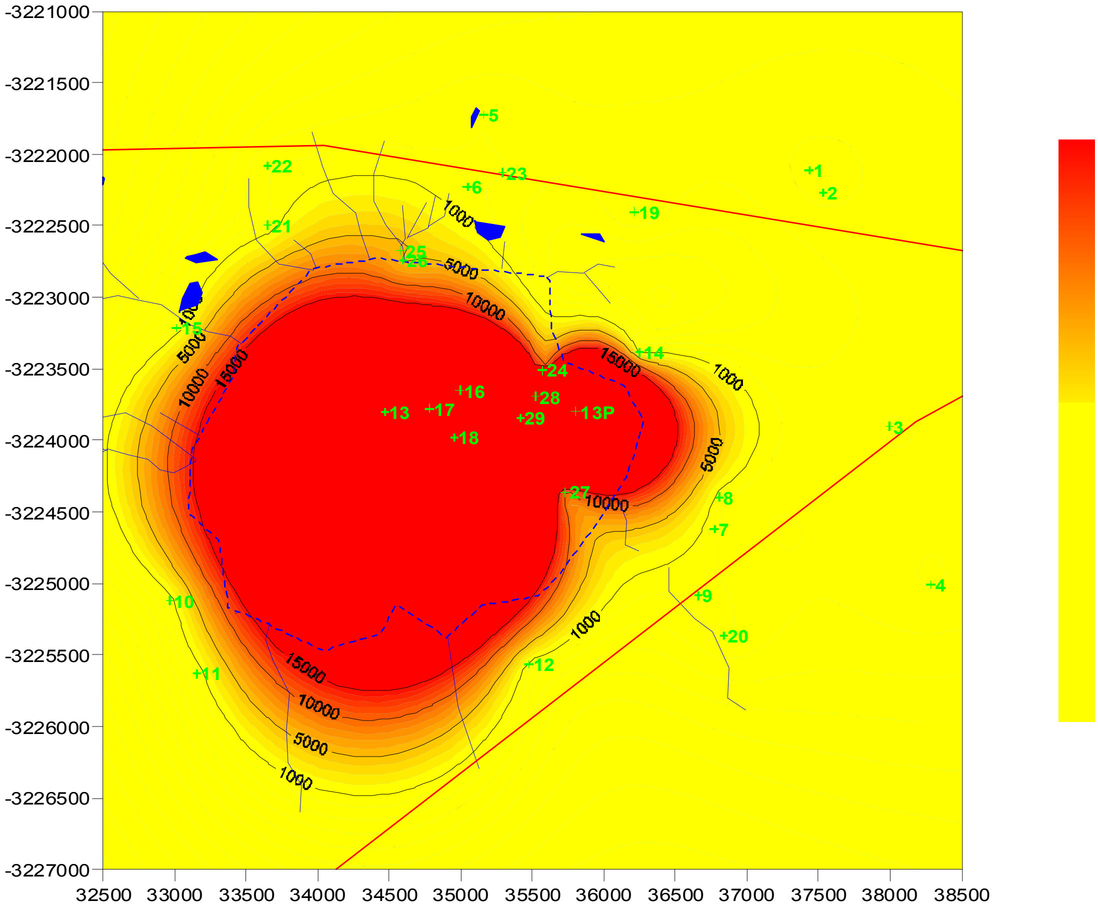


__Figure 45__ Chloride concentration of groundwater samples taken in the vicinity of Liebenberg's Pan. Concentrations at respective sampling locations (denoted "+") have been capped at 15000 mg/L for display purposes.

The orientation of the EWL determined from brine samples was determined to be $\delta^2H = 3.65.\delta^{18}O + {}^{-}4.71$ (refer **Figure 44**), which while having a lesser slope than that determined for surface water samples taken in hotter, drier areas of South Africa ($\delta^2H = 4.40.\delta^{18}O + {}^{-}1.21$; refer Section 4) is still above that determined for EWL-U in Botswana by Beekman et al. (1997; $\delta^2H = 2.5.\delta^{18}O + {}^{-}18.3$). Another characteristic of Petrusburg data of interest is that evaporation-induced enrichment has not been excessive as would be expected in this type of environment, with all groundwater samples having a $\delta^{18}O$ concentration 3.3‰ or less. Indeed, the highest value was measured in the evaporation pond sample, where evaporation had been encouraged ($\delta^{18}O$ = 6‰). This suggests that brine has mixed with isotopically depleted water from another source, the most likely being groundwater from upslope areas, a finding supported by the occurrence of freshwater springs at various locations around the perimeter of the pan, and the observed decrease in brine concentrations in production bores over time.

Available SWL, chloride and $\delta^{18}O$ data clearly indicate that flow is towards the pan (refer **Figure 45** and **Figure 46**), the standing water level varying from about 16 m in more elevated areas, to less than a metre in pan boreholes. A small depression had been excavated to collect runoff adjacent to borehole B5, the relatively high $\delta^{18}O$ value indicating that dammed runoff has entered the aquifer in this area.

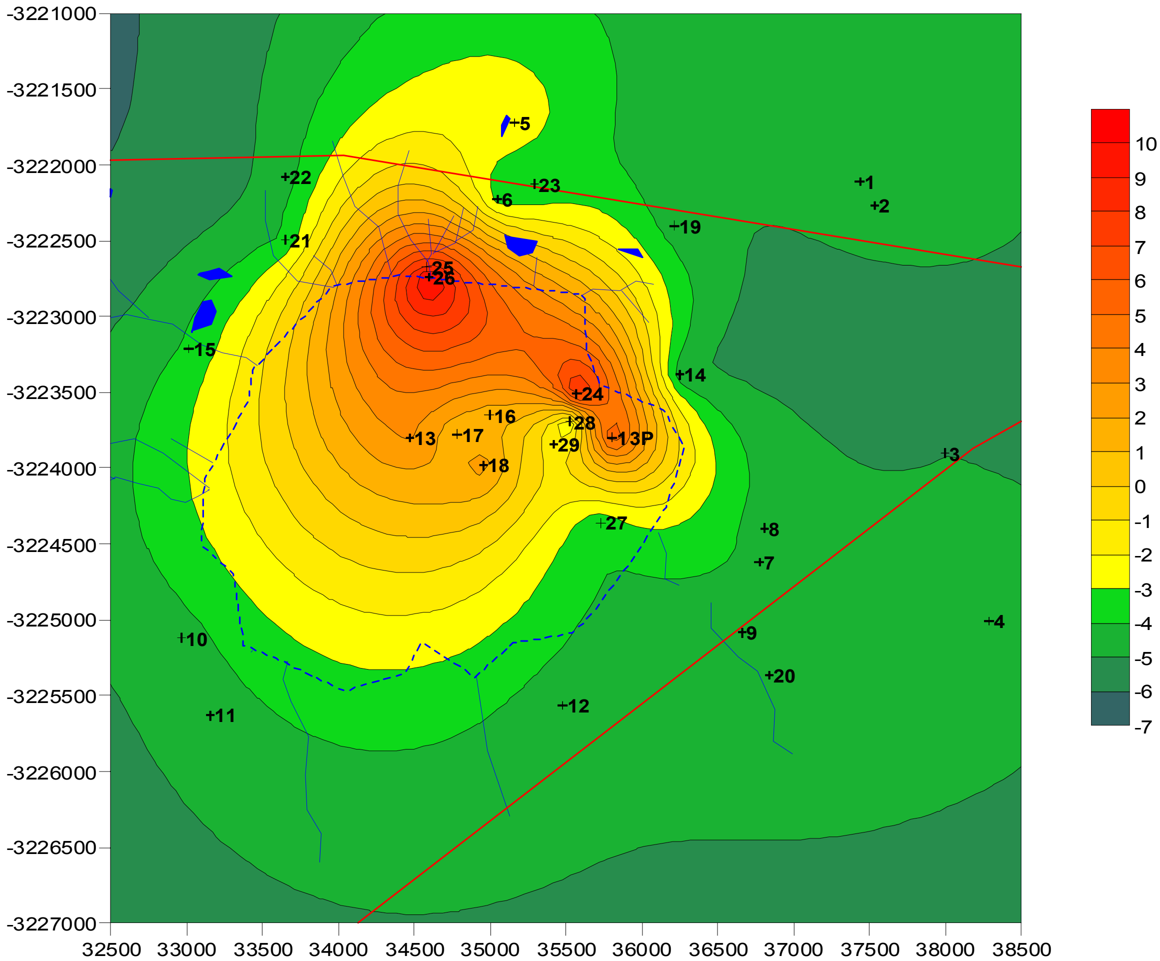


Figure 46 *$\delta^{18}O$ concentration of groundwater samples taken in the vicinity of Liebenberg's Pan ("+" denotes sampling location).*

PP_{flow} estimated using the MAE Method is between 33 and 25% assuming an EWL-U slope of $3.65.\delta^{18}O$ and $2.5.\delta^{18}O$, respectively (refer **Figure 47**). However, given the potential for brine/fresh groundwater mixing, the lower figure would be more acceptable in this instance. Indeed, in the absence of reliable, site-specific data, it is suggested that a slope of $2.5.\delta^{18}O$ be assumed for inland areas of South Africa.

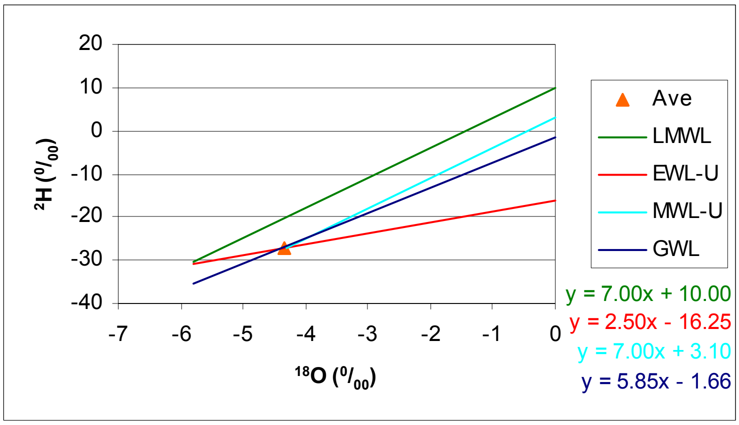


Figure 47 *Line characteristics used to determine PP_{flow} at Liebenberg's Pan. Using as assumed EWL-U orientated* $\delta^2H = 2.5\delta^{18}O + {}^-16.25$, *a recharge threshold of 150 mm is suggested using amount effect data for Windhoek.*

7.2 The relationship between recharge and SWL data

DWAF SWL data for the area tends to support a matrix-predominant recharge model. When compared with available rainfall data for the site (refer **Figure 48**), a lag of up to 200 days is often observed between rainfall and recharge events. This is significant given that the water table fluctuates between a depth of 7 and 9 m. However, there is evidence to suggest the recharge lag time can vary at a given monitoring location; at bore G47353 the lag was found to vary between 20 and 80 days (refer **Figure 49**). Possible reasons for this include variations in:

i. Land use. For example, some crop types may use water more efficiently than others;
ii. Pumping rates. Pumping may have been progressively increased following the recharge event such that the arrival of the recharge pulse is not represented in water level data;
iii. Unsaturated zone moisture content. The recharge flux could be temporarily reduced due to seasonal-related moisture content decreases, and associated reductions in permeability;
iv. Recharge water flow paths. It is not unreasonable to expect the recharge threshold to be lower, and for recharge to occur more quickly, if recharge water enters site aquifers via preferentially pathways as opposed to the matrix. Thus, preferential pathway-derived recharge would be expected to have a relatively short lag time compared to matrix-derived recharge. Further, given the amount effect observed in South African precipitation, the isotopic composition of preferential and matrix-derived recharge should also differ.

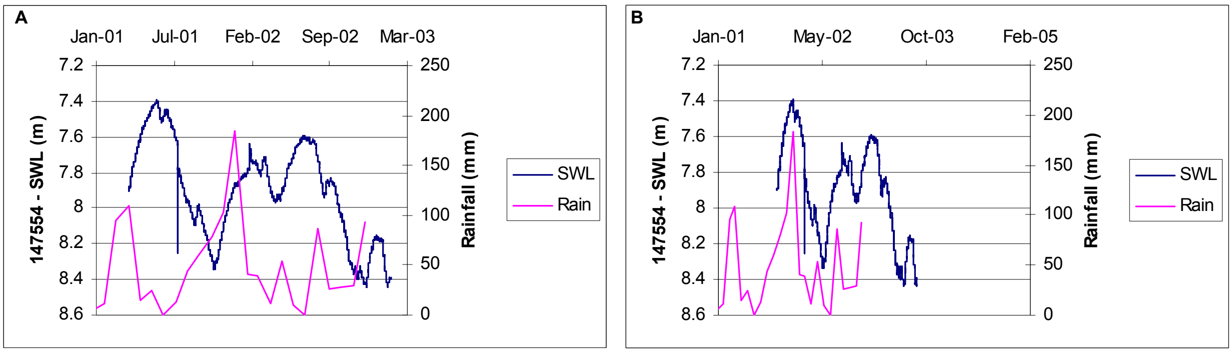


Figure 48 *Relationship between rainfall and water table response in Bore G147554. Note the poor relationship between actual rainfall and SWL data (Plot A), as opposed to an almost perfect fit occurs when a rainfall/response lag of 200 days is assumed (Plot B).*

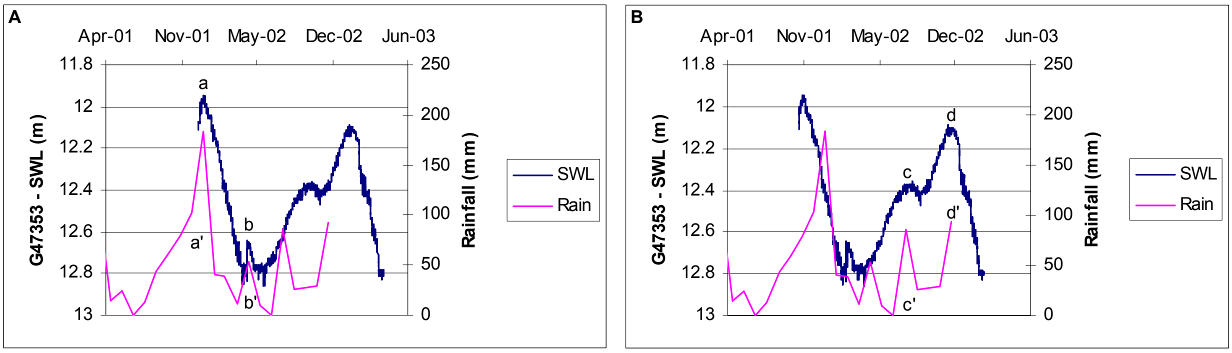


Figure 49 *Relationship between rainfall and water table response in Bore G 47353. Note the variations in the fit between rainfall and SWL data assuming a lag of 80 (Plot A, peaks a-a' and b-b') and 20 (Plot B, peaks c-c' and d-d') days.*

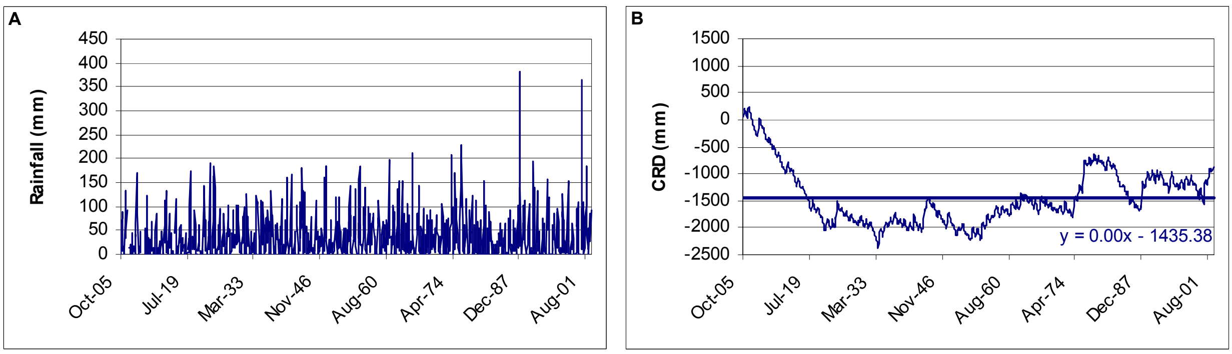


Figure 50 *Relationship between rainfall and CRD for Petrusburg. The amount of rainfall (Plot A) required to represent average conditions (i.e. no CRD) was 35.7 mm/month, as shown by the blue line on Plot B. Under field conditions though, this recharge threshold is unrealistic as it ignores episodic recharge processes that are characteristic of semi-arid and arid areas.*

Further insight into site recharge processes can be obtained when variations observed in recharge threshold estimates obtained using CRD and MAE techniques are considered. On the basis of 98 years of rainfall data for Petrusburg, the average monthly rainfall is 35.7 mm (refer **Figure 50** and Appendix 7), this value also representing the long-term recharge threshold for an aquifer in equilibrium if seasonal conditions are ignored. In theory therefore, there would be no change in water levels if 35.7 mm of rain fell at the site every month. Under field conditions though, this does not occur; prolonged periods of below average rainfall are evident throughout the Petrusburg dataset. Thus, in order to restore equilibrium conditions such that the average recharge threshold again decreases to 35.7 mm/month, a given catchment must receive above average rainfall. This observation is significant because it indicates that, for a given aquifer in a semi-arid and arid area, multiple recharge thresholds will be represented in site water level data.

Table 14 Steps that must be taken so that the average recharge threshold can be calculated. The approach assumes that; a) $\delta^{18}O_{rw\text{-}ave}$ equals the average concentration of $\delta^{18}O$ in site groundwater, and; b) that both preferential pathway and matrix-derived recharge occurs over the same catchment area, thereby allowing the mass of $\delta^{18}O$ entering the aquifer for each flow path to be calculated as shown in Step D, J, and K. By altering the value of H until the condition L = D is satisfied, the isotopic composition of recharge water required (H and I) to exceed the recharge threshold for both preferential pathway and matrix flow can be estimated. The recharge threshold as an equivalent rainfall depth can then be determined by converting H and I using amount effect data (refer Table 12).

Step	Description	Value
A	Proportion preferential pathway flow as determined using MAE Method {%}	25
B	Recharge threshold determined using the MAE Method {mm}	150
C	Average $\delta^{18}O$ concentration of groundwater {‰}	-5.8
D	Total mass of ^{18}O entering aquifer {B x C}	-870
E	Depth of preferential pathway-derived flow entering aquifer {A x B}	37.5
F	Depth of matrix-derived flow entering aquifer {(1 – A) x B}	112.5
G	Matrix to preferential pathway-derived flow proportioning factor {F/E}	3
H	Preferential pathway-derived $\delta^{18}O$ concentration {‰}	-2.3
I	Matrix-derived $\delta^{18}O$ concentration {‰}	-6.9
J	Total mass of preferential pathway-derived $\delta^{18}O$ entering aquifer {E x H}	-86.25
K	Total mass of matrix-derived $\delta^{18}O$ entering aquifer {F x I}	-776.25
L	J + K (must equal D if H has been selected correctly)	-862.5
M	Preferential pathway recharge threshold expressed as an equivalent rainfall depth (mm)	15
N	Matrix recharge threshold expressed as an equivalent rainfall depth (mm)	200

Table 15 Tabulated amount effect data for Windhoek and Pretoria. So as to allow an equivalent rainfall depth to be calculated from stable isotope data, it was assumed that there was a linear relationship between interval averages (i.e. for Windhoek data, a $\delta^{18}O$ concentration of –3.15‰ was assumed to equate with a rainfall depth of 46 mm).

Windhoek			***Pretoria***		
Interval (mm)	**Interval average (mm)**	**$\delta^{18}O$ (‰)**	**Interval (mm)**	**Interval average (mm)**	**$\delta^{18}O$ (‰)**
0-50	20	-2.47	0-50	22	-1.97
50-100	72	-3.83	50-100	72	-3.15
100-150	124	-5.15	100-150	127	-4.00
>150	215	-7.30	150-200	175	-5.42
-	-	-	>200	249	-6.15

Multiple recharge thresholds that are likely to be of importance include those necessary to induce recharge via:

1. Preferential pathways after a period of below-average rainfall;
2. The matrix after a period of below-average rainfall;
3. Preferential pathways once aquifer equilibrium has been restored;
4. The matrix once aquifer equilibrium has been restored.

Each of these recharge thresholds can be approximated using available site stable isotope data by applying the mass balance equation:

$$RT_{ave}.\delta^{18}O_{RT-ave} = \{RT_{low}.(X.\delta^{18}O_{RT-low})\} + \{RT_{high}.(X-1)\delta^{18}O_{RT-high}\} \quad \textbf{Equation 60}$$

Where,

RT = Average recharge threshold expressed as an equivalent rainfall depth (mm);
RT_{low} = Average recharge threshold to be exceeded if recharge via preferential pathways is to occur (mm);
RT_{high} = Average recharge threshold to be exceeded if recharge via the matrix is to occur (mm);
$\delta^{18}O_{RT-low}$ = Average $\delta^{18}O$ concentration of preferential pathway-derived recharge water (‰);
$\delta^{18}O_{rw-high}$ = Average $\delta^{18}O$ concentration of matrix-derived recharge water (‰); and,
X = Preferential pathway to matrix proportioning factor.

Table 16 Calculation of average lower recharge thresholds.

Step	Description	Value
A	Proportion preferential pathway flow as determined using MAE Method {%}	25
B	Recharge threshold determined using the CRD Method {mm}	35
C	Average $\delta^{18}O$ concentration of groundwater {‰}	-2.9
D	Total mass of ^{18}O entering aquifer {B x C}	-103.4
E	Depth of preferential pathway-derived flow entering aquifer {A x B}	8.9
F	Depth of matrix-derived flow entering aquifer {(1 – A) x B}	26.7
G	Matrix to preferential pathway-derived flow proportioning factor {F/E}	3
H	Preferential pathway-derived $\delta^{18}O$ concentration {‰}	-1.2
I	Matrix-derived $\delta^{18}O$ concentration {‰}	-3.6
J	Total mass of preferential pathway-derived $\delta^{18}O$ entering aquifer {E x H}	-10.70
K	Total mass of matrix-derived $\delta^{18}O$ entering aquifer {F x I}	-96.28
L	J + K (must equal D if H has been selected correctly)	-106.98
M	Preferential pathway recharge threshold expressed as an equivalent rainfall depth (mm)	0
N	Matrix recharge threshold expressed as an equivalent rainfall depth (mm)	65

The threshold averages to be exceeded before recharge occurs via the matrix, and preferential pathways, have been calculated in **Table 15**. Note that these values represent long-term averages, and not the upper and lower limits recharge thresholds. These limit thresholds can be calculated, however, by considering CRD and long-term average values together. For example, the CRD Method indicates that, for an aquifer under equilibrium conditions, the recharge threshold is approximately 35 mm/month. Since, on average, the recharge threshold cannot be lower than this amount, it must represent the average lower recharge threshold. Thus, the respective average lower recharge thresholds can be calculated once the isotopic composition of rainfall for an equivalent depth of 35 mm has been estimated from amount effect data (refer **Table 16**).

Once the lower and average long-term thresholds for both preferential pathway (RT_{low-pp} and RT_{ave-pp}) and matrix-medium recharge ($RT_{low-uzm}$ and $RT_{ave-uzm}$), the upper recharge thresholds $RT_{high-pp}$ and $RT_{high-uzm}$ can also be calculated i.e.

$$RT_{high} = 2.RT_{ave} - RT_{low} \quad \textbf{Equation 61}$$

In this instance, this equates to concentrations of 30 – 0 = 30 mm and 400 - 65 = 335 mm for $RT_{high-pp}$ and $RT_{high-uzm}$, respectively.

Recharge thresholds can be similarly calculated for the Hotazel dataset discussed earlier (refer **Table 17** and Appendix 7). When compared to the Petrusburg estimates, preferential pathway-derived recharge is clearly more episodic in the Hotazel area as shown by the lower $RT_{low\text{-}pp}$, $RT_{ave\text{-}pp}$, and $RT_{high\text{-}pp}$ values. However, while only 25% of recharge at Petrusburg occurs via preferential pathways, on average, recharge occurs via these pathways in more than 50% of all rainfall events ($RT_{ave\text{-}pp}$ = 56.4%). In comparison, $RT_{ave\text{-}uzm}$ is exceeded less than 1% of the time. Thus, in episodic recharge environments, resource managers must ensure that allocated water can be used for the entire period between major recharge events, which where recharge via the matrix predominates, can be significant. Indeed, in many instances it may be more realistic to base groundwater allocations on the proportion of bypass flow-derived recharge entering site aquifers initially, the allocations increasing once aquifer storage, recharge threshold, and recharge event return period characteristics are better understood.

Table 17 Summary of calculated recharge thresholds for Petrusburg and Hotazel. The number of times, expressed as a percentage, that the recharge threshold has been exceeded is also shown (total number of months in Petrusburg and Hotazel datasets equals 1136 and 508, respectively).

Recharge Threshold	Petrusburg (mm)	Exceeded (%)	Hotazel (mm)	Exceeded (%)
Low-pp	0	78.3	10	52.0
Ave-pp	15	56.4	35	27.6
High-pp	30	41.9	55	19.3
Low-uzm	65	19.0	40	24.8
Ave-uzm	200	0.5	235	1.2
High-uzm	335	0.2	430	0

Given the observed relationship between CRD and rainfall in South Africa, and the significant period of time that can elapse between rainfall events of sufficient depth to induce recharge via the matrix, it follows that CRD Method is more often than not a representation of bypass flow processes. It is therefore reasonable to assume that a better CRD/SWL relationship could be determined for a given site if $RT_{pp\text{-}low}$ and $RT_{pp\text{-}high}$ were incorporated into the assessment process. In this instance rainfall for the preceding month (P_{i-1}) was assumed to influence the recharge threshold for a given month (P_i). For example, if the condition $P_{i-1} > RT_{high\text{-}pp}$ was satisfied, then, providing $P_i > RT_{low\text{-}pp}$:

$$CRD_i = P_i + CRD_{i-1} \qquad \textbf{Equation 62}$$

If $P_i < RT_{low\text{-}pp}$ or $P_i = RT_{low\text{-}pp}$, then:

$$CRD_i = CRD_{i-1} - K$$ **Equation 63**

Where K was assumed to be a constant. Thus, in the event there were several months where $P_i < RT_{low-pp}$ or $P_i = RT_{low-pp}$, a continuing linear decrease in CRD was observed. This was reversed, however, once $P_i > RT_{high-pp}$, at which time Equation 62 was again used to determine CRD_i. The resulting CRD plot tends to accentuate the dataset, as significant recharge is only indicated after several months of continuous wet weather (refer **Figure 51**). It should be appreciated, however, that a departure from any observed relationship between CRD and SWL will occur once recharge via the matrix occurs, as:

- This recharge will significantly increase SWL;
- The lag time between a given rainfall event and the arrival of the recharge front will be longer when recharge occurs via the matrix (refer **Figure 52**).

Note though that, for a significant part of the CRD record, matrix influences will not be observed due to the length of the return period between rainfall events of sufficient depth to induce recharge via the matrix.

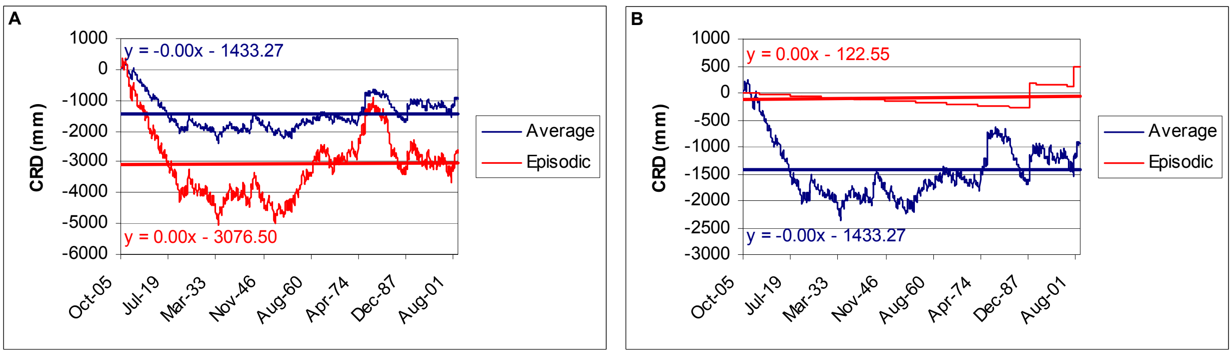


Figure 51 *Recharge threshold data incorporated into the CRD plot for Petrusburg. Plots A and B show the modelled response for recharge via preferential pathways and the matrix, respectively. Note that; a) K values of 74.3 (Plot A) and 0.28 (Plot B) mm/month were used in this instance, and; b) modelling suggests recharge via the matrix occurred in February 2001. The CRD plot for the site assuming* ${}_{ave}^{1}CRD_i = (P_i - P_{ave}) + {}_{ave}^{1}CRD_{i-1}$ *is also shown (blue line denoted "average").*

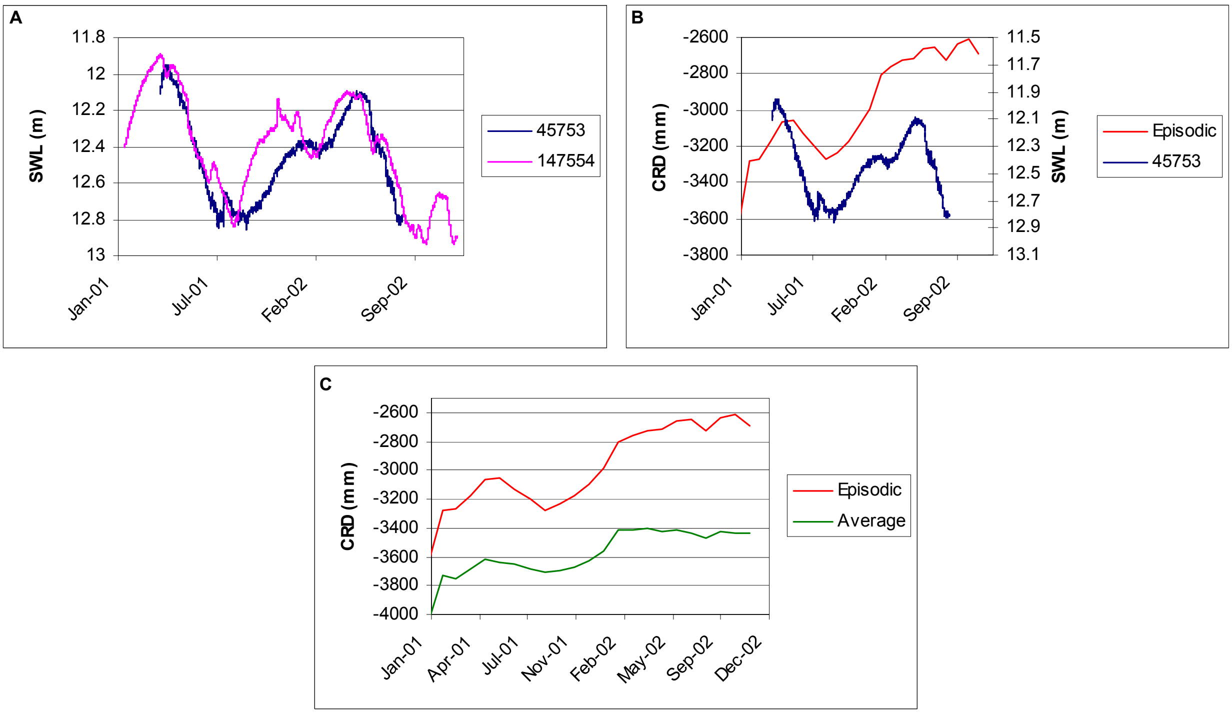


Figure 52 *Comparison between SWL and modelled episodic CRD response. SWL's in boreholes 45753 and 147554 have been overlain by varying the lag times for each (180 and 70 days, respectively), and subtracting 4.5 m from each of the SWL measurements in 147554's dataset. The significant lag time between rainfall and water response at the respective sites suggests that matrix-derived recharge water is entering the aquifer, which was predicted using the suggested episodic CRD approach (refer* ***Figure 51****). Note that smaller rainfall events appear to have influenced the shallower SWL in 147554, suggesting recharge via preferential pathways has subsequently occurred there. When compared to water level data for 45753 (Plot B), the episodic CRD plot shows reasonable agreement, although the modelled water level recession was less than observed. This may be because the modelled data does not consider the influence of artificial extraction on groundwater levels. The episodic and average CRD methods for the period have also been compared by subtracting 2500 from each of the average CRD values to allow a better visual comparison (Plot C). Note that there is a reasonable agreement between both, although modelled water table response to periods of prolonged wet weather is greater when the episodic approach is used.*

7.3 The relationship between recharge and groundwater quality

The influence of recharge processes on resulting water quality also warrants consideration. As shown previously, the proportion of chloride entering an aquifer with recharge water, be it via the matrix or preferred pathways, satisfies the equation:

$$R_{ave} = \{(Cl_p / Cl_{uzm}).MAP\} + \{(Cl_p / Cl_{pp}).MAP\}$$

It should be appreciated, however, that R_{ave} represents the long-term average condition. Since it has been shown that recharge water might only enter the aquifer via the matrix a few times every century, it follows than when it does, a significantly greater mass of salt is suddenly introduced into the system. Thus, there is a significant potential for a sudden degradation in groundwater quality as a result of natural recharge processes, which is dependent on:

1. The amount of groundwater stored in the aquifer at the time of recharge. If the amount of recharge entering an aquifer is significantly less than the volume of groundwater in that aquifer, minimal degradation could be expected. Note though that, in the case of recent, intensive, artificial extraction, degradation may be more apparent;

2. The rate at which recharge water/groundwater mixing occurs.

Note that the suggested relationship between recharge via the matrix and declines in groundwater quality tends to support the inferred, recharge-related degradation that was observed by local residents in the Hotazel (1974) and Petrusburg (2001; van Tonder, 2003) districts.

On occasions, improvements in groundwater quality have been reported sometime after a given recharge event. While this subject has been given minimal treatment in published literature, and is beyond the scope of this investigation, some possible mechanisms are suggested. These include:

- Mixing of recharge water with groundwater of better quality. While quality would improve relative to the initial arrival of the recharge front, conservative ion concentrations in groundwater would gradually increase over time unless follow-up recharge was regularly received;
- The hydraulic behaviour of the unsaturated zone. To represent flow in the unsaturated zone, Darcy's Law (Darcy, 1856) can be adapted to (from Hillel, 1971):

  $$\mathbf{q} = -K(\theta) \text{ Grad } H \quad \textbf{Equation 64}$$

  Where **q**, K, θ, and H represent specific discharge (m/s), hydraulic conductivity (m/s), volumetric moisture content (%), and potential head (H), respectively. As a recharge front moves through the unsaturated zone, soluble ions such as chloride are dissolved first. However, unless all infiltrating water in the front has been thoroughly mixed within the ETM zone, recharge water that enters the aquifer initially must have the highest ion concentration for a given piston-type recharge event. It could be argued that the potential for mixing would be reduced when recharge is significant, sudden, and rapid, as would be expected if flow via the matrix was initiated. This potential would be further reduced if the effective porosity of the unsaturated zone matrix was low (i.e. a recharge front would be 4 m thick if an equivalent rainfall depth of 200 mm moved as a rectangular-shaped pulse through unsaturated zone material with $n_{uz} = 5\%$). As the recharge front entered the aquifer, θ, H, and therefore **q**, would decrease progressively, a condition that would be further encouraged once the piezometric head in the aquifer began to rise. Such a response would delay the entry of better quality recharge water into the aquifer and prevent groundwater quality from stabilizing in the short-term.

7.4 Summary

The slope of EWL-U in the Petrusburg area is less than $3.65.\delta^{18}O$, and was assumed to be $2.5.\delta^{18}O$ when applying the MAE Method. The method itself can be adapted to estimate both preferential pathway and matrix recharge thresholds for an aquifer system, which once known, allow an aquifer's response to recharge to be better assessed. Some significant findings which resulted from this adaptation were that:

i. In many instances, it may be more realistic to base groundwater allocations on the proportion of bypass flow-derived recharge entering site aquifers initially, the allocations increasing once aquifer storage, recharge threshold, and recharge event return period characteristics are better understood;

ii. Recharge only enters the aquifer via the matrix a few times each century, resulting in the sudden introduction of unsaturated zone-derived salt and subsequent short-term degradation of the groundwater quality. Such recharge-related degradation would influence any CMB Method-derived estimates if insufficient time was allowed for groundwater chloride concentrations to stabilize before sampling. These effects would be most apparent in drier areas where the entry of matrix-derived recharge into the aquifer occurs less often. Thus, given that rainfall is seasonal across most of Southern Africa, recharge calculations should be based on chloride concentrations of groundwater samples taken at the end of the dry season, and;

iii. Given that Cl_{pp} and Cl_{uzm} can change over time, unsaturated zone chloride concentrations should not be used as input variables when estimating recharge using the CMB Method in Southern Africa.

8 The use of environmental tracers in wetter inland areas

8.1 Introduction

Significant advances in the understanding of recharge processes have been made through the use of environmental tracers in semi-arid and arid areas worldwide. However, there are climatically wetter areas within Southern Africa where isotope and CMB Method techniques may have less application. This section outlines findings made during an investigation undertaken at Kriel and Matla Power Stations, the facilities located within a higher rainfall area of inland South Africa. The Eskom-owned properties were constructed on adjoining properties to exploit the extensive bituminous coal deposits that occur southeast of Pretoria in Mpumalanga Province. Power generation facilities of this type can have a significant impact on site hydrology if poorly managed, for reasons including:

- Extensive water use and the installation of cut-off drains reducing groundwater levels;
- Disruption of stream flow due to stream diversion construction;
- Acid Mine Drainage (AMD) from mined areas; and
- Leachate migration from ash dumps.

Numerous hydrological investigations have been undertaken at the respective sites, most generally being conducted to provide background information on specific site problems (refer Appendix 8). One notable problem was the difficulty in distinguishing between recharge sources, be it artificial recharge from a leaking ash dam or rainfall recharging naturally through site spoils (SRK, 1989). Given the potential for the respective sources to have different isotopic characteristics, a comprehensive water-sampling programme was initiated. Associated field activities commenced 14 February 2001 and extended for a month, with particular attention given to siting new boreholes, and identifying geohydrological conditions that may have been overlooked during previous investigations.

While located within a rural area approximately 200 km by road southeast of Pretoria, the site itself is well developed, due to the presence of the two power stations, three abandoned mine pits, the existing Kriel and Matla Colliery shafts, the Kriel Mine offices, and associated infrastructure comprised of stockyards, delivery plant, hostels, and a golf course (refer **Figure 53**). Prior to development, however, the site was probably a commercial stock and cropping farm similar to those now present along the boundaries of the respective power stations.

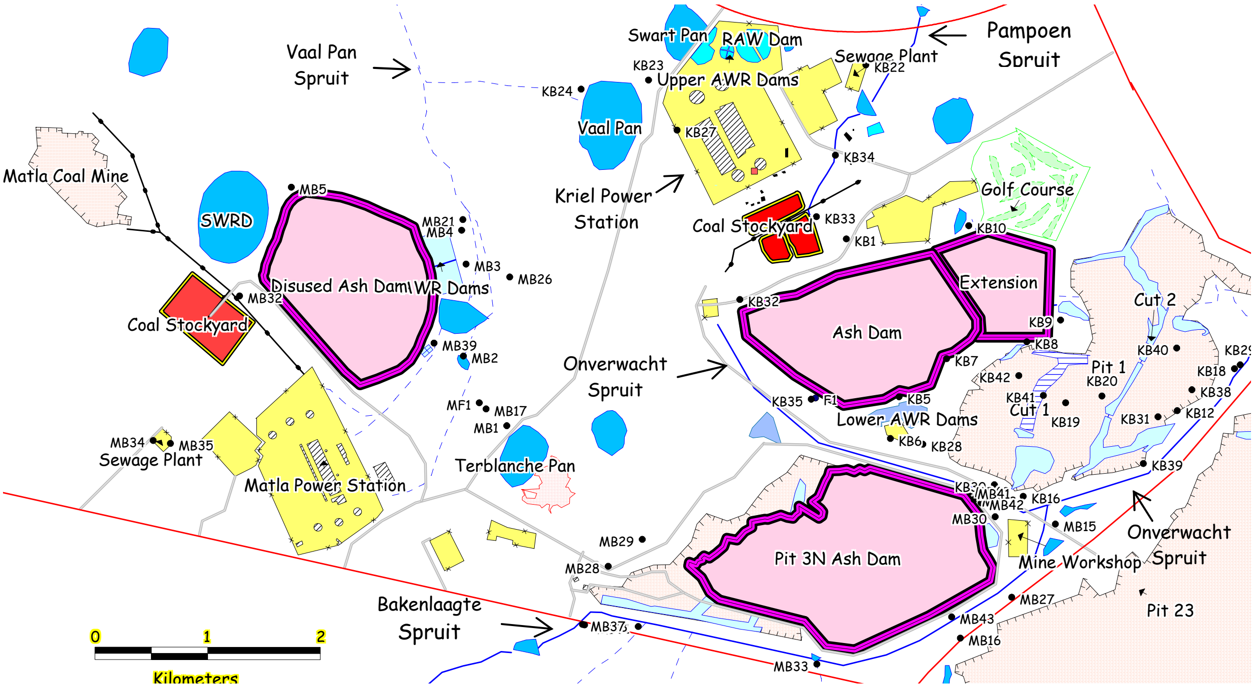


Figure 53 *Site map of Kriel and Matla Power Stations showing monitoring bore locations.*

Topographic maps of the area show a well developed recurring block type drainage pattern, particularly to the north of the respective power stations, characterized by stream sections orientated southwest-northeast and northwest-southeast. Drainage of this type is often structurally controlled, and thus may provide some insight into the orientation of regional and convergent stresses.

The power stations themselves have been constructed in gently undulating country on a southwest-northeast trending ridge crest approximately 5 km apart, on each side of which several springs occur. Springs in the vicinity of Kriel Power Station feed the seasonal Onverwacht, Pampoen, and Vaal Pan Spruits (which drain to the east, north, and west respectively), while those adjacent to Matla generally drain to the northwest into Vaal Pan Spruit. Numerous other springs occur to the east of the ridge, with the bulk of these draining into Onverwacht Spruit. Ultimately, all surface water from this area drains into the Olifants River via the Riet (water draining north and west of the ridge), and Steenkool (water draining east) Spruits approximately 10 km to the east of the site.

The southwest-northeast orientated Bakenlaagte Spruit is another drainage feature of significance, as it is the only local stream that originates outside of the project area. Further, this stream was diverted to prevent ingress into surface mine areas, and remains so due to the location the current Matla Power Station ash dam.

Several man-made features are also of significance at the site. Numerous dams have been constructed for a variety of purposes, the most obvious of which are the ash disposal dams. To date, three of these have been constructed, although the dam to the north of Matla power station is no longer used, apparently due to its potential to impact upon the stability of underground mine workings (Wessels, 2001). These dams are several kilometres in circumference, with heights in excess of 40 m in some instances. One of the Matla Power Station dams has been constructed within an old mine pit, with the remaining two supposedly founded on in situ profiles.

Although initially planned as an entirely underground mine, open cut mining commenced at the Kriel Colliery in 1975 (Amcoal, 1993). Three surface mining pits occur in the immediate vicinity of the power stations:

- *Pit 1*. This pit is located to the southeast and east of Kriel and Matla Power Stations, respectively, on Kriel Power Station property. The pit was infilled with mine spoils, except for the voids adjacent to two cut faces, known as Cut 1 and Cut 2. Ash was subsequently placed into Cut 1, while Cut 2 remains open. Most of the pit has now been rehabilitated, although spoil stockpiles are still present in the northern quarter;
- *Pit 3N*. Pit 3N is the closest abandoned surface mine to the east of Matla Power Station. The pit was partially infilled with spoils and rehabilitated. However, at some later date the decision was made to construct an ash dam within the pit void. Spoil heaps can still be observed along the western flank of the pit, and some dumping of discards form the Matla Power Station coal stockyard and power station waste still occurs here;
- *Pit 23*. This pit is located to the east of Pit 3N beyond the Kriel-Kinross Road, and is thus outside the investigated area. The pit has now been rehabilitated.

Power stations and associated mines in the vicinity of the project area are supported by extensive infrastructure that includes workshops and offices. Coal from the nearby Kriel open cuts (beyond the eastern boundary of the study area) is transferred to the Kriel Power Station coal stockyard in dump trucks via an unsealed all weather mine road that runs alongside the upper reaches of Onverwacht Spruit, while colliery derived coal is transported using conveyor belts.

Significant proportions of the total mine and power station staff are housed on site in hostels containing essential amenities and serviced by sewage treatment works. Most water used during the daily operations of the power stations and associated infrastructure is piped into the site from the Usutu-Vaal Water Scheme, with an onsite DWAF office (located to the east of Matla Power

Station) administering distribution. Some low quality water is sourced onsite from areas such as the old mine cuts, particularly for use as ash slurry make-up water. This water is generally lifted to the respective powers stations using high capacity barge pumps.

An extensive hydraulic system has been developed to dispose of ash at the respective power station sites. Ash is pumped to the sites via a network large diameter steel pipes several kilometres long. At Kriel Power Station, shallow concrete-lined channels installed around the perimeter of the ash dams themselves intercept water derived from the ash dam, drain under gravity to large ponds, from where water is pumped back to the power station for re-use as make-up water. A similar channel system is used in conjunction with a sub-surface drain to direct ash water to a pump out sump that has been constructed at the lowest hydraulic point at Matla Power Station. Water from the sump is pumped to the still open final cut in the southwestern corner of Pit 3N, from where it is lifted via barge pumps back to the power station.

Other drains are of significance within the project area. An open channel that discharges to Onverwacht Spruit near the Ogies-Kriel Road bridge, has been constructed to the north of both the Kriel ash dam and Pit 1. Concrete lined in part, the channel has been constructed to limit the interaction between clean and potentially polluted surface water at the site. The diversion of Bakenlaagte Spruit has also been constructed to intercept runoff from topographically higher areas to the south of Pit 3N.

A subsurface drain was constructed to the west of the current Matla ash dam to limit the amount of groundwater entering the structure from the elevated areas here. A cut-off trench has also been installed around the dam to prevent seepage entering Onverwacht Spruit from shallow aquifers during the initial stages of operation.

Several roads have been constructed within the investigated area. Generally, all roads exposed to continual vehicular access between each of the facilities and public roads, and within the respective power stations, have been sealed. Unsealed all weather roads provide access to most other areas of the sites used as part of normal daily operations, although access to sites within Pit 1 is limited to four wheel drive vehicles following prolonged periods of wet weather.

Within the respective power station compounds and surrounds, vegetation is restricted to lawn grasses, small shrubs, and occasional trees, while crops such as maize are grown on adjoining properties. Several pasture species have also been planted on the rehabilitated area of Pit 1, with lucerne and other non-native species farmed for commercial purposes. A small stand of eucalypts has also been planted to the south of Cut 2.

Reeds occur across each of the sites in areas with a high groundwater table, or where surface water of shallow depth stands.

8.2 Climate

Table 18 Official climate data for Witbank and Bethal based on data collected between 1948 and 2003, and 1961 and 1990, respectively (South African Weather Bureau, 2003). With the exception of rainfall data for Witbank, which is located about 60 km to the north of the power stations, all data summarized here was measured at Bethal, the nearest official station to the site (35 km to the east).

Month	**Witbank Rainfall mm**	**Bethal Rainfall mm**	**Evaporation mm**	**Maximum Temperature °C**	**Minimum Temperature °C**
January	131	146	182	25.6	13.8
February	90	75	155	25.2	13.2
March	79	61	153	24.6	11.8
April	45	48	113	21.8	8.6
May	15	14	96	19.5	4.4
June	7	7	83	16.5	0.8
July	5	6	93	17.1	1
August	8	13	141	19.9	3.8
September	23	28	181	23.2	7.5
October	78	78	198	23.9	9.9
November	117	129	171	24	11.8
December	108	106	202	25.3	13.1
Total	*708*	*711*	*1768*	*22.2*	*8.3*

The project area falls within the "Highveld" climate classification of Viterito (1987), and can thus expect warm, wet summers, and mild, dry winters, with equivalent evaporation depths exceeding precipitation (refer **Table 18**). Regular dust storms can also be expected during periods of prolonged dry weather. Average annual rainfall, for this part of Mpumalanga Province, decreases from 900 mm in the east to 650 mm in the west, with approximately 85% falling between October and April. In the vicinity of Kriel and Matla Power Stations the estimated rainfall from showers and thunderstorms is about 710 mm/year, based on available South African Weather Bureau records.

Average daily maximum temperatures vary from 27°C in January to 17°C in July, but in extreme cases these may rise to 38 and 26°C, respectively. In comparison, average daily minima of 13 and 0°C can be expected, with temperatures falling to 1 and –13°C, respectively, on unusually cold days. Frost conditions are also common over the 120-day period from May to September.

Amcoal (1993) notes that prevailing wind directions are northwesterly to northeasterly, with an average wind velocity of 14.5 km/h, although tornadoes do occur on rare occasions.

8.3 Geology and geohydrology

The site forms part of the Highveld Coalfield and falls within the Carboniferous to early Jurassic aged Karoo Basin. In the Kriel area, shales typically define lower and upper levels of the series, with coal measures and associated detrital sediments present between (Truswell, 1977; Amcoal, 1993). Two sedimentary units are of interest in the Kriel Coalfield, the Dwyka and Vryheid Formations. The Dwyka Formation is essentially comprised of a succession of glacial deposits characterized by angular to rounded clasts of basement within a silt and clay matrix that were emplaced from the Late Permian, although varved shales, sandstone, and conglomerates typical of a fluvio-glacial environment also occur (Botha et al., 1998). The formation unconformably overlies an undulating basement surface defined by lithologies associated with the Bushveld Complex in the Kriel area (Amcoal, 1993).

The younger Vryheid Formation is comprised of a succession of sandstones and minor interbeds of siltstone and mudstone to a thickness of 180 m at the site. Typically, five seams, numbered 1 (youngest) to 5 (oldest) are represented across the Highveld Coalfield, although Seam 1 is often absent. Seam 4, a flat lying to gently undulating unit with a thickness of about 4.8 m and regional dip of less than 1° to the southwest, is the only seam currently mined by the Kriel Colliery, and typically occurs at a depth of about 30 m in open cut areas. While the entire thickness of the seam is extracted during surface mining, underground operations only exploit the lower two thirds of the unit. The layout of mine operations and subsequent extraction of the coal is influenced by the presence of dolerite sills that tend to displace the coal measures, thereby compartmentalizing the reserves (Amcoal, 1993).

Numerous doleritic dykes and sills have been mapped in the area. One sill, located below Seam 2, is up to 14m thick and surrounded by an extensive zone of burnt coal, with observed displacements resulting from sill intrusion generally equivalent to the thickness of the structure. Burnt coal zones from 1 to 30 m wide are also observed along the predominantly southwest to northeast trending doleritic dykes in the area, but unlike adjacent sills, the extent of these zones is apparently independent of the dyke thickness (Amcoal, 1993).

Borelogs suggest that a relatively deep weathering zone has developed across the site, with weathered in situ material extending to depths of more than 18 m. Many of the site soils appear to be derived from this material, either forming in situ upon the weathered horizons themselves, or following mobilization and subsequent formation of alluvial and colluvial deposits. In terms of the Unified Classification System (Casagrande, 1948), site soils are generally less than 3 m thick and comprise silty sandy clays (Cl-CI) or clayey sands (SC), with the sandier material predominant. While the primary colour of most site soils is brown, a range of secondary colours was observed (i.e. yellowish brown, greyish brown, etc), with many of the observed soils having a mottled appearance. Typically, mottled zones within a soil profile are indicative of seasonal variations in moisture content and lateral drainage, which implies that the permeability of the Ecca Series sediments is less than that of the overlying soil profile.

Groundwater was commonly perched within surficial weathered horizons, or at deeper bedding interfaces between shale/carbonaceous shale, and underlying slight to moderately weathered fine-grained sandstone. Thus, the presence of groundwater in both shallow and deep aquifers across the combined properties is suggested, albeit not always in significant quantities nor interconnected throughout. Further, secondary porosity appears to be of significance in site aquifers, consistent with findings made elsewhere in the Karoo Basin (Botha et al., 1998).

8.4 Chemical and isotopic characteristics of water samples

Tested groundwater samples, all of which were taken from Karoo Basin sediments, either plot on the EWL, or immediately adjacent to LMWL (refer **Figure 54** and Appendix 9), the transition between rainfall and surface water-derived recharge occurring between $\delta^{18}O$ abundances of -3.2 and -2.5‰. When considered spatially (refer **Figure 55**), ^{18}O concentrations indicate that aquifers in the vicinity of the Kriel Power Station sewage treatment works, and those in, and down-hydraulic gradient of, Pit 1, have been recharged with water that has been exposed to evaporation. The areas to the east of the old Matla Power Station ash dam near the dirty water channels and abandoned waste disposal site, and southwest of the current Kriel Power Station ash dam, have a similar recharge history. In comparison, there is only a slight suggestion of recharge water having an evaporative signature at one sample site (MB30) around the perimeter of the current Matla Power Station ash dam.

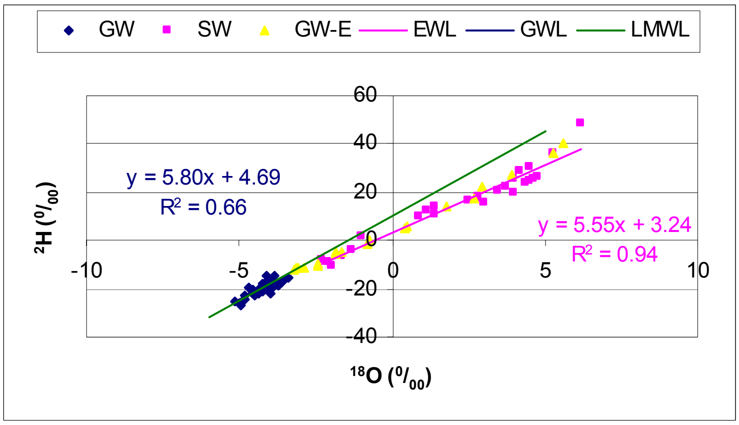


Figure 54 *Stable isotope concentrations in Kriel and Matla Power Station waters. "GW", "SW", and "GW-E" denote groundwater, surface water, and groundwater having an evaporated signature, respectively.*

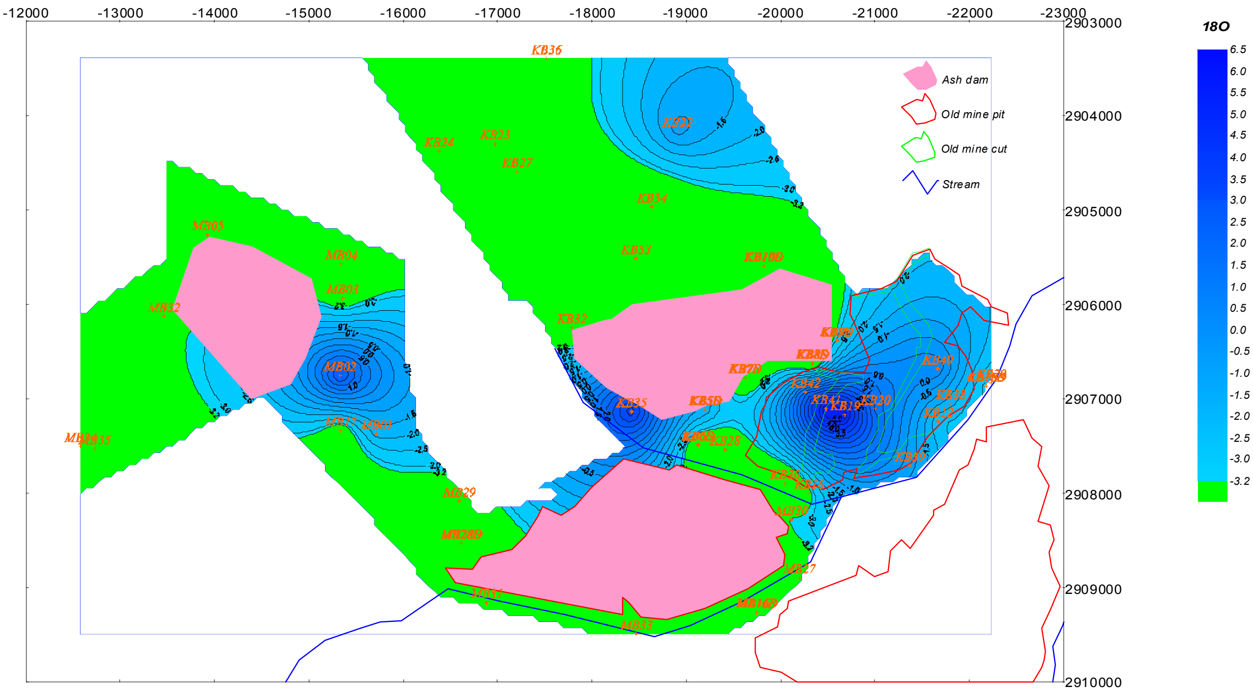


Figure 55 *Contoured $\delta^{18}O$ concentrations across the combined power station properties. Values with a concentration less than -3.2‰ represent aquifers recharged directly from rainfall.*

Laboratory test results (refer Appendix 9) suggest that, while water quality varies across the site, either sodium bicarbonate or calcium-magnesium-bicarbonate type waters, or some combination thereof, are represented. The distinction between different water-type is, however, more apparent if the major anion segment of a Piper Diagram plot is considered independently (refer **Figure 56**). Since areas recharged by rainfall are defined by $\delta^{18}O$ < -3.2‰, the background groundwater type can also be determined if the chemistry of these sites is considered, which in this instance is characterized by a predominance of bicarbonate anions.

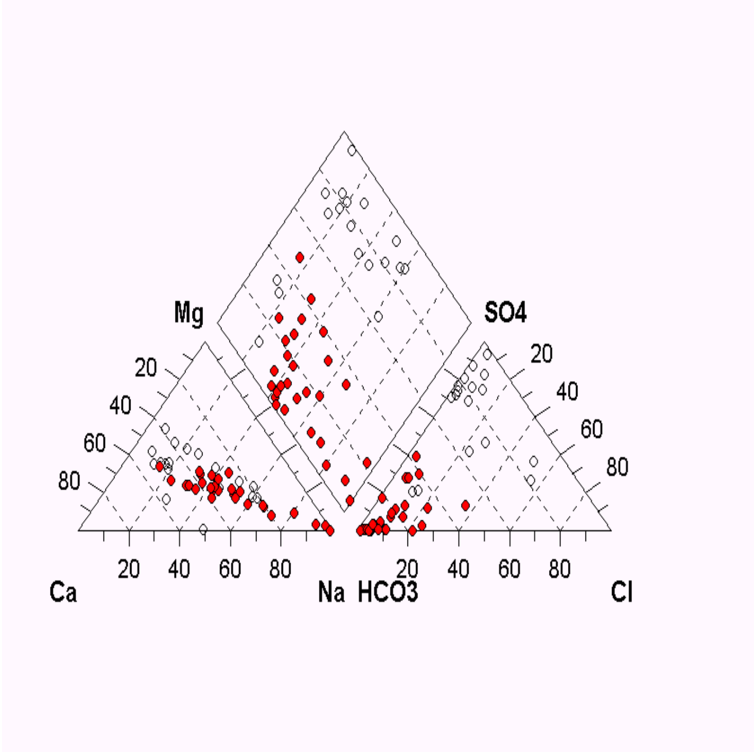


Figure 56 *Relative proportions of major ions in groundwater samples plotted on a Piper Diagram. Solid markers show those sites recharged by rainfall.*

Sulphate is often produced in response to the oxidation of lithology-hosted sulphides at Mpumalanga mine and power station sites, and is therefore regarded as a pollution indicator in these environments. When contoured, elevated groundwater sulphate concentrations are represented within Pit 1, and along the southeastern perimeter of the feature (refer **Figure 57**). Significantly higher values are also observed adjacent to the abandoned waste disposal area and dirty water system to the northeast of Matla Power Station, and down hydraulic gradient of the southwestern and southeastern corners of the Kriel Power Station ash dam. Groundwater sulphate contents to the northeast of the coal stockyard (KB34), and adjacent to the sewage treatment works at both power generation facilities (KB22 and MB35) also appear to be above background values. Of interest, however, is that while the sulphate content is relatively low in KB16 and KB30 (30.3 and 0.8 mg/L, respectively), it is noticeably higher in MB30, a monitoring bore also installed down-hydraulic gradient of the Matla Power Station ash dam (116.9 mg/L).

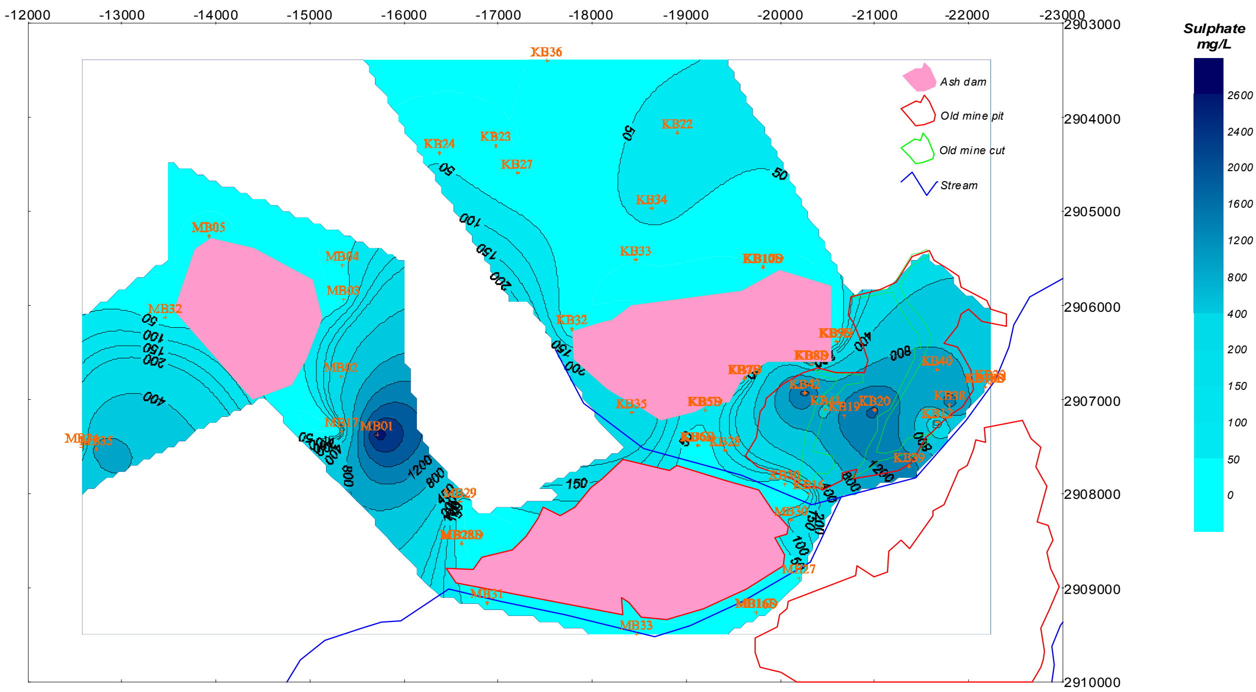


***Figure 57** Contoured sulphate concentrations across the combined power station properties.*

When considered together, stable isotope and sulphate results for groundwater sampled from bores within, and down hydraulic gradient of, the now abandoned Pit 1, provide insight into the recharge history of the site. With the exception of KB16 and KB30, groundwater at these sites contains appreciable sulphate and has an evaporated water signature, which implies that the pit and its surrounds have been recharged from a surface water body. While surface water is standing in ponds at the toe of Cut 1, and throughout Cut 2, water appears to be more enriched (i.e. has been evaporated more) in the deeper parts of the pit that occur below the decant level (refer **Figure 58**). This observation can be explained by considering site management on completion of mining, and the significant differences observed between the permeability of aquifers within the Vryheid Formation, and adjacent mine spoil and ash material. The deepest excavation in Pit 1 was made in the vicinity of the northern limit of Cut 1. On completion of mining, the pit was backfilled with spoils to the east and west of both Cut 1 and Cut 2, with ash subsequently disposed in Cut 1 only. If the permeability of the respective site material is considered, it is reasonable to assume that groundwater would flow preferentially through the ash and mining spoils, which a plot of SWL relative to site topography confirms to be true (refer **Figure 59**). Indeed, the material is that permeable that the pit water level is essentially level, which suggests that water in the pit has characteristics in common with a lake or dam. In contrast, Vryheid Formation aquifers have a very low permeability, with the piezometric surface a reflection of topography. It is therefore possible that water could pond in areas of the pit where the floor level is below the decant level.

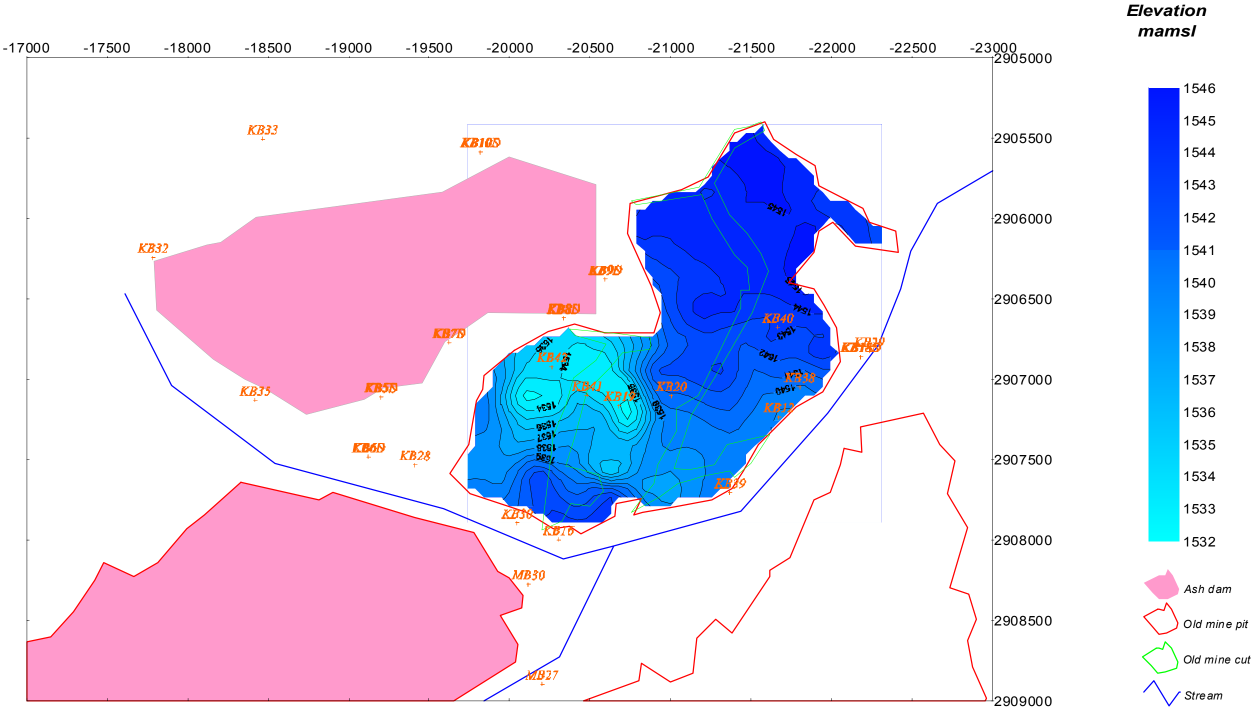


Figure 58 *Contoured floor elevations for Pit 1, Kriel Power Station.*

Significant volumes of water are used for ash disposal in a wet system, some of which drains to perimeter drains around the dam following ash placement. However, water derived from ash placed in Cut 1 would not drain towards the outlet of Pit 1 initially, flowing instead towards the lowest point. Thus, water here has the potential to better retain the evaporated characteristics of ash dam water when compared to other bores due to the reduced potential for mixing with background groundwater and natural recharge.

While seepage from the nearby Kriel Power Station ash dam and adjacent small reservoirs could be contributing to the observed isotope results within Pit 1, water derived from ash placement in Cut 1 seems a more feasible explanation considering the significant volume of evaporated water required to influence the water chemistry of the entire pit.

As noted previously, groundwater sampled at KB16 and KB30 did not show evidence of evaporation-induced enrichment of stable isotopes. This may be due to the influence of the natural hydraulic gradient at these sites, mixing of ash water with naturally recharged groundwater, or a combination of the two factors. While inconclusive at the other two sites, the more elevated sulphate concentration observed at MB30 (116.9 mg/L) suggests that the combined effects may be influencing water quality here.

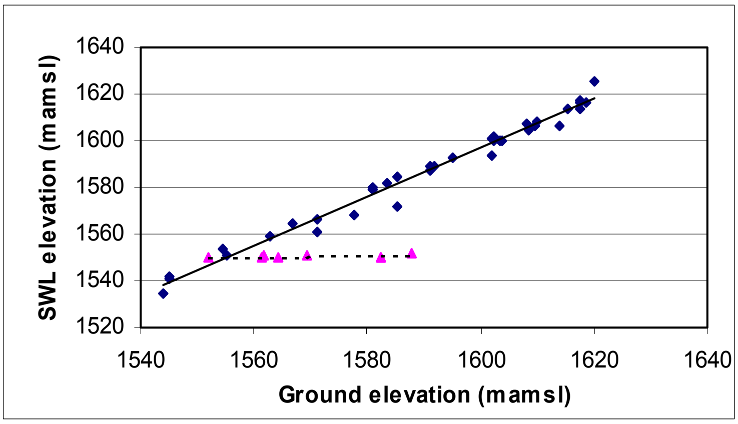


Figure 59 *Relationship between site topography and the elevation of the water table. The blue diamonds and pink triangles denote water level elevations for boreholes installed into in situ and pit spoil material, respectively. Note that the SWL only follows topography in those boreholes installed within in situ material, the SWL typically less than 5 m in the area surrounding the site.*

8.5 Recharge processes

The plot of stable isotope results was used as a tool to identify background groundwater chloride concentrations at the site, with only those sampling sites where $\delta^{18}O < -3.2‰$ considered. Further, sites where polluted water was suspected to have mixed with groundwater were not included in calculations. A frequency distribution plot was then constructed (refer **Figure 60**), the plot confirming that background abundances are very low, consistent with an aquifer containing no chloride salts within its matrix.

In the absence of long-term site data, the weighted average chloride concentration of Bloemfontein precipitation (0.6 mg/L; refer Section 3) was used for recharge calculations. Thus, assuming Cl_{gw} = 19.4 mg/l, estimated rainfall-derived recharge is $0.6/19.4 = 3\%MAP$. This compares well with earlier estimates of Kirchner et al. (1991), who suggest that recharge to Ecca Series sediments is typically 1 to 3% of annual rainfall. It should be appreciated, however, that recharge can be as high as 15% at isolated sites within the Mpumalanga coalfields (Hodgson and Krantz, 1998).

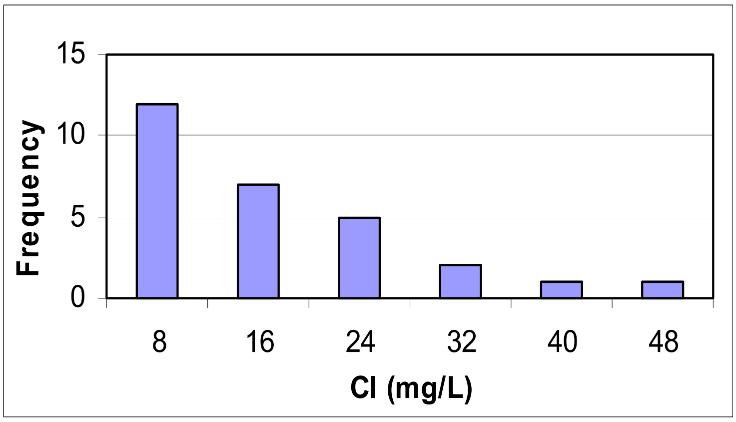


Figure 60 *Frequency distribution for naturally recharged groundwater sampled at Kriel and Matla Power Stations. Note that; a) the number of sites falling into each 8 mg/L segment is shown, and; b) data for 18D (111.4 mg/L) and B28 (100.7 mg/L) are not shown as long-term monitoring data indicates that polluted groundwater has entered these boreholes in the past.*

Unlike the CMB Method, the SI Method initially proved unreliable, a response to the proximity of the average isotopic concentration of sampled groundwater to the LMWL. Indeed, estimated recharge is 100% MAP (750 mm) assuming C = 20 and $\Delta\delta^2H = 10 - 10.2 = ^{-}0.2$ ‰ (refer **Figure 61**), which suggests that recharge water has not been evaporated within the unsaturated zone. Of interest, however, is that the GWL still plots at a lesser slope to the LMWL, thus implying that sufficient evaporation contrast between matrix and bypass flow is represented in site data, the MAE Method-calculated proportion of preferential pathway-derived flow being 28%. Considered with findings when applying the CMB Method, this implies that:

i. The site climate is unsuited for the reliable application of the SI Method;

ii. Enrichment of unsaturated zone chloride concentrations is predominantly a response to transpiration, as opposed to evaporation;

iii. While evaporation effects may not be initially observed in site groundwater data, they are nevertheless represented;

iv. Unlike the SI Method, the MAE Method can be applied in wetter areas of Southern Africa.

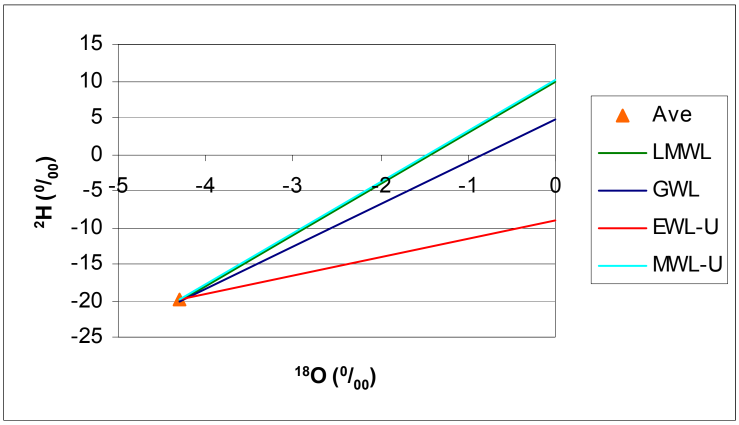


Figure 61 *Isotopic characteristics used to determine input parameters for the SI and MAE Methods for data collected in February and March 2001.*

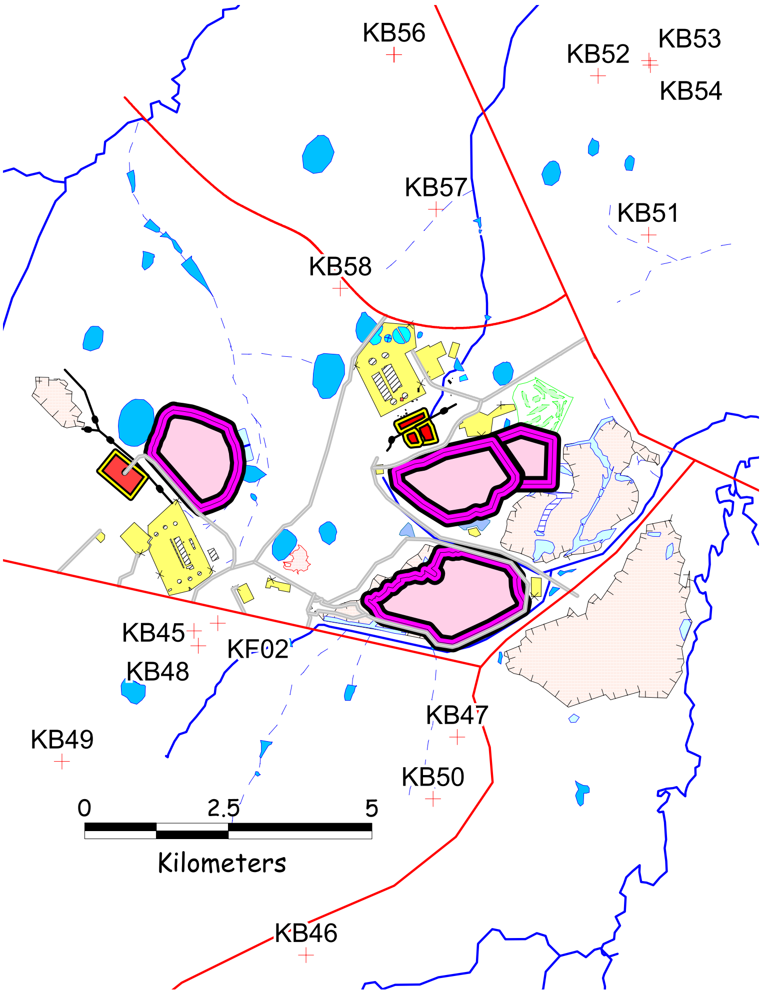


Figure 62 *Groundwater sampling locations, November 2002.*

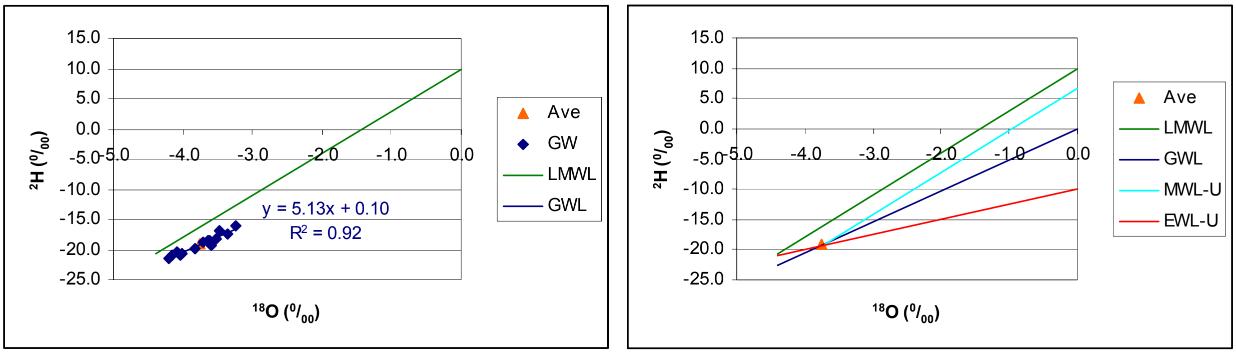


***Figure 63** Isotopic characteristics used to determine input parameters for the SI and MAE Methods for data collected in November 2002.*

However, a different picture emerges when follow-up data collected in November 2002 is considered (refer **Figure 62** and Appendix 9). In this instance, tested groundwater samples were taken from boreholes on surrounding properties during a hydro-census. When compared to the earlier dataset (refer **Figure 61** and **Figure 63**), it is clear that the average $\delta^{18}O$ composition has increased from -4.3 to -3.7‰, indicating exposure to evaporation within the unsaturated zone prior to recharge; MWL-U is now offset below LMWL as a consequence. Indeed, when the SI Method was applied, a reasonable estimate of 37 mm (5% MAP; CMB Method estimate for the same dataset 3.3% MAP) was obtained assuming C = 20 and $\Delta\delta^2 H = 10 - 6.7 = 3.3$ ‰. Further, the orientation of GWL has changed slightly, which suggests the bypass flow flux has increased from 28 to 40%. Of most significance, however, is the common point of intersection between LMWL and EWL-U ($\delta^{18}O$ = -4.3 and –4.4‰ for earlier and later datasets, respectively), which confirms that EWL-U in wetter and drier parts of South Africa has an orientation that approximates the equation $\delta^2 H = 2.5.\delta^{18} O + d$.

Recharge thresholds calculated using MAE and CRD Method data (refer **Figure 63**, **Figure 64**, and Appendix 10) are summarized in **Table 19**. Note that, when compared to data for drier Petrusburg (460 mm MAP), recharge via preferential pathways occurs less frequently, the return period for matrix-derived recharge also lower. Of more significance, however, is the relationship between the calculated recharge thresholds, and Witbank rainfall for the period preceding groundwater-sampling dates. Prior to initial sampling, site rainfall exceeded the matrix recharge threshold, and thus recharge would have entered site aquifers via both preferential pathways and the matrix (refer **Figure 64**). Indeed, given the time sampling was undertaken, there would have been limited opportunity for preferential pathway and matrix-derived water to mix in the aquifer. Further, given the low in situ storativity of aquifers in the area (estimated here to be between 1E-4 and 1E-7), it is reasonable to assume that:

- Groundwater sampled in the period end of February to beginning of March 2001 was comprised predominantly of matrix-derived water;
- There was virtually no storage within the unsaturated zone prior to recharge. There is strong evidence for this given that groundwater stable isotope data plots along the LMWL (i.e. there is no evidence of recharge water having been significantly evaporated within the unsaturated zone prior to entering site aquifers).

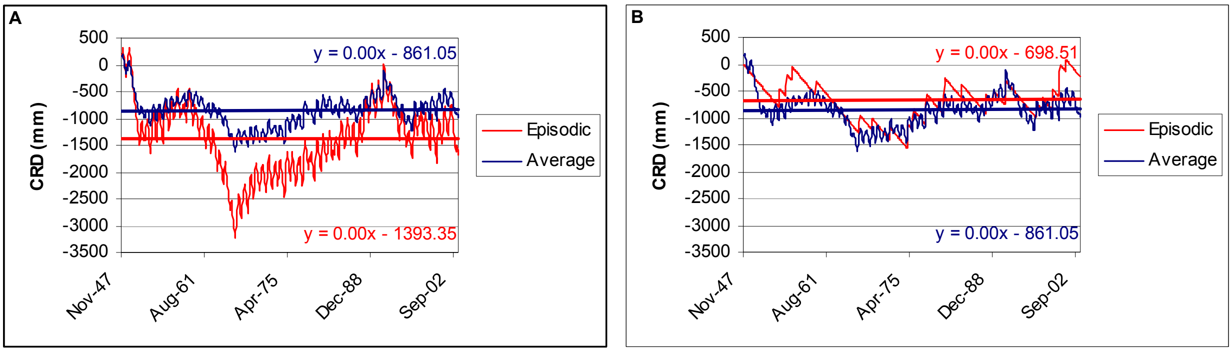


Figure 64 *Average and episodic CRD plots based on Witbank rainfall data. Note that; a) in terms of modelled response, there is excellent agreement between the average CRD and episodic recharge via preferential pathways plot (Graph A), which is to be expected in a wetter, more temperate area; b) the episodic plot accentuates the recovery in CRD once sufficient rainfall has been received; c) the matrix recharge threshold (Graph B) was most recently exceeded in January 2001, and; d) the recession factor for preferential pathway and matrix-derived recharge is 89.5 and 11.4 mm/month, respectively.*

In comparison, the November 2002 samples were taken at the end of the dry season, 22 months after the matrix recharge threshold was last exceeded (220.4 mm in January, 2001). By this time several months of preferential pathway-derived recharge would have occurred, the lower rainfall also encouraging evaporation of recharge water as it migrated through the unsaturated zone. This would not only have increased the proportion of preferential pathway-derived recharge entering site aquifers, but also resulted in groundwater stable isotope data being offset from the LMWL.

Table 19 Summary of calculated recharge thresholds for Kriel and Matla Power Stations. The number of times, expressed as a percentage, that monthly rainfall has exceeded the estimated recharge threshold is also shown (based on rainfall data for Witbank; total number of months in dataset = 639 months). Note that significant differences are apparent when the calculated recharge thresholds are compared to those estimated for Petrusburg, thus confirming that, while aquifers occur within Karoo basin aquifers at both sites, the recharge behaviour of each is unique. Further, it highlights the danger of ignoring climatic data, and assuming site recharge behaviour on the basis of site lithology alone.

Recharge Threshold	Kriel and Matla (mm)	Exceeded (%)	Petrusburg (mm)	Exceeded (%)
Low-pp	30	55.9	0	78.3
Ave-pp	60	43.0	15	56.4
High-pp	80	28.3	30	41.9
Low-uzm	80	32.9	65	19.0
Ave-uzm	135	13.3	200	0.5
High-uzm	190	3.6	335	0.2

8.6 Summary

Data for the combined power station properties and their surrounds indicates that the stable isotopic character of site groundwater varies depending on whether recharge occurs via preferential pathways or the matrix. Further, it suggests the EWL-U line slopes at $2.5.\delta^{18}O$, consistent with measurements made in drier area of Botswana by Beekman et al. (1997b). This later observation is significant as it implies that the slope of EWL-U is independent of site rainfall and may therefore be relatively constant across much of Southern Africa.

The MAE Method is sensitive enough to distinguish between the relative proportions of water entering an aquifer via preferential pathways and the matrix for different rainfall events. This is significant because the current alternative for obtaining this information is via detailed, time consuming, relatively expensive and potentially unrepresentative unsaturated zone investigations.

Given that the stable isotopic composition of groundwater was found to vary between sampling events, care must be taken when estimating recharge using the SI Method. It is now clear that, dependent on climatic conditions prior to sampling, SI Method estimates based on unsaturated zone data are unlikely to be representative of long-term average aquifer conditions. However, it appears that, providing sufficient time is allowed to pass between the entry of the recharge front into the aquifer and sampling, the SI Method does have application in wetter parts of Southern

Africa. Indeed, reasonable agreement between SI and CMB Method estimates was obtained when sampling was delayed until the end of the dry season.

9 Conclusions and recommendations

The most important findings made during this investigation relate to the application of stable isotope techniques during recharge investigations in Southern Africa. While applied by many researchers in the region, it is clear that stable isotope methods can contribute much more than previously thought to geohydrological investigations, particularly in terms of gaining a better understanding of recharge processes.

The MAE Method, a new stable isotope-based technique developed during this study, provides insight into episodic recharge processes by estimating the proportion of preferential pathway-to-matrix-derived flow entering an aquifer, and the amount of rainfall required to initiate recharge via the respective flow paths. Significantly, the proportion of bypass flow can be determined without undertaking expensive and time consuming unsaturated zone studies, both factors often of primary concern when undertaking recharge investigations in developing countries.

Four recharge thresholds can be identified using the MAE Method; the low and high recharge thresholds that must be exceeded before recharge occurs via preferential pathways or the matrix, respectively. These represent threshold limits, the low value only of importance following successive months of wet weather, the high value representing the rainfall that must be received to restore an aquifer system to equilibrium after prolonged dry spells. Once these thresholds are known, the recharge history of a site can be modelled using available rainfall data by adapting the CRD Method. An important finding of modelling undertaken during this investigation is that in those semi-arid to arid areas where most recharge water enters the aquifer via the matrix, the period of time that elapses between successive rainfall events that exceed the matrix recharge threshold often extends to scores of years. ***This has significant resource management implications for much of the region as it indicates that the current approach of basing allocations on average recharge estimates is only justified if sufficient groundwater is available for use over the entire period between recharge events. Indeed, in many instances it may be more realistic to base groundwater allocations on the proportion of bypass flow-derived recharge entering site aquifers initially, the allocations increasing once aquifer storage, recharge threshold, and recharge event return period characteristics are better understood.***

Modelling of recharge processes could be significantly refined if long-term SWL and stable isotope data was available for a given aquifer. Indeed, the most important recommendation in this report is to encourage the collection of monthly rainfall, SWL, stable isotope and chemistry (rain, surface, and groundwater) data at selected sites in Southern Africa. Sites should be selected on the basis of land use, climatic zone, and aquifer type, with a view to extrapolating findings made there to similar locations elsewhere, and data stored and managed using centralized databases. This can be best achieved with government funds, although given the recent changes in legislation requiring industry to ensure site monitoring is undertaken in some countries in the region, there is considerable scope for private money to contribute to data collection. The development of a standardized monitoring code of practice for industries operating in the region, which outlines minimum monitoring frequencies for input parameters necessary for recharge estimation, should therefore be a priority.

In terms of recharge estimation, the SI Method was found to return comparable results to the CMB Method in both wetter and drier inland areas of South Africa. However, both these and the MAE Methods were found to be sensitive to the recharge history of the site, the returned recharge estimate often un-representative of the long-term average when calculated immediately after recharge via the matrix had occurred. This is not to say that these estimates were wrong (indeed they were representative of site recharge processes at the time of sampling), but that rainfall in the months prior to sampling should be considered. In general though, sampling should be undertaken near the end of the dry season, which in the summer-dominant rainfall areas of Southern Africa is between September and November (allowing for a 30 to 60 day lag time between rainfall and subsequent recharge).

Given the observed sensitivity between SI and CMB Method estimates and site recharge history, there is a potential for those estimates based on unsaturated zone moisture concentrations to be a reflection of the last recharge event and not long-term recharge to the aquifer. As such, it is recommended that, in Southern Africa, estimates be based on chloride and stable isotope concentrations determined for saturated zone (i.e. groundwater) samples only.

While the CMB Method is an attractive recharge estimation option in Southern Africa, geomorphological and geological controls were found to significantly influence the techniques application, particularly at sites where recharge via preferential pathways occurs. Of concern, however, is that the method represents a long-term average condition, which dependent on the volume of groundwater stored in a given aquifer, could extend to thousands of years or more. Thus, the validity of applying the method could be questioned at some sites because of past land use and climatic changes, and indeed those that may be currently occurring as a result of global warming. To restore confidence in the method, steps should be taken to assess what influence these changes may have had on aquifer chloride concentrations using an inverse modelling approach. Further, the impact of future changes on the chemical and isotopic composition of recharge water should also be considered.

Given the limitations of the CMB method, it may seem paradoxical that its use be recommended within some fractured rock terrains. On a regional scale, fractured rock aquifers are commonly regarded as equivalent porous mediums for modelling purposes, a necessity given the significant variations in porosity, hydraulic conductivity, and storage that occur between adjacent areas. Thus, even where long-term water level data is available, the hydraulic conditions that contribute to the observed water table response at a given site following recharge represent an average for the area surrounding a given borehole. The CMB Method negates the need for measuring or estimating these hydraulic parameters, as it already represents a long-term average of recharge. This is not to say that water levels should not be taken, but rather that recharge calculated using water balance methods is checked using CMB Methods in those areas completely overlain by a porous unsaturated zone of significant thickness. Indeed, the comparison of results obtained using multiple estimation technique's is recommended during all recharge-based investigations, whether conducted in fractured rock or porous environments.

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Appendix 1: Concentration of selected anions in Hotazel rainfall.

Table A1-1: Concentration of selected anions in Hotazel rainfall.

Month	Cl (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)
February 2002	1.72	<0.01	0.30	0.66	3
March 2002	3.55	0.02	0.42	0.53	5.7
April 2002	12.22	0.04	1.18	-	15.12
May 2002	16.26	0.10	1.01	-	20.25
June 2002	2.21	0.02	0.62	-	6.07
July 2002	No sample taken				
August 2002	1.98	0.02	0.61	-	4.1
September 2002	19.78	0.06	0.84	12.77	31.26
October 2002	12.76	0.09	1.63	4.1	23.08
November 2002	11.63	0.03	0.49	4.69	18.3
December 2002	1.97	<0.01	0.31	1.42	3.56
January 2002	29.23	0.19	0.6	6.81	31.06

Appendix 2: Stable isotopic composition of surface water samples

Table A2-1: Stable isotopic composition of surface water samples taken from inland areas of South Africa.

Matimba Power Station via Ellisras, Limpopo Province		Kalahari Manganese Field via Hotazel, Northern Cape Province		Kriel and Matla Power Stations via Bethal, Mpumalanga Province		Hendrina Power Station via Bethal, Mpumalanga Province		Tutuka Power Station via Bethal, Mpumalanga Province	
$\delta^{18}O$ (‰)	$\delta^{2}H$ (‰)	$\delta^{18}O$ (‰)	$\delta^{2}H$ (‰)	$\delta^{18}O$ (‰)	$\delta^{2}H$ (‰)	$\delta^{18}O$ (‰)	$\delta^{2}H$ (‰)	$\delta^{18}O$ (‰)	$\delta^{2}H$ (‰)
0.04	-0.2	1.6	3.9	-1.31	-4.3	-2.3	-8	1.2	12
0.27	2.5	2.2	5.1	-1.03	1.7	-2.1	-9	1.4	14
0.52	0.8	-1.8	-13.7	0.86	10.4	-2.0	-11	2.8	18
0.71	4.1	-1.2	-10.7	1.37	10.9	-1.7	-6	2.8	17
2.49	14.0	2.0	12	2.51	16.8			3.0	16
2.87	12.9	8.9	36	3.49	20.7			6.2	49
5.10	22.0	1.2	8	3.74	22.5				
		9.2	36	3.95	19.8				
		1.5	9	3.99	25.3				
		1.7	8	4.20	29.0				
		1.4	2	4.40	23.8				
		0.2	-4.1	4.49	30.8				
				4.53	24.9				
				4.66	25.6				
				4.75	26.3				

Appendix 3: Chemical and physical characteristics of representative lithologies, Kalahari Manganese Field

Table A3-1: Results of XRF testing on Ongeluk Lava Formation and debrite samples taken at the Smartt-Rissik prospect and Mamatwan Mine, respectively ("**" denotes debrite sample).

Parameter	JB8 94-100m	JB21** 77-81m
SiO_2	50.43	51.83
TiO_2	1.37	1.33
Al_2O_3	14.9	11.73
Fe_2O_3	13.23	14.92
MnO	0.2	0.66
MgO	5.61	5.87
CaO	6.4	3.95
Na_2O	3.11	3.88
K_2O	1.31	0.14
P_2O_5	0.21	0.19
H_2O	0.33	0.85
LOI	2.68	3.65
Total	***99.78***	***99***

Table A3-2: XRF test results for selected Hotazel Formation samples (depth shown where necessary). Samples from Middelplaas and Wessels Mines were taken from existing stockpiles, while the Mamatwan sample was taken from the blast face. The tested samples were placed in airtight bags, and transported to the Geology Department of the University of the Free State for testing.

Parameter	JB8 25-28m	JB8 40-45m	JB8 47-50m	Middel-plaas	Mamatwan	Wessels
SiO_2	11.52	24.29	31.79	12.43	10.87	12.01
TiO_2	0.04	0.04	0.02	0.04	0.04	0.06
Al_2O_3	0.47	0.35	0.28	0.12	0.04	0.26
Fe_2O_3	9.84	44.87	55.05	6.58	6.84	21
MnO	51.33	11.89	4.03	44.53	44.31	55.22
MgO	1.02	4.55	2.24	2.38	3.28	0.08
CaO	11.83	3.81	4.08	15.93	16.36	5.77
Na_2O	0.21	0.08	0.33	0	0	0
K_2O	0.46	0.03	0.13	0.2	0.22	0.65
P_2O5	0.09	0.1	0.1	0.06	0.06	0.12
H_2O	1.47	1.02	0.05	0.11	0.06	0.05
LOI	12.07	8.41	1.64	16.99	17.8	4.52
Total	***100.35***	***99.44***	***99.74***	***99.37***	***99.88***	***99.74***

Table A3-3: Results of ABA undertaken on Hotazel Formation samples. Drill cuttings from JB8 were sampled along with stockpiled ore, these subsequently tested by the Institute for Groundwater Studies at the University of the Free State. Water-soluble constituents are shown in plain text, while concentrations released following complete oxidation have been italicised and underlined (only common or measurable parameters are shown here). Note that the abbreviations "Mid", "Mam", and "Wes" have been used for Middelplaas, Mamatwan, and Wessels Mines, respectively.

Depth m	**pH**	**Al kg/t**	**Ca kg/t**	**Fe kg/t**	**K kg/t**	**Mg kg/t**	**Mn kg/t**	**Na kg/t**	**Zn kg/t**	**SO_4 kg/t**
25-28*	9.06	0	0.149	0	0.014	0.095	0.001	0.147	0	0.021
*25-28**	*8.23*	*0.003*	*1.792*	*0.002*	*0.443*	*0.595*	*1.134*	*0.714*	*0.001*	*0.189*
40-45*	9.68	0	0.116	0.001	0.005	0.149	0.001	0.065	0	0.087
*40-45**	*7.26*	*0*	*0.554*	*0.005*	*0.073*	*0.9*	*0.625*	*0.177*	*0*	*0.054*
Mid	9.6	0.00079	0.1343	0.00037	0.0105	0.11639	0.00439	0.01826	0.00011	0.18887
Mid	*6.56*	*0*	*0.6642*	*0.00079*	*0.00863*	*0.33184*	*1.19189*	*0.56964*	*0.00069*	*0.57050*
Mam	9.72	0.0006	0.12261	0.00016	0.00228	0.09484	0.00659	0.0171	0.00025	0.21246
Mam	*6.1*	*0.00052*	*1.55065*	*0.00048*	*0.5581*	*0.19192*	*0.92853*	*0.60281*	*0.00037*	*0.53594*
Wes	10.27	0.00093	0.12531	0.00025	0.01458	0.01427	0.00295	0.07329	0.00011	0.47857
Wes	*5.98*	*0.00156*	*0.91237*	*0.00167*	*0.00467*	*0.14303*	*1.63687*	*0.6366*	*0.00117*	*0.97301*

Table A3-4: Acid Base Potential (ABP) calculations for the tested Hotazel formation samples. Note that the abbreviations "Mid", "Mam", and "Wes" have been used for Middelplaas, Mamatwan, and Wessels Mines, respectively.

Depth m	**Initial pH**	**Final pH**	**Acid (Open)**	**Acid (Closed)**	**Base**	**NNP (Open)**	**NNP (Closed)**
JB8:25-28	9.06	8.23	0.1966	0.3931	182.22	182.02	181.83
JB8:40-45	9.68	7.26	0.0560	0.1121	150.31	150.25	150.20
Mid	9.6	6.56	0.59	1.19	462.04	461.45	460.9
Mam	9.72	6.10	0.56	1.12	466.71	466.15	465.6
Wes	10.27	5.98	1.01	2.03	36.65	35.64	34.6

Table A3-5: ABA results for slimes dam and waste rock (discards) samples that were taken at the respective mine sites. Water-soluble constituents are shown in plain text, while concentrations released following complete oxidation have been italicised and underlined (only common or measurable parameters are shown here). Note that the following abbreviations have been used: HSD – Hotazel Mine slimes dam; HD – Hotazel Mine discards; MidD – Middelplaas Mine discards; MSD – Mamatwan Mine slimes dam; MD – Mamatwan Mine discards; WSD – Wessels Mine slimes dam; WD - Wessels Mine discards.

Site	pH	Al kg/t	Ca kg/t	Fe kg/t	K kg/t	Mg kg/t	Mn kg/t	Na kg/t	Zn kg/t	SO_4 kg/t
HSD	9.15	0.0003	0.16239	0.00053	0.01545	0.09321	0.00774	0.05314	0.00017	0.02405
HSD	6.89	0.00066	0.30994	0.00056	0.06537	0.23834	1.38404	0.63639	0.00071	2.60695
HD#1	9.45	0.00028	0.15084	0.0012	0.01218	0.10136	0.02371	0.05521	0.00061	0.19828
HD#1	6.69	0.00068	0.52530	0.00133	0.02459	0.30464	1.41571	0.58104	0.0007	0.44457
HD#2	9.25	0.00024	0.12646	0.00035	0.00672	0.02833	0.00121	0.02883	0.00018	0.33514
HD#2	7.12	0.00049	0.19898	0.00161	0.12065	0.16215	1.34995	0.65799	0.00071	1.26742
MidD	9.39	0.00023	0.15438	0.0004	0.2221	0.10806	0.0102	0.02784	0.00032	0.31176
MidD	6.61	0.00039	0.62612	0.00024	0.02128	0.35158	1.15989	0.59620	0.00033	0.00824
MSD	9.76	0.00067	0.82462	0.00057	0.02046	0.23561	0.00908	0.11067	0.00023	1.49808
MSD	6.63	0	0.29229	0	0.05710	0.25224	1.63854	0.63449	0.00077	2.06917
MamD#1	9.40	0.0005	0.14148	0.00026	0.00878	0.10863	0.00551	0.02949	0.00035	0.02740
MamD#1	6.70	0.00025	0.44661	0.00027	0.02046	0.19821	1.5016	0.63162	0.00068	1.47507
MamD#2	9.09	0.00022	0.14469	0.00023	0.0044	0.10273	0.00526	0.08411	0.0002	0.10876
MamD#2	8.24	0.00097	0.33992	0.00109	0.14678	0.32993	0.38824	0.80560	0.00080	1.39705
WSD	10.06	0.00069	0.22372	0.00027	0.01392	0.11025	0.00319	0.10773	0.00011	0.69562
WSD	6.99	0.00007	0.67707	0.00059	0.00182	1.14933	0.31811	0.60866	0.00045	1.44178
WD#1	9.8	0.0005	0.11841	0.00028	0.1840	0.0478	0.0032	0.0547	0.00035	0.25549
WD#1	6.04	0.00256	0.80185	0.00238	0.01048	0.29051	1.447	0.60838	0.00045	1.44178

Table A3-6: Acid Base Potential (ABP) calculations for the tested slimes dam and waste rock (discards) samples. Note that the following abbreviations have been used: HSD – Hotazel Mine slimes dam; HD – Hotazel Mine discards; MidD – Middelplaas Mine discards; MSD – Mamatwan Mine slimes dam; MD – Mamatwan Mine discards; WSD – Wessels Mine slimes dam; WD - Wessels Mine discards.

Site	Initial pH	Final pH	Acid (Open)	Acid (Closed)	Base	NNP (Open)	NNP (Closed)
HSD	9.15	6.89	2.72	5.43	383.98	381.27	378.6
HD#1	9.45	6.69	0.46	0.93	294.25	293.79	293.3
HD#2	9.25	7.12	1.32	2.64	67.38	66.06	64.7
MidD	9.39	6.61	0.01	0.02	458.82	458.82	458.8
MSD	9.76	6.63	2.16	4.31	48.71	46.56	44.4
MD#1	9.40	6.70	1.54	3.07	447.38	445.85	444.3
MD#2	9.09	8.24	1.46	2.91	319.76	318.3	316.8
WSD	10.06	6.99	1.50	3.00	90.76	89.26	87.8
WD#1	9.80	6.04	0.00	0.01	70.94	70.94	70.9

Table A3-7: XRF test results for Kalahari Formation samples (sampling location and depth shown). The tested samples were taken during monitoring bore installation, placed in airtight bags, and transported to the Geology Department of the University of the Free State for testing.

Parameter	JB8: 0-1m	JB8: 5-8m	JB10: 14-18m	JB32: 66-67m
SiO_2	94.21	91.27	31.09	44.81
TiO_2	0.35	0.36	0.18	0.45
Al_2O_3	2.08	3.43	3.04	5.74
Fe_2O_3	1.36	1.85	1.62	3.86
MnO	0.05	0.04	0.05	0.22
MgO	0	0	10.7	11.1
CaO	0.06	0.18	25.2	12.43
Na_2O	0.12	0.14	0.07	0.29
K_2O	0.36	0.42	0.36	0.37
P_2O5	0.02	0.02	0.02	0.04
H_2O	0.32	0.67	2.88	1.36
LOI	0.72	1.29	24.64	19.12
Total	***99.65***	***99.67***	***99.85***	***99.79***

Table A3-8: Some physical characteristics for Kalahari Formation sediments. Sampled material was placed in an airtight bag, and transported to Simlab, a Bloemfontein based material testing laboratory, for testing.

Attribute/Site	JB32: 2 – 3m	JB32: 66 –67m	Wessels waste site	JB39: 0m
Initial moisture content (%)	1.2	21.2	1.6	0.4
Passing 4.75 mm sieve (%)	99	99	-	-
Passing 2 mm sieve (%)	98	96	100	100
Passing 0.425 mm sieve (%)	93	93	91	91
Passing 0.075 mm sieve (%)	7	87	8	11
Passing 0.002 mm sieve (%)	2	30	4	5
Liquid Limit (%)	-	105	-	-
Plasticity Index	Non-plastic	77	Non-plastic	Non-plastic
Linear Shrinkage (%)	0	20.0	0	0

Appendix 4: Monitoring bore locations and lithological characteristics, Kalahari Manganese Field

Table A4-1: Location of installed Smartt-Rissik prospect monitoring bores, from south to north. Depth to water table values equate to the thickness of the unsaturated zone at respective monitoring bore sites. 11 bores were initially installed across the Smartt-Rissik prospect between February and April 2002, these listed as they occur along a north-south section (in italics and underlined). An additional four boreholes (JB3, JB4, JB5, and JB6) were constructed in August-September 2003 to allow water levels and qualities between the Smartt-Rissik, Mamatwan, and Middelplaas prospects to be better compared. Note that "T.O.C." denotes Top of Casing.

Site	X m	Y m	Z TOC mamsl	Depth to water table m	TOC (above GL) m	SWL (Elev) mamsl
JB2	*2604.55*	*3026084.58*	*1087.57*	*30.85*	*0.69*	*1057.41*
JB7	*2647.03*	*3025101.38*	*1086.65*	*28.86*	*0.65*	*1058.44*
JB9	*3112.72*	*3024388.27*	*1082.15*	*28.47*	*0.61*	*1054.29*
JB10	*2226.96*	*3023757.43*	*1085.31*	*28.36*	*0.54*	*1057.49*
JB8	*2722.74*	*3023264*	*1079.58*	*25.62*	*0.69*	*1054.65*
JB11	*2930.57*	*3022709.9*	*1079.42*	*25.94*	*0.59*	*1054.07*
JB12	*3274.14*	*3022170.42*	*1075.63*	*29.73*	*0.45*	*1046.35*
JB13	*3748.62*	*3021564.61*	*1071.75*	*25.98*	*0.48*	*1046.25*
JB14	*4051.7*	*3020852.99*	*1065.99*	*23.32*	*0.61*	*1043.28*
JB15	*3479.35*	*3020208.78*	*1062.87*	*20.12*	*0.49*	*1043.24*
Perth mine	*4000*	*3020036.26*	-	-	-	*1037.9*
JB1	*4344.95*	*3019863.75*	*1055.37*	*27.24*	*0.75*	*1028.88*
JB3	3061.31	3026520.81	1086.92	32.04	0.68	1055.56
JB4	3149.41	3027787.48	1089.26	34.58	0.85	1055.53
JB5	2222.62	3027302.41	1091.45	33.91	0.42	1057.96
JB6	2600.41	3026084.10	1087.62	30.32	0.37	1057.67

Table A4-2: Blow yields, aquifer description, and aquifer permeability at monitoring bore sites on the Smartt-Rissik prospect.

Site	Depth of water strike *m*	Formation description	K *m/d*	Blow yield *L/s*
JB1	36 67	Bedding interface between different BIF units. Bedding interface between different BIF units.	0.08	Seepage Seepage
JB2	46 57 65	Pebble bed within the Kalahari Formation Pebble bed within the Kalahari Formation Adjacent to unconformity at base of Kalahari Formation	0.45*	0.1 0.6 5.6
JB3	45	Clay horizon within the Kalahari Formation	0.38	0.13
JB4	58	Bedding interface within Hotazel Formation	0.12	Seepage
JB5	35	Pebble bed within Kalahari Formation	3.37	0.3
JB6	32	Pebble bed within Kalahari Formation	0.25*	Seepage
JB7	39 49	Adjacent to unconformity at base of Kalahari Formation Fractured Mn ore	0.60	Seepage 0.7
JB8	28 37 39	Bedding interface between different BIF units Fracture within BIF unit (confirmed with drill cuttings) and possible bedding interface between different BIF units Fracture within BIF unit (confirmed with drill cuttings)	14.7	Seepage 12.5 to 19
JB9	53	Bedding interface between different BIF units (Dyke material intercepted at top of upper BIF beds).	1.88	3.4
JB10	37	Weathered Ongeluk Formation	0.12	Seepage
JB11	27	Fracture within BIF unit (confirmed with drill cuttings) and possible bedding interface between different BIF units	0.84	0.1
JB12	33 38 62	Weathered sill Weathered sill Weathered Ongeluk Formation	0.03	Seepage Seepage Seepage
JB13	32 37	Calcrete and pebble bed within Kalahari Formation Calcrete and pebble bed within Kalahari Formation	1.20	0.6 Seepage
JB14	33 44	Pebble bed within Kalahari Formation Adjacent to unconformity at base of Kalahari Formation	0.02	Seepage Seepage
JB15	37 43 44 53 60	Weathered dyke Weathered dyke Weathered dyke Weathered dyke Weathered dyke	0.04	Seepage Seepage Seepage Seepage Seepage

Table A4-3: Location of monitoring bores installed at Mamatwan Mine, and a pre-existing domestic water supply borehole (JB19). Note that; a) depth to water table values equate to the thickness of the unsaturated zone at respective monitoring bore sites, and; b) "T.O.C." denotes Top of Casing.

Site	X m	Y m	Z TOC mamsl	Depth to water table m	TOC (above GL) m	SWL (Elev) mamsl
JB17	446.93	3030927.29	1105.35	12.13	0.58	1057.41
JB18	780.86	3031510.34	1103.71	11.83	0.23	1058.44
JB19	855.97	3030381.98	1101.42	17.32	0.0	1054.29
JB20	1023.59	3030442.51	1101.61	17.69	0.46	1057.49
JB21	1787.94	3030055.57	1097.77	27.38	0.78	1054.65
JB22	1306.71	3029539.66	1083.78	38.66	0.39	1054.07
JB23	1324.18	3030872.87	1100.12	14.63	0.38	1046.35
JB24	1064.48	3031367.51	1102.72	13.47	0.39	1046.25

Table A4-4: Blow yields, aquifer description, and aquifer permeability at Mamatwan Mine monitoring bore sites. Note that; a) No data has been included for JB19 as this was a pre-existing water supply bore for which no construction information was available, and; b) K was determined using slug tests at all sites except JB22, at which site the tested profiles were too permeable to allow a result to be obtained.

Site	Depth of water strike *m*	Formation description	K *m/d*	Blow yield *L/s*
JB17	22	Pebble bed in calcrete matrix – Kalahari Formation	0.46	0.19
JB18	21	Pebble bed in Kalahari Formation	0.33	0.25
JB20	21 61 70	Pebble bed in calcrete matrix – Kalahari Formation Pebble bed in Kalahari Formation Fractured debrite – Hotazel Formation	0.086	0.03 0.03 0.5
JB21	32 49	Sand and gravel beds with Kalahari Formation Interbed parting within Hotazel Formation sediments	0.09	0.03
JB22	?	Fill – mine spoils	>20	?
JB23	21	Sand beds within Kalahari Formation	0.31	0.01
JB24	20	Sand beds within Kalahari Formation	1.12	0.6

Table A4-5: Location of monitoring bores installed at Middelplaas Mine. Depth to water table values equate to the thickness of the unsaturated zone at respective monitoring bore sites, "T.O.C." denoting Top of Casing.

Site	X m	Y m	Z TOC mamsl	Depth to water table m	TOC (above GL) m	SWL (Elev) mamsl
JB16	5903.67	3026898.84	1078.77	29.11	0.65	1049.66
JB25	6280.70	3027458.67	1078.76		0.48	1058.44
JB26	6021.69	3027338.68	1078.75	27.08	0.55	1051.67
JB27	6313.76	3026474.76	1076.23	29.85	0.87	1046.38

Table A4-6: Blow yields, aquifer description, and aquifer permeability at Middelplaas Mine monitoring bore sites. Water strike depths listed for JB25 below 50m were approximated due to the collapsing ground conditions encountered during drilling. Down hole logging was subsequently undertaken at the site to more accurately determine where groundwater was entering the borehole. Slug testing was also performed to determine the hydraulic conductivity of site aquifers where shown.

Site	Depth of water strike *m*	Formation description	K *m/d*	Blow yield *L/s*
JB16	36	Gravel bearing Kalahari Formation calcretes	0.16	0.3
JB25	41 125 236	Gravel beds within Kalahari Formation Gravel beds within Kalahari Formation Weathered Mooidraai Formation dolomites	-	0.5 0.75? 0.5?
JB26	37	Gravel beds within Kalahari Formation	0.57	0.63
JB27	36	Gravel beds within Kalahari Formation	0.30	0.16

Table A4-7: Summary of down hole logging findings at JB25. The contractor, Mr B. Venter (DWAF), was of the opinion that the Electrical Conductivity (EC) and temperature probes were faulty at the time of logging, and thus conclusions drawn from data generated using these two probes should be treated with caution.

Probe	Suggested water strike depth *(m)*	Formation description
Electrical Conductivity (uS/cm)	45 65 115 135 180 225	Gravel beds within Kalahari Formation Red clay within Kalahari Formation Sand beds with Kalahari Formation Gravel bed within Kalahari Formation Dwyka Formation containing sand Contact between silty sand material and siltstone/sandstone/mudstone interbeds in Dwyka Formation
Temperature (^{0}C)	65 92 182	Red clay within Kalahari Formation Red clay within Kalahari Formation Dwyka Formation containing sand
Self-Potential (SP)	-	Inconclusive
Gamma (cps)	-	Inconclusive results. Did, however, confirm that the clay content of material between approximately 135 and 180m varied significantly.
Full Wave Sonic	158 to 165 175 to 183 211 to 212 235 to 236	Dwyka Formation containing sand and gravel Dwyka Formation containing clay and sand Dwyka Formation containing sand Contact between weathered and more massive dolomite
Neutron (cps)	-	Generally. Results did, however, define the contact between the weathered and more massive dolomite at base of hole, and when considered in conjunction with gamma data, appeared to suggest that alternating interbeds of clay and gravel occur between 145 and 188m.

Table A4-8: Location of monitoring bores installed at Wessels Mine. Depth to water table values equate to the thickness of the unsaturated zone at respective monitoring bore sites, while "T.O.C." denotes Top of Casing.

Site	X TOC m	Y TOC m	Z TOC mamsl	Depth to water table m	TOC (above GL) m	SWL (Elev) mamsl
JB28	14001.81	2999402.37	1037.74	27.15	0.7	1010.59
JB29	13759.62	2999598.68	1036.67	26.32	0.49	1010.35
JB30	13730.63	2999865.94	1038.99	27.22	0.46	1011.77
JB31	13663.49	3000248.61	1040.06	29.67	0.36	1010.39
JB32	13927.13	3000304.88	1039.52	35.07	0.44	1004.45
JB33	13919.76	3101143.08	1041.38	39.04	0.66	1002.34
JB34	14387.61	3000496.98	1041.80	37.61	0.54	1004.19
JB35	14494.23	3000343.58	1040.46	37.47	0.41	1002.99
JB36	14346.04	2999772.14	1039.62	28.01	0.54	1011.61
JB37	15041.54	3000306.28	1042.61	48.57	0.46	994.04

Table A4-9: Blow yields, aquifer description, and aquifer permeability at Wessels Mine monitoring bore sites. Note that K was determined from slug tests at all sites.

Site	Depth of water strike *m*	Formation description	K *m/d*	Blow yield *L/s*
JB28	32 57	Gravel bed with Kalahari Formation Calcrete hosted pebble bed within Kalahari Formation	0.27	0.06 5.6
JB29	36	Calcrete hosted pebble bed within Kalahari Formation	1.78	1.25
JB30	42	Calcrete hosted pebble bed within Kalahari Formation	0.41	1.25
JB31	42	Calcrete hosted pebble bed within Kalahari Formation	2.73	1.25
JB32	61	Calcrete hosted pebble bed within Kalahari Formation	0.13	0.03
JB33	49	Calcrete hosted pebble bed within Kalahari Formation	0.57	0.03
JB34	50	Calcrete hosted pebble bed within Kalahari Formation	1.31	0.9
JB35	49	Calcrete hosted pebble bed within Kalahari Formation	0.50	1.7
JB36	37	Calcrete hosted pebble bed within Kalahari Formation	0.56	0.06
JB37	55	Calcrete hosted pebble bed within Kalahari Formation	0.41	0.06

Table A4-10: Location of monitoring bores installed at the now-derelict Hotazel Mine. Depth to water table values equate to the thickness of the unsaturated zone at respective monitoring bore sites. Note that; a) "T.O.C." denotes Top of Casing above ground level, and; b) JB44 is an existing production bore used to supply water to the adjacent mine hostel playing fields for irrigation purposes, which has now also been incorporated into the mine monitoring system.

Site	X m	Y m	Z mamsl	Depth to water table m	TOC m	SWL (Elev) mamsl
JB38	3099.17	3009487.24	1064.14	21.31	0.47	1042.83
JB39	2076.17	300909.61	1067.77	27.16	0.38	1040.61
JB40	1215.65	3008920.19	1065.75	23.17	0.29	1042.58
JB41	1190.70	3009884.16	1068.36	23.48	0.54	1044.88
JB42	3152.09	3010202.32	1064.68	26.71	0.32	1037.97
JB43	3876.48	3010515.19	1063.14	21.27	0.66	1041.87
JB44	3305.37	3010980.29	1065.80	-	-	-

Table A4-11: Blow yields, aquifer description, and aquifer permeability at Hotazel Mine monitoring bore sites installed as part of this investigation. Note that K was determined from slug tests at all sites except JB42, where a 72-hour constant discharge pump test was undertaken.

Site	Depth of water strike *m*	Formation description	K *m/d*	Blow yield *L/s*
JB38	37 60	Fractured Ongeluk Lava Formation Fractured Ongeluk Lava Formation	0.28	0.06 0.9
JB39	44	Fractured Ongeluk Lava Formation	0.19	0.25
JB40	28	Weathered Ongeluk Lava Formation	28	0.13
JB41	44	Dyke	0.31	Seepage
JB42	37 59	Weathered, fractured Ongeluk Lava Formation Fault zone within Ongeluk Lava Formation	1	0.25 18
JB43	26 41	Kalahari Formation calcrete Fault Zone within Ongeluk Lava Formation	1.66	0.06 1.7

Appendix 5: Chemical and isotopic composition of water samples, Kalahari Manganese Field

Table A5-1a: Summary of chemical testing undertaken on groundwater samples.

Site	pH	EC	Ca	Mg	Na	K	MAlk	F	Cl	SO4	Fe	Mn	NO2(N)	NO3(N)	NH4(N)	B	TDS
		mS/m	mg/L	mg/L	mg/L	mg/L	as mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
JB-3	7.80	325	275	149	75	5.8	220	0.24	557	20	0.042	0.021	<0.012	156.0	0.09	0.223	2166
JB-4	8.08	107	96	64	45	4.6	339	0.21	59	21	0.028	0.019	<0.012	54.9	0.23	0.187	839
JB-5	7.68	387	345	178	69	6.7	227	0.13	602	41	0.034	0.086	<0.012	221.0	0.75	0.219	2550
JB-16	8.00	220	164	113	101	7.4	383	0.53	201	53	0.014	0.072	<0.012	112.0	0.50	0.311	1396
JB-17	8.16	166	130	71	113	7.4	293	0.39	165	244	0.022	0.023	<0.012	40.1	0.15	2.275	1209
JB-18	7.87	665	460	260	353	24.6	247	0.25	595	369	0.012	0.047	<0.012	430.0	0.99	0.933	4764
JB-19	8.13	84	24	28	25	13.4	216	0.08	95	1	0.053	0.969	<0.012	0.2	27.74	0.242	624
JB-20	8.17	176	151	89	73	6.0	281	0.24	193	87	0.080	0.068	<0.012	81.5	0.25	0.353	1189
JB-21	8.10	221	177	119	80	5.5	301	0.51	248	49	0.035	0.057	<0.012	128.0	0.05	0.309	1670
JB-22	8.27	214	105	145	127	5.2	178	0.72	370	49	0.018	0.334	<0.012	134.0	0.12	0.800	1511
JB-23	8.11	284	178	107	218	7.3	281	0.54	308	162	0.035	0.014	<0.012	163.0	0.05	0.671	2010
JB-24	8.17	193	142	77	130	9.9	206	0.53	254	185	0.029	0.011	<0.012	64.0	0.06	2.363	1341
JB-26	8.13	235	155	113	126	8.7	355	0.59	314	72	0.019	0.038	<0.012	86.5	0.04	0.566	1548
JB-27	8.15	198	133	92	97	6.9	375	0.34	189	56	0.034	0.012	<0.012	61.0	0.06	0.471	1260
JB-28	8.12	295	130	74	334	16.2	192	0.40	480	310	0.021	0.013	<0.012	75.0	0.05	2.535	1851
JB-29	8.04	308	127	67	339	17.8	209	0.56	440	301	0.127	0.015	<0.012	75.0	0.04	2.892	1891
JB-30	8.06	386	186	78	408	16.7	120	0.57	547	482	0.022	0.006	<0.012	122.0	0.06	3.172	2485
JB-31	8.26	290	195	132	151	19.5	219	0.55	492	225	0.009	0.026	<0.012	97.2	0.15	0.918	1870
JB-32	7.98	351	173	104	292	20.9	160	0.31	479	353	0.011	0.025	0.730	78.0	0.23	2.545	2266
JB-33	8.11	223	155	115	83	18.4	303	0.45	338	55	0.023	0.015	<0.012	77.0	0.04	0.581	1489
JB-34	8.06	241	173	96	151	12.9	390	0.35	286	288	0.048	0.025	<0.012	33.5	0.12	0.621	1473
JB-35	8.29	390	245	140	211	16.1	271	0.21	659	72	0.011	0.018	<0.012	97.0	0.04	0.399	2162
JB-36	8.09	345	265	141	147	19.8	196	0.43	550	260	0.049	0.030	<0.012	135.0	0.15	0.479	2399
JB-37	8.09	196	166	98	64	13.2	324	0.31	211	35	0.014	0.048	<0.012	88.0	0.05	0.305	1348
JB-38	8.35	87.1	91	27	52	3.7	147	0.07	76	82	0.064	0.070	<0.012	43.4	0.43	0.956	634
JB-39	7.83	758	662	300	168	7.0	174	0.06	1142	72	0.038	0.743	<0.012	448.0	2.66	0.521	5260
JB-40	8.38	394	217	145	311	8.0	277	0.20	661	157	0.013	0.197	<0.012	169.0	0.29	1.161	2429
JB-41	8.33	176	91	82	156	6.4	382	0.27	184	58	0.088	0.088	<0.012	55.6	0.24	0.670	959
JB-42	6.99	349	358	104	110	6.4	79	<0.01	476	79.5	0.259	0.307	<0.012	219.3	6.03	4.050	2470
JB-43	7.88	573	551	178	223	9.1	196	0.01	534	237	0.028	1.688	<0.012	394.0	1.41	0.364	3812
M24	8.00	153	62	54	194	4.6	255	1.37	237	138	0.041	0.001	<0.012	3.4	0.48	1.905	948
19	8.91	83.6	5	3	170	16.1	320	0.52	38	28	0.073	0.003	<0.012	10.0	0.06	0.363	612
23	8.53	81.6	65	31	51	7.6	253	0.18	83	26	0.059	0.007	<0.012	12.5	0.07	0.208	508
32	8.21	292	150	103	135	15.3	252	0.26	612	57	0.037	0.004	<0.012	5.3	0.16	0.521	1687
46	8.51	177	134	99	87	5.0	278	0.43	263	66	0.048	0.006	<0.012	40.5	0.25	0.538	1180

Table A5-1b Summary of chemical testing undertaken on groundwater samples.

Site	pH	EC	Ca	Mg	Na	K	MAlk	F	Cl	SO4	Fe	Mn	NO2(N)	NO3(N)	NH4(N)	B	TDS
		mS/m	mg/L	mg/L	mg/L	mg/L	as mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
53	7.91	823	594	405	432	6.6	250	0.80	2153	456	0.018	0.002	<0.012	108.3	0.14	1.473	5448
55	8.44	117	87	80	45	2.5	327	0.50	79	83	0.041	0.005	<0.012	22.3	0.35	0.342	629
57	8.34	57	58	40	18	6.8	290	0.18	17.5	19	0.030	0.006	<0.012	2.3	0.12	0.173	355
1A	8.64	79.6	74	35	55	8.5	270	0.14	61	35	0.022	0.004	<0.012	12.2	0.06	0.246	556
3A	8.57	126	75	92	52	5.9	387	0.13	126	62	0.019	0.004	<0.012	3.6	0.09	0.150	803
4A	8.64	123	73	65	49	3.2	301	0.15	129	83	0.031	0.024	<0.012	11.1	0.11	0.228	735
6A	8.38	99	24	97	55	7.0	288	0.13	122	111	0.048	0.013	<0.012	0.0	0.73	0.164	701
7A	8.47	80.2	79	50	21	3.4	394	0.47	30	16	0.079	0.011	<0.012	2.4	0.13	0.161	515
8A	8.26	117	78	35	60	9.0	279	0.36	65	55	0.035	0.010	<0.012	24.2	0.10	0.202	667
14A	8.02	206	83	69	209	12.8	208	0.33	404	215	0.027	0.022	<0.012	10.6	0.13	0.557	1296
15A	8.21	172	136	95	56	13.5	311	0.33	191	35	0.015	0.003	<0.012	91.2	0.07	0.317	976
20A	8.13	132	77	97	64	3.4	420	0.31	144	82	0.011	0.004	<0.012	9.9	0.13	0.168	918
26A	8.24	376	104	195	337	9.7	495	0.34	739	372	0.017	0.006	<0.012	10.5	0.38	0.531	2038
43A	8.28	183	174	99	49	4.0	416	0.67	141	41	0.024	0.018	<0.012	83.5	0.13	0.339	1232
47A	8.44	74.8	89	45	38	2.7	349	0.39	48	21	0.019	0.006	<0.012	11.5	0.09	0.223	617
48A	7.91	261	141	116	199	8.5	370	0.55	508	85	0.011	0.005	<0.012	27.3	0.10	0.948	1534
49A	8.21	265	115	159	158	7.1	351	0.55	318	94	0.023	0.006	<0.012	84.3	0.16	1.102	1592
51A	8.29	74	78	53	43	3.0	318	0.27	73	17.1	0.046	0.004	<0.012	10.5	0.13	0.272	576
52A	8.32	95.7	87	58	35	2.2	303	0.56	38	24	0.051	0.005	<0.012	47.9	0.10	0.241	711
54A	8.12	97.7	104	53	31	1.7	308	0.47	66	14	0.051	0.005	<0.012	35.4	0.37	0.202	584
56A	8.45	114	85	50	69	2.0	344	0.54	119	46	0.043	0.018	<0.012	8.9	0.10	0.327	745
2B	8.36	84.7	16	9	160	4.7	243	1.13	69	105	0.040	0.005	<0.012	4.6	0.17	1.664	631
6B	8.23	154	83	97	70	3.7	398	0.12	131	82	0.048	0.019	<0.012	12.6	0.24	0.241	984
49B	8.61	134	71	81	102	4.6	501	0.73	129	28	0.028	0.006	<0.012	4.0	0.62	0.676	726
51B	8.56	97.1	101	55	44	2.7	395	0.47	70	16.4	0.042	0.007	<0.012	10.3	0.23	0.266	604
52B	8.54	233	182	107	89	2.9	286	0.23	331	40	0.022	0.041	<0.012	89.4	0.20	0.434	1675
52C	8.35	247	170	96	96	3.6	310	0.08	338	45	0.044	0.014	0.950	61.2	0.57	0.516	1403
52D	8.15	127	120	62	69	2.5	359	0.16	145	27.1	0.013	0.004	<0.012	29.4	0.11	0.349	890
28/1	8.07	270	179	129	134	8.5	262	0.38	607	154	0.038	0.043	<0.012	3.3	0.16	0.604	1621
28/2	8.26	262	178	134	133	6.7	289	0.48	519	194	0.021	0.004	<0.012	7.6	0.13	0.669	1597
31/1	8.23	142	103	80	85	5.7	426	0.87	152	89	0.039	0.012	<0.012	8.8	0.09	0.565	817
31/2	8.37	198	145	79	122	18.4	336	0.48	336	162	0.070	0.008	<0.012	1.0	0.16	0.585	1212
42/1	8.55	141	94	72	87	5.5	404	0.63	154	60	0.017	0.007	<0.012	9.6	0.13	0.509	881
Devon	8.16	316	190	154	162	9.0	237	0.51	472	109	0.034	0.040	<0.012	142.0	0.13	0.782	2051
Hope	8.41	179	109	82	117	5.9	298	0.57	305	81	0.024	0.004	<0.012	3.9	0.22	0.490	1057

Table A5-2: Results of chemical testing undertaken on surface water samples. The following abbreviations were used; "HM" - Hotazel Mine, "MSD - Mamatwan Mine Slimes Dam", "WDP" - Wessels Mine Duck Pond, and WSD - Wessels Mine Slimes Dam.

Site	pH	EC	Ca	Mg	Na	K	MAlk	F	Cl	SO4	Fe	Mn	NO2(N)	NO3(N)	NH4(N)	B	TDS
		mS/m	mg/L	mg/L	mg/L	mg/L	as mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HM	8.06	407	302	139	123	4.8	101	0.28	434	130	0.071	0.006	<0.012	231.0	0.27	18.64	2720
MSD#1	8.17	246	143	131	99	3.8	93	0.49	267	282	0.015	0.385	0.740	108.0	1.27	3.46	1531
MSD#2	8.21	250	140	128	105	5.0	85	0.47	296	271	0.011	0.068	1.920	119.0	5.53	3.18	1644
WDP	8.55	265	92	87	258	20.0	179	0.51	364	227	0.021	0.007	1.400	65.0	0.21	3.20	1591
WSD	9.72	473	469	9	346	25.9	39	0.27	478	731	0.012	0.003	5.220	137.0	1.78	3.97	3008

Table A5-3a: Classification of groundwater samples as per DWAF guidelines. Almost all samples are of the "Class 4" type, that is, "Dangerous water quality – totally unsuitable for use. Acute effects may occur". However, if nitrate concentrations are ignored, site waters are generally of the "Class 1" or "Class 2" type i.e. good to marginal quality water, with negative health effects associated with use in some instances.

Site	Class ignoring NO_3 content	Class considering NO_3 content	Site	Class ignoring NO_3 content	Class considering NO_3 content
28A	1 to 2	2	52B	2	4
28B	1 to 2	3	53A	3 to 4	4
31A	0 to 1	3	54A	0 to 1	4
31B	1 to 2	0	55A	0 to 1	4
32A	1 to 2	3	56A	0 to 1	3
42A	0 to 1	4	57A	0	2
43A	1 to 2	4	58A	1 to 2	2
46A	1 to 2	4	Milner BH1	1	4
47A	0 to 1	4	Milner BH2	3 to 4	4
48A	1 to 2	4	Perth BH1	2	4
49A	1 to 2	4	Perth BH2	1	4
49B	0 to 1	2	Perth BH3	3 to 4	4
51A	0 to 1	4	Rissik BH1	2 to 4	4
51B	0 to 1	4	Rissik BH2	2	4
52A	0 to 1	4	M24	1 to 2	2

Table A5-3b: Classification of groundwater samples as per DWAF guidelines (continued).

Site	Class ignoring NO_3 content	Class considering NO_3 content	Site	Class ignoring NO_3 content	Class considering NO_3 content
JB1	1 to 2	2	JB31	2	4
JB2	1 to 2	4	JB32	2	4
JB3	2	4	JB33	2	4
JB4	1	4	JB34	1 to 2	4
JB5	3	4	JB35	2 to 3	4
JB6	Not tested	Not tested	JB36	2	4
JB7	1	4	JB37	2	4
JB8	2	4	JB38	1	4
JB9	2	4	JB39	3 to 4	4
JB10	1 to 2	4	JB40	2 to 3	4
JB11	1	4	JB41	1 to 2	4
JB12	3 to 4	4	JB42	1 to 2	4
JB13	1	4	JB43	2 to 3	4
JB14	1	4	1A	0 to 1	4
JB15	2	4	2B	0 to 1	2
JB16	2	4	3A	0 to 1	2
JB17	1 to 2	4	4A	0 to 1	4
JB18	4	4	5A	0 to 1	3
JB19	0 to 1	0 to 1	6A	0 to 1	0
JB20	2	4	6B	1 to 2	4
JB21	2	4	7A	0 to 1	2
JB22	1 to 2	4	8A	0 to 1	4
JB23	2	4	13A	0 to 1	3
JB24	1 to 2	4	14A	1 to 2	4
JB25			15A	1 to 2	4
JB26	2	4	19	0 to 1	4
JB27	1	4	20A	0 to 1	4
JB28	1 to 2	4	22A	1 to 2	4
JB29	2	4	23A	1 to 2	4
JB30	2 to 3	4	26A	2 to 3	4

Table A5-4a: Results of isotope analyses on groundwater samples.

Site	^{18}O *‰ SMOW*	^{2}H *‰ SMOW*	^{15}N *‰*	^{14}C *P.M.C.*	^{13}C *‰ PDB*	^{3}H *T.U.*
JB1	-3.67	-26.5	36.8	-	-	-
JB2/REX158	-5.14	-30.9	9.8	28.3±0.4	-9.6	0.4±0.2
JB3	-4.8	-32.5	-	-	-	-
JB4	-5.0	-34.2	-	-	-	-
JB5	-4.7	-28.3	-	-	-	-
JB7	-4.58	-31	13.9	-	-	-
JB8	-3.83	-24	11.1	-	-	-
JB9	-5.23	-31.1	8.3	-	-	-
JB10	-4.91	-30	11.8	-	-	-
JB11	-4.73	-29.6	8.7	-	-	-
JB12	-5.18	-32.4	8.5	-	-	-
JB13	-5.15	-31.3	8	-	-	-
JB14	-4.97	-29.5	7.1	-	-	-
JB15	-5.54	-33.1	9.8	79.8±0.7	-10.8	0±0.2
JB16	-4.8	-33.1	-	70.2±0.8	-9.8	1.2±0.2
JB17	-2.7	-18.8	-	73±0.7	-10.4	1.9±0.2
JB18	-5.0	-34.7	-	-	-	-
JB19	-4.0	-18.0	-	-	-	-
JB20	-4.7	-31.5	-	-	-	-
JB21	-4.7	-31.1	7.3	75.4±0.6	-8.2	0.2±0.2
JB22	-5.0	-34.2	8.8	-	-	-
JB23	-3.2	-22.3	5.9	-	-	-
JB24	-0.4	-7.4	-	-	-	-
JB26	-4.7	-31.2	-	-	-	-
JB27	-4.8	-32.0	-	-	-	-
JB28	-3.4	-17.3	7.5	-	-	-
JB29	-3.3	-19.3	-	-	-	-
JB30	-3.4	-21.7	6.0	-	-	-
JB31	-4.3	-26.2	-	-	-	-
JB32	-4.0	-23.2	-	-	-	-
JB33	-4.6	-30.4	5.7	80.9±0.8	-8.6	0.0±0.2
JB34	2.1	13.8	-	-	-	-

Table A5-4b: Results of isotope analyses on groundwater samples (continued).

Site	^{18}O ‰ *SMOW*	^{2}H ‰ *SMOW*	^{15}N ‰	^{14}C *P.M.C.*	^{13}C ‰ *PDB*	^{3}H *T.U.*
JB35	-3.0	-19.0	-	-	-	-
JB26	-4.2	-27.4	-	-	-	-
JB37	-4.2	-28.1	-	-	-	-
JB38	-2.9	-17.0	9.0	-	-	-
JB39	-4.6	-30.8	-	-	-	-
JB40	-4.9	-33.3	-	95.2±0.9	-8.2	0.0±0.2
JB41	-5.0	-33.8	-	-	-	-
JB43	-4.2	-28.1	-	-	-	-
1A	-5.3	-34.2	-	-	-	-
2B	-5.6	-36.7	-	-	-	-
3A	-3.5	-25.1	-	-	-	-
4A	-3.8	-23.5	-	-	-	-
5A	-4.7	-31.6	-	-	-	-
6A	4.7	13.0	-	-	-	-
6B	-2.8	-22.1	-	-	-	-
7A	-6.1	-37	-	-	-	-
8A	-5.7	-36.6	-	-	-	-
13A	-3.7	-25.4	-	-	-	-
14A	-5.5	-35.5	-	-	-	-
15A	-4.9	-31.5	-	-	-	-
19A	-5.4	-35.6	10.5	-	-	-
20A	-3.5	-23.4	6.4	-	-	-
22A	-4.9	-33.8	-	-	-	-
23A	-5.3	-34.5	-	-	-	-
26A	-4.8	-31.5	-	-	-	-
28A	-5.6	-36.3	-	-	-	-
28B	-6.3	-41.8	-	-	-	-
31A	-5.9	-37.5	-	-	-	-
31B	-5.5	-35.1	-	-	-	-
32	-5.4	-34.8	-	-	-	-
42A	-5.8	-38.1	-	-	-	-
43A	-5.0	-33.0	-	-	-	-
46	-3.9	-28.1	-	-	-	-

Table A5-4c: Results of isotope analyses on groundwater samples (continued).

Site	^{18}O ‰ *SMOW*	^{2}H ‰ *SMOW*	^{15}N ‰	^{14}C *P.M.C.*	^{13}C ‰ *PDB*	^{3}H *T.U.*
47A	-5.3	-35.2	-	-	-	-
48A	-5.5	-36.5	-	-	-	-
49A	-4.4	-31.1	-	-	-	-
49B	-5.3	-32.3	-	-	-	-
51A	-5.7	-36.5	-	-	-	-
51B	-5.7	-37.0	-	-	-	-
52A	-4.6	-33.1	-	-	-	-
52B	-4.9	-32.6	-	-	-	-
52C	-4.9	-33.2	-	-	-	-
52D	-5.1	-33.7	-	-	-	-
53A	-5.1	-34.5	-	-	-	-
54A	-5.2	-34.7	-	-	-	-
55A	-5.0	-33.4	-	-	-	-
56A	-5.3	-34.9	-	-	-	-
57A	-6.3	-38.6	-	-	-	-
58A	-5.4	-37.2	-	-	-	-
M24	-5.2	-35.1	-	2.8±0.3	-7.7	0.0±0.2
Perth BH1	-4.94	-33.2	-	-	-	-
Perth BH2	-5.39	-34.2	-	-	-	-
Perth BH3	-5.36	-35.6	-	-	-	-
Rissik BH1	-5.29	-35.4	-	-	-	-
Rissik BH2	-4.89	-36.1	-	-	-	-
Milner BH1	-5.51	-36.9	-	-	-	-
Milner BH2	-4.87	-30.5	-	-	-	-

Table A5-5: Results of isotope testing on surface water samples. The following abbreviations have been used: "SD – Slimes Dam", "STW – Sewage Treatment Works", and "DP – Duck Pond".

Site	^{18}O ‰ *SMOW*	^{2}H ‰ *SMOW*	^{15}N ‰	*Site*	^{18}O ‰ *SMOW*	^{2}H ‰ *SMOW*	^{15}N ‰
SP1*	1.95	12.1	-	WesDP	-1.8	-30.7	-
MamSD#1	1.6	3.9	-	WesSTW	1.2	8.0	10.9
MamSD#2	2.2	5.1	-	PerthMine#1	8.9	36.0	-
MamMine	1.4	2	8.9	PerthMine#2	9.2	36.0	-
MamSTW	1.7	8.0	-	HotazelMine	0.2	-4.1	-
WesSD	-1.2	-10.7	-	HotSTW	1.5	9.0	20.2

Appendix 6: Chemical and isotopic composition of water samples, Liebenberg's Pan

Table A6-1: Isotopic characteristics of groundwater sampled in the vicinity of Liebenberg's Pan, Petrusburg. SWL's measured during field investigations are also shown.

SiteName	Ycoord	Xcoord	Zcoord	SiteType	SWL (m)	^{18}O ($^{0}/_{00}$)	^{2}H ($^{0}/_{00}$)
Site 1:	3222113	-37435.43	-	Borehole	5.14	-4.5	-28
Site 2:	3222269	-37532.25	-	Borehole	5.04	-4.7	-29
Site 3:	3223902	-37995	-	Borehole	11.13	-5	-31
Site 4:	3225008	-38285.2	-	Borehole	-	-4.8	-30
Site 5:	3221724	-35159.04	-	Borehole	-	-2	-8
Site 6:	3222227	-35046.54	-	Borehole	-	-3.5	-21
Site 7:	3224619	-36771.68	-	Borehole	-	-4.1	-26
Site 8:	3224397	-36806.13	-	Borehole	6.83	-4.5	-28
Site 9:	3225083	-36659.91	-	Borehole	-	-4.5	-29
Site 10:	3225117	-32964.09	-	Borehole	6.40	-4.4	-28
Site 11:	3225629	-33155.27	-	Borehole	-	-4.5	-29
Site 12:	3225564	-35476.14	-	Borehole	-	-4.5	-29
Site 13:	3223802	-34471.43	-	Borehole	-	3.1	6
Site 13-Pan:	3223798	-35802.76	-	Pan	-	6.00	18.00
Site 14:	3223384	-36248.81	-	Borehole	-	-4.70	-30.00
Site 14-Tank:	3223384	-36248.81	-	Pan	-	-4.20	-28.00
Site 15:	3223214	-33014.34	-	Borehole	8.17	-3.80	-24.00
Site 15-Tank:	3223214	-33014.34	-	Pan	-	-3.70	-24.00
Site 16:	3223648	-34993.53	-	Borehole	1.05	1.40	-4.00
Site 17:	3223779	-34779.03	-	Borehole	1.08	1.00	3.00
Site 18:	3223981	-34952.61	-	Borehole	1.14	2.50	4.00
Site 19:	3222403	-36211.04	-	Borehole	-	-4.50	-26.00
Site 20:	3225364	-36837.08	-	Borehole	14.93	-4.50	-29.00
Site 21:	3222494	-33648.07	-	Borehole	-	-3.80	-25.00
Site 22:	3222082	-33649.25	-	Borehole	16.20	-4.40	-23.00
Site 23:	3222128	-35290.17	-	Borehole	12.00	-4.00	-23.00
Site 24:	3223509	-35567.17	-	Pan	-	8.40	47.00
Site 25:	3222674	-34579.94	-	Fontein	-	8.00	40.00
Site 26:	3222742	-34596.28	-	Pan	-	10.50	58.00
Site 27:	3224360	-35726.07	-	Borehole	0.78	-3.80	-26.00
Site 28:	3223691	-35520.87	-	Borehole	0.76	3.30	9.00
Site 29:	3223841	-35416.27	-	Borehole	0.76	-	-

Table A6-2: Chemical characteristics of water sampled in the vicinity of Liebenberg's Pan.

SiteName	pH	EC mS/m	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	MALKmg/l	Cl mg/l	SO4 mg/l	$N\text{-}NO_3$mg/l	F mg/l	PO_4 mg/l
Site 1:	7.20	203.00	61.00	100.00	270.00	9.80	477.00	384.00	59.00	2.31	1.00	1.40
Site 2:	7.3	188.0	51.0	88.0	257.0	10.6	472.0	292.0	109.0	2.0	1.4	1.40
Site 3:	7.2	118.0	56.0	53.0	132.0	5.8	374.0	142.0	40.0	1.9	1.1	1.40
Site 4:	7.3	133.0	44.0	50.0	186.0	7.6	395.0	151.0	61.0	2.6	1.2	1.40
Site 5:	6.7	29.0	23.0	16.0	12.3	0.8	137.0	10.0	7.0	-	0.4	1.00
Site 6:	6.9	114.0	107.0	68.0	42.0	2.1	377.0	122.0	82.0	1.8	0.5	1.30
Site 7:	7.2	163.0	58.0	75.0	195.0	8.4	335.0	242.0	99.0	5.7	1.0	1.40
Site 8:	7.2	136.0	55.0	60.0	148.0	7.0	315.0	190.0	67.0	3.9	1.4	1.30
Site 9:	7.3	248.0	62.0	118.0	325.0	20.0	440.0	493.0	207.0	3.9	1.1	1.40
Site 10:	7.2	74.0	46.0	36.0	57.0	3.9	297.0	53.0	27.0	1.3	0.8	1.20
Site 11:	7.3	101.0	63.0	49.0	79.0	4.0	328.0	96.0	64.0	2.6	0.6	1.00
Site 12:	7.6	128.0	47.0	62.0	139.0	9.4	344.0	160.0	81.0	3.1	0.9	1.40
Site 13:	8.8	12530.0	1.2	7.6	46800.0	1820.0	2815.0	69600.0	16500.0	17.6	8.7	9.60
Site 13-Pan	9.0	15810.0	1.5	6.5	72400.0	2540.0	4115.0	108400.0	21940.0	17.4	-	13.00
Site 14:	7.5	161.0	54.0	70.0	162.0	7.6	446.0	343.0	78.0	1.2	1.3	1.50
Site 15:	7.2	67.0	64.0	35.0	26.0	1.3	280.0	27.0	30.0	1.3	0.7	3.60
Site 15-Tank	7.2	67.0	59.0	36.0	27.0	1.6	278.0	28.0	30.0	1.2	0.6	3.40
Site 16:	8.9	11770.0	2.5	3.3	61500.0	1350.0	2468.0	63360.0	33000.0	9.5	7.3	8.20
Site 17:	9.0	9470.0	6.7	3.0	41250.0	1025.0	1576.0	46474.0	8350.0	9.3	2.1	5.10
Site 18:	9.1	11930.0	1.4	1.9	58250.0	1325.0	3135.0	143300.0	10130.0	13.8	7.3	10.30
Site 19:	7.7	176.0	62.0	96.0	145.0	7.9	416.0	259.0	104.0	2.2	1.1	4.00
Site 20:	7.7	234.0	59.0	100.0	283.0	12.9	407.0	207.0	148.0	5.2	1.1	4.00
Site 21:	7.6	85.0	81.0	40.0	33.0	22.0	326.0	55.0	37.0	1.2	0.6	4.70
Site 22:	7.3	78.0	55.0	42.0	40.0	2.0	299.0	68.0	26.0	-0.5	0.8	4.80
Site 23:	7.3	112.0	51.0	61.0	38.0	2.3	362.0	116.0	59.0	1.4	0.6	3.80
Site 24:	9.2	2810.0	27.0	102.0	6400.0	200.0	650.0	10090.0	780.0	-0.5	1.3	-0.53
Site 25:	8.4	1690.0	67.0	190.0	3650.0	121.0	2640.0	6130.0	378.0	0.9	2.0	22.00
Site 26:	9.0	1280.0	23.0	25.0	2660.0	91.0	798.0	4233.0	307.0	0.6	1.2	2.50
Site 27:	8.1	2400.0	69.0	206.0	4400.0	185.0	602.0	7860.0	1440.0	1.9	1.3	3.40
Site 28:	8.8	15330.0	3.3	7.3	80750.0	1800.0	3840.0	111700.0	45250.0	0.8	7.8	10.50

Appendix 7: CRD calculations for Petrusburg and Hotazel

Adaption of CRD Method to allow for episodic recharge

Study area **Petrusburg**

Recharge via **Preferential pathways**

		Excel formulas used
CRD_{ave} =	$CRD_i = P_i + CRD_{i-1} - P_{ave}$	
A =	Values above high threshold	if(P_i < high threshold, 0, P_i)
B =	Test to see whether Pi > high theshold	and(Pi > high theshold)
C =	Test to see whether Pi > low theshold	and(P_i > low threshold
D =	Test to see whether low threshold follows high threshold	and(C_i = true, B_{i-1} = true)
E =	Test to confirm thesholds are in correct order	and(B_{i-1} = true, B_i = false,C_i = true)
F =	Test to determine where sequential recharge occurs	if(E_i = true, E_i, 0)
G =	Test to see whether the high or low recharge threshold has been exceeded	or(A_i > 0,F_i > 0)
H =	Test to see whether CRDi = CRDi-1+Pi or CRDi = CRDi-1 - RF	if(G = true, CRD_{i-1} + P_i, CRD_{i-1} - RF)

Note: a) To obtain episodic CRD, plot Month versus "H (mm)";
b) RF must be adjusted until trendline through episodic CRD plot is horizontal;
c) "I (mm)" is used for averaging calculations only.

Average episodic threshold (low)	0	mm
Average episodic threshold (high)	30	mm
Total number of months	1134	months
No. of months above CRD2 threshold	625	months
Average (all values)	35.7	mm
Average CRD2 values	59.7	mm
% Recharge months	55.1	%
Recession Factor (RF)	74.3	mm/month

Month	Rain	CRD_{ave}(mm)	A (mm)	B	C	D	E	F (mm)	G	H (mm)	I (mm)
Jan-06	42.6	42.6	42.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	42.6	42.6
Feb-06	64.3	106.9	64.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	106.9	64.3
Mar-06	73.7	180.6	73.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	180.6	73.7
Apr-06	87.9	268.5	87.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	268.5	87.9
May-06	88.8	357.3	88.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	357.3	88.8
Jun-06	6.1	363.4	0	FALSE	TRUE	TRUE	TRUE	6.1	TRUE	363.4	6.1
Jul-06	12.9	376.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	289.1	0
Aug-06	17.8	394.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	214.8	0
Sep-06	0	394.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	140.5	0
Oct-06	0	394.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	66.2	0
Nov-06	2.5	396.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-8.1	0
Dec-06	81.8	478.4	81.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	73.7	81.8
Jan-07	132.5	610.9	132.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	206.2	132.5
Feb-07	33.5	644.4	33.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	239.7	33.5
Mar-07	47.4	691.8	47.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	287.1	47.4
Apr-07	90.5	782.3	90.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	377.6	90.5
May-07		782.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	303.3	0
Jun-07		782.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	229	0
Jul-07		782.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	154.7	0
Aug-07		782.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	80.4	0
Sep-07		782.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	6.1	0
Oct-07		782.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-68.2	0
Nov-07	15.2	797.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-142.5	0
Dec-07	15.2	812.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-216.8	0
Jan-08	0	812.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-291.1	0
Feb-08	21.6	834.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-365.4	0
Mar-08	0	834.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-439.7	0
Apr-08	0	834.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-514	0
May-08	43.1	877.4	43.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-470.9	43.1
Jun-08	0	877.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-545.2	0
Jul-08	0	877.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-619.5	0
Aug-08	11.7	889.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-693.8	0
Sep-08	14.8	903.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-768.1	0
Oct-08	15.7	919.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-842.4	0
Nov-08	16	935.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-916.7	0
Dec-08	0	935.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-991	0
Jan-09	39.4	975	39.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-951.6	39.4
Feb-09	36.9	1011.9	36.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-914.7	36.9
Mar-09	63.8	1075.7	63.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-850.9	63.8
Apr-09	169.9	1245.6	169.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-681	169.9
May-09	99.9	1345.5	99.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-581.1	99.9

Jun-09	89.7	1435.2	89.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-491.4	89.7
Jul-09	85.1	1520.3	85.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-406.3	85.1
Aug-09	0	1520.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-480.6	0
Sep-09	0	1520.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-554.9	0
Oct-09		1520.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-629.2	0
Nov-09	17.8	1538.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-703.5	0
Dec-09	5	1543.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-777.8	0
Jan-10	25.4	1568.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-852.1	0
Feb-10	34.3	1602.8	34.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-817.8	34.3
Mar-10	46.2	1649	46.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-771.6	46.2
Apr-10		1649	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-845.9	0
May-10	45.7	1694.7	45.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-800.2	45.7
Jun-10		1694.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-874.5	0
Jul-10		1694.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-948.8	0
Aug-10		1694.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1023.1	0
Sep-10		1694.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1097.4	0
Oct-10		1694.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1171.7	0
Nov-10		1694.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1246	0
Dec-10	55.9	1750.6	55.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1190.1	55.9
Jan-11	24.4	1775	0	FALSE	TRUE	TRUE	TRUE	24.4	TRUE	-1165.7	24.4
Feb-11	0	1775	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1240	0
Mar-11	50.8	1825.8	50.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1189.2	50.8
Apr-11	0	1825.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1263.5	0
May-11	121.9	1947.7	121.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1141.6	121.9
Jun-11	8.9	1956.6	0	FALSE	TRUE	TRUE	TRUE	8.9	TRUE	-1132.7	8.9
Jul-11	54.8	2011.4	54.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1077.9	54.8
Aug-11	0	2011.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1152.2	0
Sep-11	35.5	2046.9	35.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1116.7	35.5
Oct-11	0	2046.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1191	0
Nov-11	0	2046.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1265.3	0
Dec-11	31.8	2078.7	31.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1233.5	31.8
Jan-12	12.7	2091.4	0	FALSE	TRUE	TRUE	TRUE	12.7	TRUE	-1220.8	12.7
Feb-12	0	2091.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1295.1	0
Mar-12	0	2091.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1369.4	0
Apr-12	42	2133.4	42	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1327.4	42
May-12	56	2189.4	56	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1271.4	56
Jun-12	67.3	2256.7	67.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1204.1	67.3
Jul-12	6.9	2263.6	0	FALSE	TRUE	TRUE	TRUE	6.9	TRUE	-1197.2	6.9
Aug-12	14	2277.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1271.5	0
Sep-12	12.2	2289.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1345.8	0
Oct-12	0	2289.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1420.1	0
Nov-12	0	2289.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1494.4	0
Dec-12	12.7	2302.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1568.7	0
Jan-13	0	2302.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1643	0
Feb-13	32.8	2335.3	32.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1610.2	32.8
Mar-13	46.3	2381.6	46.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1563.9	46.3
Apr-13	86.7	2468.3	86.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1477.2	86.7
May-13	53.6	2521.9	53.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1423.6	53.6
Jun-13	29.5	2551.4	0	FALSE	TRUE	TRUE	TRUE	29.5	TRUE	-1394.1	29.5
Jul-13	0	2551.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1468.4	0
Aug-13	15	2566.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1542.7	0
Sep-13	1.8	2568.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1617	0
Oct-13	9.7	2577.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1691.3	0
Nov-13	0	2577.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1765.6	0
Dec-13	27.2	2605.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1839.9	0
Jan-14	0	2605.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1914.2	0
Feb-14	0	2605.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1988.5	0
Mar-14	0	2605.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2062.8	0
Apr-14	35.4	2640.5	35.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2027.4	35.4
May-14	24.8	2665.3	0	FALSE	TRUE	TRUE	TRUE	24.8	TRUE	-2002.6	24.8
Jun-14	46.4	2711.7	46.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1956.2	46.4
Jul-14	29.3	2741	0	FALSE	TRUE	TRUE	TRUE	29.3	TRUE	-1926.9	29.3
Aug-14	9.1	2750.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2001.2	0
Sep-14	0	2750.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2075.5	0
Oct-14	3.6	2753.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2149.8	0
Nov-14	27.9	2781.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2224.1	0
Dec-14	62.5	2844.1	62.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2161.6	62.5
Jan-15	59.5	2903.6	59.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2102.1	59.5
Feb-15	112.5	3016.1	112.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1989.6	112.5
Mar-15	23.8	3039.9	0	FALSE	TRUE	TRUE	TRUE	23.8	TRUE	-1965.8	23.8

Apr-15	132.2	3172.1	132.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1833.6	132.2
May-15	3.8	3175.9	0	FALSE	TRUE	TRUE	TRUE	3.8	TRUE	-1829.8	3.8
Jun-15	7.6	3183.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1904.1	0
Jul-15	20.6	3204.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1978.4	0
Aug-15	0	3204.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2052.7	0
Sep-15	28.2	3232.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2127	0
Oct-15	0	3232.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2201.3	0
Nov-15	10.4	3242.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2275.6	0
Dec-15	84.6	3327.3	84.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2191	84.6
Jan-16	25.4	3352.7	0	FALSE	TRUE	TRUE	TRUE	25.4	TRUE	-2165.6	25.4
Feb-16	12.7	3365.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2239.9	0
Mar-16	38.9	3404.3	38.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2201	38.9
Apr-16	28.7	3433	0	FALSE	TRUE	TRUE	TRUE	28.7	TRUE	-2172.3	28.7
May-16	43.7	3476.7	43.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2128.6	43.7
Jun-16	0	3476.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2202.9	0
Jul-16	0	3476.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2277.2	0
Aug-16	0	3476.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2351.5	0
Sep-16	6.4	3483.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2425.8	0
Oct-16	0	3483.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2500.1	0
Nov-16	0	3483.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2574.4	0
Dec-16		3483.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2648.7	0
Jan-17		3483.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2723	0
Feb-17	50.4	3533.5	50.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2672.6	50.4
Mar-17	44	3577.5	44	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2628.6	44
Apr-17	114.5	3692	114.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2514.1	114.5
May-17	83.9	3775.9	83.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2430.2	83.9
Jun-17	28.2	3804.1	0	FALSE	TRUE	TRUE	TRUE	28.2	TRUE	-2402	28.2
Jul-17	0	3804.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2476.3	0
Aug-17	0	3804.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2550.6	0
Sep-17	3.8	3807.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2624.9	0
Oct-17	16.5	3824.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2699.2	0
Nov-17	8.9	3833.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2773.5	0
Dec-17	0	3833.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2847.8	0
Jan-18	42.6	3875.9	42.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2805.2	42.6
Feb-18	22.2	3898.1	0	FALSE	TRUE	TRUE	TRUE	22.2	TRUE	-2783	22.2
Mar-18	37.8	3935.9	37.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2745.2	37.8
Apr-18	54.6	3990.5	54.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2690.6	54.6
May-18	60.9	4051.4	60.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2629.7	60.9
Jun-18	0	4051.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2704	0
Jul-18	19.6	4071	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2778.3	0
Aug-18	0	4071	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2852.6	0
Sep-18	34.3	4105.3	34.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2818.3	34.3
Oct-18	5.3	4110.6	0	FALSE	TRUE	TRUE	TRUE	5.3	TRUE	-2813	5.3
Nov-18	33.3	4143.9	33.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2779.7	33.3
Dec-18	9.1	4153	0	FALSE	TRUE	TRUE	TRUE	9.1	TRUE	-2770.6	9.1
Jan-19	21.6	4174.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2844.9	0
Feb-19	22.1	4196.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2919.2	0
Mar-19		4196.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2993.5	0
Apr-19	0	4196.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3067.8	0
May-19	44.5	4241.2	44.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3023.3	44.5
Jun-19	41.8	4283	41.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2981.5	41.8
Jul-19	7.6	4290.6	0	FALSE	TRUE	TRUE	TRUE	7.6	TRUE	-2973.9	7.6
Aug-19	0	4290.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3048.2	0
Sep-19	2.5	4293.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3122.5	0
Oct-19	2.5	4295.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3196.8	0
Nov-19		4295.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3271.1	0
Dec-19	9.9	4305.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3345.4	0
Jan-20	33.1	4338.6	33.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3312.3	33.1
Feb-20	3.6	4342.2	0	FALSE	TRUE	TRUE	TRUE	3.6	TRUE	-3308.7	3.6
Mar-20	48.5	4390.7	48.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3260.2	48.5
Apr-20	100.6	4491.3	100.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3159.6	100.6
May-20	172.4	4663.7	172.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2987.2	172.4
Jun-20	0	4663.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3061.5	0
Jul-20	0	4663.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3135.8	0
Aug-20	0	4663.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3210.1	0
Sep-20		4663.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3284.4	0
Oct-20	10.7	4674.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3358.7	0
Nov-20	9.1	4683.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3433	0
Dec-20	37.1	4720.6	37.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3395.9	37.1
Jan-21	27.9	4748.5	0	FALSE	TRUE	TRUE	TRUE	27.9	TRUE	-3368	27.9

Feb-21	12.2	4760.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3442.3	0
Mar-21	9.2	4769.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3516.6	0
Apr-21	91.3	4861.2	91.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3425.3	91.3
May-21	60.1	4921.3	60.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3365.2	60.1
Jun-21	45.1	4966.4	45.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3320.1	45.1
Jul-21	51.3	5017.7	51.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3268.8	51.3
Aug-21	0	5017.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3343.1	0
Sep-21	0	5017.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3417.4	0
Oct-21		5017.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3491.7	0
Nov-21	9.2	5026.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3566	0
Dec-21	7.6	5034.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3640.3	0
Jan-22	28	5062.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3714.6	0
Feb-22	16	5078.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3788.9	0
Mar-22	63	5141.5	63	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3725.9	63
Apr-22	6	5147.5	0	FALSE	TRUE	TRUE	TRUE	6	TRUE	-3719.9	6
May-22		5147.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3794.2	0
Jun-22	0	5147.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3868.5	0
Jul-22	7.4	5154.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3942.8	0
Aug-22	4.3	5159.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4017.1	0
Sep-22	0	5159.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4091.4	0
Oct-22	10.2	5169.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4165.7	0
Nov-22	0	5169.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4240	0
Dec-22	7.4	5176.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4314.3	0
Jan-23	109.2	5286	109.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4205.1	109.2
Feb-23	37.9	5323.9	37.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4167.2	37.9
Mar-23	60.3	5384.2	60.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4106.9	60.3
Apr-23	142.9	5527.1	142.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3964	142.9
May-23	5.6	5532.7	0	FALSE	TRUE	TRUE	TRUE	5.6	TRUE	-3958.4	5.6
Jun-23	72.5	5605.2	72.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3885.9	72.5
Jul-23	37.9	5643.1	37.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3848	37.9
Aug-23	11.3	5654.4	0	FALSE	TRUE	TRUE	TRUE	11.3	TRUE	-3836.7	11.3
Sep-23	6.4	5660.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3911	0
Oct-23	4.8	5665.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3985.3	0
Nov-23	0	5665.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4059.6	0
Dec-23	5.5	5671.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4133.9	0
Jan-24	38.4	5709.5	38.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4095.5	38.4
Feb-24	9.6	5719.1	0	FALSE	TRUE	TRUE	TRUE	9.6	TRUE	-4085.9	9.6
Mar-24	68.4	5787.5	68.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4017.5	68.4
Apr-24	23.7	5811.2	0	FALSE	TRUE	TRUE	TRUE	23.7	TRUE	-3993.8	23.7
May-24	191.8	6003	191.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3802	191.8
Jun-24	20.3	6023.3	0	FALSE	TRUE	TRUE	TRUE	20.3	TRUE	-3781.7	20.3
Jul-24	5.6	6028.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3856	0
Aug-24	0	6028.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3930.3	0
Sep-24	0	6028.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4004.6	0
Oct-24	0	6028.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4078.9	0
Nov-24	37.8	6066.7	37.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4041.1	37.8
Dec-24	38.6	6105.3	38.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4002.5	38.6
Jan-25	78.7	6184	78.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3923.8	78.7
Feb-25	165.1	6349.1	165.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3758.7	165.1
Mar-25	12.5	6361.6	0	FALSE	TRUE	TRUE	TRUE	12.5	TRUE	-3746.2	12.5
Apr-25	182.9	6544.5	182.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3563.3	182.9
May-25	140.9	6685.4	140.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3422.4	140.9
Jun-25	95.5	6780.9	95.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3326.9	95.5
Jul-25	62.2	6843.1	62.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3264.7	62.2
Aug-25	0	6843.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3339	0
Sep-25	0	6843.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3413.3	0
Oct-25	5.6	6848.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3487.6	0
Nov-25	8.7	6857.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3561.9	0
Dec-25	7.1	6864.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3636.2	0
Jan-26	19.3	6883.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3710.5	0
Feb-26	61.6	6945.4	61.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3648.9	61.6
Mar-26	11.5	6956.9	0	FALSE	TRUE	TRUE	TRUE	11.5	TRUE	-3637.4	11.5
Apr-26	27.2	6984.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3711.7	0
May-26	96.5	7080.6	96.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3615.2	96.5
Jun-26	30	7110.6	30	FALSE	TRUE	TRUE	TRUE	30	TRUE	-3585.2	30
Jul-26	16.8	7127.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3659.5	0
Aug-26	0	7127.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3733.8	0
Sep-26	0	7127.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3808.1	0
Oct-26	0	7127.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3882.4	0
Nov-26	3.8	7131.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3956.7	0

Dec-26	26.7	7157.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4031	0
Jan-27	47.4	7205.3	47.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3983.6	47.4
Feb-27	66.5	7271.8	66.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3917.1	66.5
Mar-27	18.3	7290.1	0	FALSE	TRUE	TRUE	TRUE	18.3	TRUE	-3898.8	18.3
Apr-27	58.2	7348.3	58.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3840.6	58.2
May-27	86.1	7434.4	86.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3754.5	86.1
Jun-27	12.4	7446.8	0	FALSE	TRUE	TRUE	TRUE	12.4	TRUE	-3742.1	12.4
Jul-27	1.5	7448.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3816.4	0
Aug-27	0	7448.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3890.7	0
Sep-27	9.9	7458.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3965	0
Oct-27	7.1	7465.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4039.3	0
Nov-27	0	7465.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4113.6	0
Dec-27	45.8	7511.1	45.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4067.8	45.8
Jan-28	21.9	7533	0	FALSE	TRUE	TRUE	TRUE	21.9	TRUE	-4045.9	21.9
Feb-28	75.1	7608.1	75.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3970.8	75.1
Mar-28	101.8	7709.9	101.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3869	101.8
Apr-28	36.8	7746.7	36.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3832.2	36.8
May-28	55.8	7802.5	55.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3776.4	55.8
Jun-28	50.8	7853.3	50.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3725.6	50.8
Jul-28	0	7853.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3799.9	0
Aug-28	0	7853.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3874.2	0
Sep-28	0	7853.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3948.5	0
Oct-28	6.6	7859.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4022.8	0
Nov-28	7.6	7867.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4097.1	0
Dec-28	39.3	7906.8	39.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4057.8	39.3
Jan-29	45.1	7951.9	45.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4012.7	45.1
Feb-29	15.3	7967.2	0	FALSE	TRUE	TRUE	TRUE	15.3	TRUE	-3997.4	15.3
Mar-29	90.4	8057.6	90.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3907	90.4
Apr-29	21.1	8078.7	0	FALSE	TRUE	TRUE	TRUE	21.1	TRUE	-3885.9	21.1
May-29		8078.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3960.2	0
Jun-29	26.4	8105.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4034.5	0
Jul-29	15.2	8120.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4108.8	0
Aug-29	40.1	8160.4	40.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4068.7	40.1
Sep-29	22.1	8182.5	0	FALSE	TRUE	TRUE	TRUE	22.1	TRUE	-4046.6	22.1
Oct-29	33.2	8215.7	33.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4013.4	33.2
Nov-29	103.7	8319.4	103.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3909.7	103.7
Dec-29	25.9	8345.3	0	FALSE	TRUE	TRUE	TRUE	25.9	TRUE	-3883.8	25.9
Jan-30	20.3	8365.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3958.1	0
Feb-30	28.6	8394.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4032.4	0
Mar-30	102.1	8496.3	102.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3930.3	102.1
Apr-30	63	8559.3	63	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3867.3	63
May-30	77.5	8636.8	77.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3789.8	77.5
Jun-30	22.9	8659.7	0	FALSE	TRUE	TRUE	TRUE	22.9	TRUE	-3766.9	22.9
Jul-30	5.1	8664.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3841.2	0
Aug-30		8664.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3915.5	0
Sep-30	8.1	8672.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3989.8	0
Oct-30	0	8672.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4064.1	0
Nov-30	0	8672.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4138.4	0
Dec-30	23.4	8696.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4212.7	0
Jan-31	20.9	8717.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4287	0
Feb-31	42.1	8759.3	42.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4244.9	42.1
Mar-31	77.9	8837.2	77.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4167	77.9
Apr-31	23.8	8861	0	FALSE	TRUE	TRUE	TRUE	23.8	TRUE	-4143.2	23.8
May-31	68.3	8929.3	68.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4074.9	68.3
Jun-31	98.6	9027.9	98.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3976.3	98.6
Jul-31	0	9027.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4050.6	0
Aug-31	0	9027.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4124.9	0
Sep-31	24.2	9052.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4199.2	0
Oct-31	0	9052.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4273.5	0
Nov-31	0	9052.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4347.8	0
Dec-31	22.2	9074.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4422.1	0
Jan-32	125.3	9199.6	125.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4296.8	125.3
Feb-32	16.7	9216.3	0	FALSE	TRUE	TRUE	TRUE	16.7	TRUE	-4280.1	16.7
Mar-32	33.6	9249.9	33.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4246.5	33.6
Apr-32	78.5	9328.4	78.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4168	78.5
May-32	56.4	9384.8	56.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4111.6	56.4
Jun-32	9.1	9393.9	0	FALSE	TRUE	TRUE	TRUE	9.1	TRUE	-4102.5	9.1
Jul-32	5.8	9399.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4176.8	0
Aug-32	2.5	9402.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4251.1	0
Sep-32	0	9402.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4325.4	0

Oct-32	0	9402.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4399.7	0
Nov-32	48.5	9450.7	48.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4351.2	48.5
Dec-32	8.9	9459.6	0	FALSE	TRUE	TRUE	TRUE	8.9	TRUE	-4342.3	8.9
Jan-33	18	9477.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4416.6	0
Feb-33	24	9501.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4490.9	0
Mar-33	14.9	9516.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4565.2	0
Apr-33	6.9	9523.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4639.5	0
May-33	3.8	9527.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4713.8	0
Jun-33	43.8	9571	43.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4670	43.8
Jul-33	1.8	9572.8	0	FALSE	TRUE	TRUE	TRUE	1.8	TRUE	-4668.2	1.8
Aug-33	3.6	9576.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4742.5	0
Sep-33	0	9576.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4816.8	0
Oct-33	0	9576.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4891.1	0
Nov-33	0	9576.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4965.4	0
Dec-33	0	9576.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-5039.7	0
Jan-34	121.1	9697.5	121.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4918.6	121.1
Feb-34	105	9802.5	105	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4813.6	105
Mar-34	110.2	9912.7	110.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4703.4	110.2
Apr-34	97.8	10010.5	97.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4605.6	97.8
May-34	99.3	10109.8	99.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4506.3	99.3
Jun-34	29.1	10138.9	0	FALSE	TRUE	TRUE	TRUE	29.1	TRUE	-4477.2	29.1
Jul-34	36.1	10175	36.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4441.1	36.1
Aug-34	0	10175	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4515.4	0
Sep-34	2.8	10177.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4589.7	0
Oct-34	0	10177.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4664	0
Nov-34	0	10177.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4738.3	0
Dec-34	79.5	10257.3	79.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4658.8	79.5
Jan-35	112.4	10369.7	112.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4546.4	112.4
Feb-35	76	10445.7	76	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4470.4	76
Mar-35	20.6	10466.3	0	FALSE	TRUE	TRUE	TRUE	20.6	TRUE	-4449.8	20.6
Apr-35	57.4	10523.7	57.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4392.4	57.4
May-35	108.3	10632	108.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4284.1	108.3
Jun-35	45.5	10677.5	45.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4238.6	45.5
Jul-35	61	10738.5	61	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4177.6	61
Aug-35	19.6	10758.1	0	FALSE	TRUE	TRUE	TRUE	19.6	TRUE	-4158	19.6
Sep-35	0	10758.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4232.3	0
Oct-35	8.1	10766.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4306.6	0
Nov-35	7.6	10773.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4380.9	0
Dec-35	41.4	10815.2	41.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4339.5	41.4
Jan-36	75.4	10890.6	75.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4264.1	75.4
Feb-36	78.4	10969	78.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4185.7	78.4
Mar-36	29.6	10998.6	0	FALSE	TRUE	TRUE	TRUE	29.6	TRUE	-4156.1	29.6
Apr-36	25.4	11024	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4230.4	0
May-36	90.5	11114.5	90.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4139.9	90.5
Jun-36	48.7	11163.2	48.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4091.2	48.7
Jul-36	66.6	11229.8	66.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4024.6	66.6
Aug-36	2	11231.8	0	FALSE	TRUE	TRUE	TRUE	2	TRUE	-4022.6	2
Sep-36	0	11231.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4096.9	0
Oct-36	0	11231.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4171.2	0
Nov-36	31.2	11263	31.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4140	31.2
Dec-36	49.5	11312.5	49.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4090.5	49.5
Jan-37	131.8	11444.3	131.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3958.7	131.8
Feb-37	57.8	11502.1	57.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3900.9	57.8
Mar-37	36.8	11538.9	36.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3864.1	36.8
Apr-37	64.1	11603	64.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3800	64.1
May-37	81.2	11684.2	81.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3718.8	81.2
Jun-37	0	11684.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3793.1	0
Jul-37	16.5	11700.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3867.4	0
Aug-37	0	11700.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3941.7	0
Sep-37	3.3	11704	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4016	0
Oct-37	0	11704	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4090.3	0
Nov-37	0	11704	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4164.6	0
Dec-37	20.3	11724.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4238.9	0
Jan-38	54.1	11778.4	54.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4184.8	54.1
Feb-38	62	11840.4	62	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4122.8	62
Mar-38	29.9	11870.3	0	FALSE	TRUE	TRUE	TRUE	29.9	TRUE	-4092.9	29.9
Apr-38	53.4	11923.7	53.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4039.5	53.4
May-38	33.6	11957.3	33.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4005.9	33.6
Jun-38	63.6	12020.9	63.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3942.3	63.6
Jul-38	0	12020.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4016.6	0

Aug-38	30.2	12051.1	30.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3986.4	30.2
Sep-38	6.3	12057.4	0	FALSE	TRUE	TRUE	TRUE	6.3	TRUE	-3980.1	6.3
Oct-38	12.7	12070.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4054.4	0
Nov-38	0	12070.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4128.7	0
Dec-38	55.8	12125.9	55.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4072.9	55.8
Jan-39	56.3	12182.2	56.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4016.6	56.3
Feb-39	18.8	12201	0	FALSE	TRUE	TRUE	TRUE	18.8	TRUE	-3997.8	18.8
Mar-39	117.4	12318.4	117.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3880.4	117.4
Apr-39	63.9	12382.3	63.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3816.5	63.9
May-39	3	12385.3	0	FALSE	TRUE	TRUE	TRUE	3	TRUE	-3813.5	3
Jun-39	0	12385.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3887.8	0
Jul-39	19.8	12405.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3962.1	0
Aug-39	0	12405.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4036.4	0
Sep-39	15.5	12420.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4110.7	0
Oct-39	0	12420.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4185	0
Nov-39	0	12420.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4259.3	0
Dec-39	72.1	12492.7	72.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4187.2	72.1
Jan-40	60.5	12553.2	60.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4126.7	60.5
Feb-40	2.5	12555.7	0	FALSE	TRUE	TRUE	TRUE	2.5	TRUE	-4124.2	2.5
Mar-40	26.2	12581.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4198.5	0
Apr-40	55	12636.9	55	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4143.5	55
May-40	161.1	12798	161.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3982.4	161.1
Jun-40	33.2	12831.2	33.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3949.2	33.2
Jul-40	11.9	12843.1	0	FALSE	TRUE	TRUE	TRUE	11.9	TRUE	-3937.3	11.9
Aug-40	7.1	12850.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4011.6	0
Sep-40	6.4	12856.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4085.9	0
Oct-40	0	12856.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4160.2	0
Nov-40	35.2	12891.8	35.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4125	35.2
Dec-40	17.5	12909.3	0	FALSE	TRUE	TRUE	TRUE	17.5	TRUE	-4107.5	17.5
Jan-41	32.7	12942	32.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4074.8	32.7
Feb-41	61.5	13003.5	61.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4013.3	61.5
Mar-41	168.2	13171.7	168.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3845.1	168.2
Apr-41	154.2	13325.9	154.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3690.9	154.2
May-41	0	13325.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3765.2	0
Jun-41	14.5	13340.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3839.5	0
Jul-41	0	13340.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3913.8	0
Aug-41	0	13340.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3988.1	0
Sep-41	8.9	13349.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4062.4	0
Oct-41	6.1	13355.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4136.7	0
Nov-41	25.9	13381.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4211	0
Dec-41	46.7	13428	46.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4164.3	46.7
Jan-42	0	13428	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4238.6	0
Feb-42	5.1	13433.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4312.9	0
Mar-42		13433.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4387.2	0
Apr-42	49.3	13482.4	49.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4337.9	49.3
May-42	103.9	13586.3	103.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4234	103.9
Jun-42	60.7	13647	60.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4173.3	60.7
Jul-42	15.5	13662.5	0	FALSE	TRUE	TRUE	TRUE	15.5	TRUE	-4157.8	15.5
Aug-42	0	13662.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4232.1	0
Sep-42	0	13662.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4306.4	0
Oct-42	12.7	13675.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4380.7	0
Nov-42	5.6	13680.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4455	0
Dec-42	90	13770.8	90	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4365	90
Jan-43	32.9	13803.7	32.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4332.1	32.9
Feb-43	109.6	13913.3	109.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4222.5	109.6
Mar-43	53.9	13967.2	53.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4168.6	53.9
Apr-43	63.5	14030.7	63.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4105.1	63.5
May-43	107.5	14138.2	107.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3997.6	107.5
Jun-43	180.5	14318.7	180.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3817.1	180.5
Jul-43	71.7	14390.4	71.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3745.4	71.7
Aug-43	0	14390.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3819.7	0
Sep-43	26.2	14416.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3894	0
Oct-43	131.3	14547.9	131.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3762.7	131.3
Nov-43	3	14550.9	0	FALSE	TRUE	TRUE	TRUE	3	TRUE	-3759.7	3
Dec-43	77.2	14628.1	77.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3682.5	77.2
Jan-44	128.4	14756.5	128.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3554.1	128.4
Feb-44	59.7	14816.2	59.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3494.4	59.7
Mar-44	48.2	14864.4	48.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3446.2	48.2
Apr-44	45	14909.4	45	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3401.2	45
May-44	58.3	14967.7	58.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3342.9	58.3

Jun-44	0	14967.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3417.2	0
Jul-44	12	14979.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3491.5	0
Aug-44	43.9	15023.6	43.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3447.6	43.9
Sep-44	0	15023.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3521.9	0
Oct-44	0	15023.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3596.2	0
Nov-44	22.2	15045.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3670.5	0
Dec-44	22.2	15068	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3744.8	0
Jan-45	27	15095	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3819.1	0
Feb-45	2.8	15097.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3893.4	0
Mar-45	80.1	15177.9	80.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3813.3	80.1
Apr-45	60.2	15238.1	60.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3753.1	60.2
May-45	61	15299.1	61	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3692.1	61
Jun-45	8.4	15307.5	0	FALSE	TRUE	TRUE	TRUE	8.4	TRUE	-3683.7	8.4
Jul-45	2.5	15310	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3758	0
Aug-45	0	15310	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3832.3	0
Sep-45	14.7	15324.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3906.6	0
Oct-45	0	15324.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3980.9	0
Nov-45	0	15324.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4055.2	0
Dec-45	1.5	15326.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4129.5	0
Jan-46	19	15345.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4203.8	0
Feb-46	7.6	15352.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4278.1	0
Mar-46	112.2	15465	112.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4165.9	112.2
Apr-46	55.6	15520.6	55.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4110.3	55.6
May-46	58.7	15579.3	58.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4051.6	58.7
Jun-46	29.7	15609	0	FALSE	TRUE	TRUE	TRUE	29.7	TRUE	-4021.9	29.7
Jul-46	47.5	15656.5	47.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3974.4	47.5
Aug-46	0	15656.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4048.7	0
Sep-46	1	15657.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4123	0
Oct-46	0	15657.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4197.3	0
Nov-46	5.3	15662.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4271.6	0
Dec-46	39	15701.8	39	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4232.6	39
Jan-47	13.4	15715.2	0	FALSE	TRUE	TRUE	TRUE	13.4	TRUE	-4219.2	13.4
Feb-47	24.2	15739.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4293.5	0
Mar-47	22.9	15762.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4367.8	0
Apr-47	18.1	15780.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4442.1	0
May-47	23.2	15803.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4516.4	0
Jun-47	55.9	15859.5	55.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4460.5	55.9
Jul-47	33.5	15893	33.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4427	33.5
Aug-47	19.9	15912.9	0	FALSE	TRUE	TRUE	TRUE	19.9	TRUE	-4407.1	19.9
Sep-47	1.1	15914	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4481.4	0
Oct-47	0	15914	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4555.7	0
Nov-47	30.6	15944.6	30.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4525.1	30.6
Dec-47	13.5	15958.1	0	FALSE	TRUE	TRUE	TRUE	13.5	TRUE	-4511.6	13.5
Jan-48	6.9	15965	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4585.9	0
Feb-48	159.3	16124.3	159.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4426.6	159.3
Mar-48	36.7	16161	36.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4389.9	36.7
Apr-48	34.7	16195.7	34.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4355.2	34.7
May-48	184.9	16380.6	184.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4170.3	184.9
Jun-48	57	16437.6	57	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4113.3	57
Jul-48	28.9	16466.5	0	FALSE	TRUE	TRUE	TRUE	28.9	TRUE	-4084.4	28.9

Aug-48	0	16466.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4158.7	0
Sep-48	0.5	16467	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4233	0
Oct-48	0	16467	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4307.3	0
Nov-48	0	16467	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4381.6	0
Dec-48	31	16498	31	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4350.6	31
Jan-49	5.9	16503.9	0	FALSE	TRUE	TRUE	TRUE	5.9	TRUE	-4344.7	5.9
Feb-49	0.8	16504.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4419	0
Mar-49	31.5	16536.2	31.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4387.5	31.5
Apr-49	13.5	16549.7	0	FALSE	TRUE	TRUE	TRUE	13.5	TRUE	-4374	13.5
May-49	70.3	16620	70.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4303.7	70.3
Jun-49	2	16622	0	FALSE	TRUE	TRUE	TRUE	2	TRUE	-4301.7	2
Jul-49	12.2	16634.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4376	0
Aug-49	13.5	16647.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4450.3	0
Sep-49	25.4	16673.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4524.6	0
Oct-49	10.2	16683.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4598.9	0
Nov-49	0	16683.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4673.2	0
Dec-49	6.1	16689.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4747.5	0
Jan-50	12.2	16701.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4821.8	0
Feb-50	28.9	16730.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4896.1	0
Mar-50	23.6	16754.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4970.4	0
Apr-50	62.3	16816.4	62.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4908.1	62.3
May-50	117.9	16934.3	117.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4790.2	117.9
Jun-50	93.4	17027.7	93.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4696.8	93.4
Jul-50	38.9	17066.6	38.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4657.9	38.9
Aug-50	2.5	17069.1	0	FALSE	TRUE	TRUE	TRUE	2.5	TRUE	-4655.4	2.5
Sep-50	1	17070.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4729.7	0
Oct-50	68.1	17138.2	68.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4661.6	68.1
Nov-50	10.9	17149.1	0	FALSE	TRUE	TRUE	TRUE	10.9	TRUE	-4650.7	10.9
Dec-50	13.8	17162.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4725	0
Jan-51	33.5	17196.4	33.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4691.5	33.5
Feb-51	120.5	17316.9	120.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4571	120.5
Mar-51	68.7	17385.6	68.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4502.3	68.7
Apr-51	37.1	17422.7	37.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4465.2	37.1
May-51	21.4	17444.1	0	FALSE	TRUE	TRUE	TRUE	21.4	TRUE	-4443.8	21.4
Jun-51	48	17492.1	48	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4395.8	48
Jul-51	14.2	17506.3	0	FALSE	TRUE	TRUE	TRUE	14.2	TRUE	-4381.6	14.2
Aug-51	0	17506.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4455.9	0
Sep-51	0	17506.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4530.2	0
Oct-51	0	17506.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4604.5	0
Nov-51	8.6	17514.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4678.8	0
Dec-51	54.8	17569.7	54.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4624	54.8
Jan-52	4.9	17574.6	0	FALSE	TRUE	TRUE	TRUE	4.9	TRUE	-4619.1	4.9
Feb-52	8.9	17583.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4693.4	0
Mar-52	40.8	17624.3	40.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4652.6	40.8
Apr-52	53.8	17678.1	53.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4598.8	53.8
May-52	33.4	17711.5	33.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4565.4	33.4
Jun-52	22.8	17734.3	0	FALSE	TRUE	TRUE	TRUE	22.8	TRUE	-4542.6	22.8
Jul-52	0	17734.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4616.9	0
Aug-52	0	17734.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4691.2	0
Sep-52	49.9	17784.2	49.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4641.3	49.9
Oct-52	0	17784.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4715.6	0
Nov-52	13.4	17797.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4789.9	0
Dec-52	50.8	17848.4	50.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4739.1	50.8
Jan-53	68.1	17916.5	68.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4671	68.1
Feb-53	26	17942.5	0	FALSE	TRUE	TRUE	TRUE	26	TRUE	-4645	26
Mar-53	98.8	18041.3	98.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4546.2	98.8
Apr-53	144.8	18186.1	144.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4401.4	144.8
May-53	37.8	18223.9	37.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4363.6	37.8
Jun-53	83.5	18307.4	83.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4280.1	83.5
Jul-53	4.5	18311.9	0	FALSE	TRUE	TRUE	TRUE	4.5	TRUE	-4275.6	4.5
Aug-53	0	18311.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4349.9	0
Sep-53	0	18311.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4424.2	0
Oct-53	0	18311.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4498.5	0
Nov-53	9	18320.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4572.8	0
Dec-53	31	18351.9	31	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4541.8	31
Jan-54	26	18377.9	0	FALSE	TRUE	TRUE	TRUE	26	TRUE	-4515.8	26
Feb-54	79.7	18457.6	79.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4436.1	79.7
Mar-54	32.4	18490	32.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4403.7	32.4
Apr-54	42.4	18532.4	42.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4361.3	42.4
May-54	137.3	18669.7	137.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4224	137.3
Jun-54	25	18694.7	0	FALSE	TRUE	TRUE	TRUE	25	TRUE	-4199	25
Jul-54	17	18711.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4273.3	0
Aug-54	0	18711.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4347.6	0
Sep-54	0	18711.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4421.9	0
Oct-54	0	18711.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4496.2	0
Nov-54	0	18711.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4570.5	0
Dec-54	0	18711.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4644.8	0
Jan-55	65.6	18777.3	65.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4579.2	65.6
Feb-55	32.4	18809.7	32.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4546.8	32.4
Mar-55	157.8	18967.5	157.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4389	157.8

Feb-56	59.8	19486.3	59.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4203.1	59.8
Mar-56	61.7	19548	61.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4141.4	61.7
Apr-56	83.6	19631.6	83.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4057.8	83.6
May-56	140.4	19772	140.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3917.4	140.4
Jun-56	50.6	19822.6	50.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3866.8	50.6
Jul-56	10.7	19833.3	0	FALSE	TRUE	TRUE	TRUE	10.7	TRUE	-3856.1	10.7
Aug-56	1.2	19834.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3930.4	0
Sep-56	2.3	19836.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4004.7	0
Oct-56	0	19836.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4079	0
Nov-56	16	19852.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4153.3	0
Dec-56	48.5	19901.3	48.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-4104.8	48.5
Jan-57	54.9	19956.2	54.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-4049.9	54.9
Feb-57	97.5	20053.7	97.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3952.4	97.5
Mar-57	21.5	20075.2	0	FALSE	TRUE	TRUE	TRUE	21.5	TRUE	-3930.9	21.5
Apr-57	86.3	20161.5	86.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3844.6	86.3
May-57	40.5	20202	40.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3804.1	40.5
Jun-57	18.2	20220.2	0	FALSE	TRUE	TRUE	TRUE	18.2	TRUE	-3785.9	18.2
Jul-57	5	20225.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3860.2	0
Aug-57	64.5	20289.7	64.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3795.7	64.5
Sep-57	19.2	20308.9	0	FALSE	TRUE	TRUE	TRUE	19.2	TRUE	-3776.5	19.2
Oct-57	58.9	20367.8	58.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3717.6	58.9
Nov-57	57.1	20424.9	57.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3660.5	57.1
Dec-57	79.6	20504.5	79.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3580.9	79.6
Jan-58	66.6	20571.1	66.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3514.3	66.6
Feb-58	85.2	20656.3	85.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3429.1	85.2
Mar-58	58.3	20714.6	58.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3370.8	58.3
Apr-58	31.7	20746.3	31.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3339.1	31.7
May-58	27.4	20773.7	0	FALSE	TRUE	TRUE	TRUE	27.4	TRUE	-3311.7	27.4
Jun-58	11.8	20785.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3386	0
Jul-58	37.9	20823.4	37.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3348.1	37.9
Aug-58	0	20823.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3422.4	0
Sep-58	0	20823.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3496.7	0
Oct-58	0	20823.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3571	0
Nov-58	4.5	20827.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3645.3	0
Dec-58	11.5	20839.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3719.6	0
Jan-59	64.5	20903.9	64.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3655.1	64.5
Feb-59	74.3	20978.2	74.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3580.8	74.3
Mar-59	63.8	21042	63.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3517	63.8
Apr-59	112	21154	112	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3405	112
May-59	54.3	21208.3	54.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3350.7	54.3
Jun-59	52.8	21261.1	52.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3297.9	52.8
Jul-59	31.3	21292.4	31.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3266.6	31.3
Aug-59	0	21292.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3340.9	0
Sep-59	16.9	21309.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3415.2	0
Oct-59	0	21309.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3489.5	0
Nov-59	0	21309.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3563.8	0
Dec-59	40.9	21350.2	40.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3522.9	40.9
Jan-60	64.4	21414.6	64.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3458.5	64.4
Feb-60	68	21482.6	68	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3390.5	68
Mar-60	20.9	21503.5	0	FALSE	TRUE	TRUE	TRUE	20.9	TRUE	-3369.6	20.9
Apr-60	13.9	21517.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3443.9	0
May-60	60.4	21577.8	60.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3383.5	60.4
Jun-60	42.7	21620.5	42.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3340.8	42.7
Jul-60	10.8	21631.3	0	FALSE	TRUE	TRUE	TRUE	10.8	TRUE	-3330	10.8
Aug-60	6.8	21638.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3404.3	0
Sep-60	8.4	21646.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3478.6	0
Oct-60	32.4	21678.9	32.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3446.2	32.4
Nov-60	1.7	21680.6	0	FALSE	TRUE	TRUE	TRUE	1.7	TRUE	-3444.5	1.7
Dec-60	71.4	21752	71.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3373.1	71.4
Jan-61	32.8	21784.8	32.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3340.3	32.8
Feb-61	48.1	21832.9	48.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3292.2	48.1
Mar-61	46.1	21879	46.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3246.1	46.1
Apr-61	20	21899	0	FALSE	TRUE	TRUE	TRUE	20	TRUE	-3226.1	20
May-61	196.2	22095.2	196.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3029.9	196.2
Jun-61	64.2	22159.4	64.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2965.7	64.2
Jul-61	37	22196.4	37	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2928.7	37
Aug-61	34.2	22230.6	34.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2894.5	34.2
Sep-61	39.2	22269.8	39.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2855.3	39.2
Oct-61	21	22290.8	0	FALSE	TRUE	TRUE	TRUE	21	TRUE	-2834.3	21
Nov-61	0	22290.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2908.6	0

Dec-61	0	22290.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2982.9	0
Jan-62	49.1	22339.9	49.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2933.8	49.1
Feb-62	18.9	22358.8	0	FALSE	TRUE	TRUE	TRUE	18.9	TRUE	-2914.9	18.9
Mar-62	33	22391.8	33	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2881.9	33
Apr-62	103	22494.8	103	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2778.9	103
May-62	70	22564.8	70	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2708.9	70
Jun-62	87	22651.8	87	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2621.9	87
Jul-62	0	22651.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2696.2	0
Aug-62	0	22651.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2770.5	0
Sep-62	0	22651.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2844.8	0
Oct-62	0	22651.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2919.1	0
Nov-62	0	22651.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2993.4	0
Dec-62	37.8	22689.6	37.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2955.6	37.8
Jan-63	63.5	22753.1	63.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2892.1	63.5
Feb-63	18	22771.1	0	FALSE	TRUE	TRUE	TRUE	18	TRUE	-2874.1	18
Mar-63	136.7	22907.8	136.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2737.4	136.7
Apr-63	15	22922.8	0	FALSE	TRUE	TRUE	TRUE	15	TRUE	-2722.4	15
May-63	154	23076.8	154	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2568.4	154
Jun-63	125.5	23202.3	125.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2442.9	125.5
Jul-63	15.2	23217.5	0	FALSE	TRUE	TRUE	TRUE	15.2	TRUE	-2427.7	15.2
Aug-63	6	23223.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2502	0
Sep-63	10	23233.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2576.3	0
Oct-63	2	23235.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2650.6	0
Nov-63	0	23235.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2724.9	0
Dec-63	41.7	23277.2	41.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2683.2	41.7
Jan-64	152	23429.2	152	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2531.2	152
Feb-64	19.3	23448.5	0	FALSE	TRUE	TRUE	TRUE	19.3	TRUE	-2511.9	19.3
Mar-64	10.4	23458.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2586.2	0
Apr-64	38	23496.9	38	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2548.2	38
May-64	83.8	23580.7	83.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2464.4	83.8
Jun-64	22.6	23603.3	0	FALSE	TRUE	TRUE	TRUE	22.6	TRUE	-2441.8	22.6
Jul-64	8.5	23611.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2516.1	0
Aug-64	22.5	23634.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2590.4	0
Sep-64	0	23634.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2664.7	0
Oct-64	0	23634.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2739	0
Nov-64	0	23634.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2813.3	0
Dec-64	66.2	23700.5	66.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2747.1	66.2
Jan-65	12	23712.5	0	FALSE	TRUE	TRUE	TRUE	12	TRUE	-2735.1	12
Feb-65	43.8	23756.3	43.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2691.3	43.8
Mar-65	107.1	23863.4	107.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2584.2	107.1
Apr-65	4	23867.4	0	FALSE	TRUE	TRUE	TRUE	4	TRUE	-2580.2	4
May-65	18.5	23885.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2654.5	0
Jun-65	83.3	23969.2	83.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2571.2	83.3
Jul-65	0	23969.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2645.5	0
Aug-65	4.5	23973.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2719.8	0
Sep-65	28	24001.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2794.1	0
Oct-65	2	24003.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2868.4	0
Nov-65	5.5	24009.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2942.7	0
Dec-65	7.7	24016.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3017	0
Jan-66	15	24031.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3091.3	0
Feb-66	15.5	24047.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3165.6	0
Mar-66	211.8	24259.2	211.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2953.8	211.8
Apr-66	44.4	24303.6	44.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2909.4	44.4
May-66	4	24307.6	0	FALSE	TRUE	TRUE	TRUE	4	TRUE	-2905.4	4
Jun-66	12.9	24320.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2979.7	0
Jul-66	0	24320.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3054	0
Aug-66	4.9	24325.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3128.3	0
Sep-66	0	24325.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3202.6	0
Oct-66	0	24325.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3276.9	0
Nov-66	0	24325.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3351.2	0
Dec-66	5.8	24331.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3425.5	0
Jan-67	41.3	24372.5	41.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3384.2	41.3
Feb-67	65.7	24438.2	65.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3318.5	65.7
Mar-67	86.9	24525.1	86.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3231.6	86.9
Apr-67	51.2	24576.3	51.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3180.4	51.2
May-67	94.5	24670.8	94.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3085.9	94.5
Jun-67	143.9	24814.7	143.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2942	143.9
Jul-67	71.5	24886.2	71.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2870.5	71.5
Aug-67	8.5	24894.7	0	FALSE	TRUE	TRUE	TRUE	8.5	TRUE	-2862	8.5
Sep-67	0	24894.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2936.3	0

Oct-67	14	24908.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3010.6	0
Nov-67	1	24909.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3084.9	0
Dec-67	57	24966.7	57	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3027.9	57
Jan-68	48.5	25015.2	48.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2979.4	48.5
Feb-68	0	25015.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3053.7	0
Mar-68	36.5	25051.7	36.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3017.2	36.5
Apr-68	3	25054.7	0	FALSE	TRUE	TRUE	TRUE	3	TRUE	-3014.2	3
May-68	84	25138.7	84	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2930.2	84
Jun-68	95	25233.7	95	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2835.2	95
Jul-68	56.6	25290.3	56.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2778.6	56.6
Aug-68	0	25290.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2852.9	0
Sep-68	0	25290.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2927.2	0
Oct-68	0	25290.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3001.5	0
Nov-68	0	25290.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3075.8	0
Dec-68	39.5	25329.8	39.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3036.3	39.5
Jan-69	14.7	25344.5	0	FALSE	TRUE	TRUE	TRUE	14.7	TRUE	-3021.6	14.7
Feb-69	80.5	25425	80.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2941.1	80.5
Mar-69	2	25427	0	FALSE	TRUE	TRUE	TRUE	2	TRUE	-2939.1	2
Apr-69	56.7	25483.7	56.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2882.4	56.7
May-69	34.5	25518.2	34.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2847.9	34.5
Jun-69	70	25588.2	70	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2777.9	70
Jul-69	40.8	25629	40.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2737.1	40.8
Aug-69	1.5	25630.5	0	FALSE	TRUE	TRUE	TRUE	1.5	TRUE	-2735.6	1.5
Sep-69	0	25630.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2809.9	0
Oct-69	2	25632.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2884.2	0
Nov-69	7.5	25640	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2958.5	0
Dec-69	90.4	25730.4	90.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2868.1	90.4
Jan-70	27	25757.4	0	FALSE	TRUE	TRUE	TRUE	27	TRUE	-2841.1	27
Feb-70	9	25766.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2915.4	0
Mar-70	72	25838.4	72	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2843.4	72
Apr-70	27	25865.4	0	FALSE	TRUE	TRUE	TRUE	27	TRUE	-2816.4	27
May-70	12	25877.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2890.7	0
Jun-70	20.5	25897.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2965	0
Jul-70	27.5	25925.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3039.3	0
Aug-70	42	25967.4	42	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2997.3	42
Sep-70	20.2	25987.6	0	FALSE	TRUE	TRUE	TRUE	20.2	TRUE	-2977.1	20.2
Oct-70	2.5	25990.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3051.4	0
Nov-70	53	26043.1	53	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2998.4	53
Dec-70	46	26089.1	46	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2952.4	46
Jan-71	11	26100.1	0	FALSE	TRUE	TRUE	TRUE	11	TRUE	-2941.4	11
Feb-71	78.5	26178.6	78.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2862.9	78.5
Mar-71	81.5	26260.1	81.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2781.4	81.5
Apr-71	55	26315.1	55	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2726.4	55
May-71	47	26362.1	47	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2679.4	47
Jun-71	39	26401.1	39	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2640.4	39
Jul-71	31.5	26432.6	31.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2608.9	31.5
Aug-71	5.5	26438.1	0	FALSE	TRUE	TRUE	TRUE	5.5	TRUE	-2603.4	5.5
Sep-71	6.5	26444.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2677.7	0
Oct-71	0	26444.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2752	0
Nov-71	0	26444.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2826.3	0
Dec-71	37.5	26482.1	37.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2788.8	37.5
Jan-72	13	26495.1	0	FALSE	TRUE	TRUE	TRUE	13	TRUE	-2775.8	13
Feb-72	35	26530.1	35	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2740.8	35
Mar-72	87.5	26617.6	87.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2653.3	87.5
Apr-72	105.5	26723.1	105.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2547.8	105.5
May-72	106.5	26829.6	106.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2441.3	106.5
Jun-72	79	26908.6	79	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2362.3	79
Jul-72	5.5	26914.1	0	FALSE	TRUE	TRUE	TRUE	5.5	TRUE	-2356.8	5.5
Aug-72	0	26914.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2431.1	0
Sep-72	0	26914.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2505.4	0
Oct-72	0	26914.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2579.7	0
Nov-72	0	26914.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2654	0
Dec-72	19	26933.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2728.3	0
Jan-73	64	26997.1	64	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2664.3	64
Feb-73	0	26997.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2738.6	0
Mar-73	22	27019.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2812.9	0
Apr-73	70.9	27090	70.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2742	70.9
May-73	14	27104	0	FALSE	TRUE	TRUE	TRUE	14	TRUE	-2728	14
Jun-73	76.3	27180.3	76.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2651.7	76.3
Jul-73	0	27180.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2726	0

Aug-73	4.5	27184.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2800.3	0
Sep-73	2	27186.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2874.6	0
Oct-73	13	27199.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2948.9	0
Nov-73	36	27235.8	36	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2912.9	36
Dec-73	6.1	27241.9	0	FALSE	TRUE	TRUE	TRUE	6.1	TRUE	-2906.8	6.1
Jan-74	54.5	27296.4	54.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2852.3	54.5
Feb-74	65.8	27362.2	65.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2786.5	65.8
Mar-74	207.5	27569.7	207.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2579	207.5
Apr-74	88.7	27658.4	88.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2490.3	88.7
May-74	85.9	27744.3	85.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2404.4	85.9
Jun-74	100	27844.3	100	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2304.4	100
Jul-74	54	27898.3	54	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2250.4	54
Aug-74	0	27898.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2324.7	0
Sep-74	0	27898.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2399	0
Oct-74	43	27941.3	43	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2356	43
Nov-74	11	27952.3	0	FALSE	TRUE	TRUE	TRUE	11	TRUE	-2345	11
Dec-74	30.5	27982.8	30.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2314.5	30.5
Jan-75	168.8	28151.6	168.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2145.7	168.8
Feb-75	24.5	28176.1	0	FALSE	TRUE	TRUE	TRUE	24.5	TRUE	-2121.2	24.5
Mar-75	91.5	28267.6	91.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2029.7	91.5
Apr-75	115.5	28383.1	115.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1914.2	115.5
May-75	75.5	28458.6	75.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1838.7	75.5
Jun-75	39.5	28498.1	39.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1799.2	39.5
Jul-75	16	28514.1	0	FALSE	TRUE	TRUE	TRUE	16	TRUE	-1783.2	16
Aug-75	16	28530.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1857.5	0
Sep-75	15	28545.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1931.8	0
Oct-75	0	28545.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2006.1	0
Nov-75	5	28550.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2080.4	0
Dec-75	7.5	28557.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2154.7	0
Jan-76	72.5	28630.1	72.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2082.2	72.5
Feb-76	157.5	28787.6	157.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1924.7	157.5
Mar-76	227	29014.6	227	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1697.7	227
Apr-76	100.5	29115.1	100.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1597.2	100.5
May-76	209	29324.1	209	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1388.2	209
Jun-76	66.5	29390.6	66.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1321.7	66.5
Jul-76	34.5	29425.1	34.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1287.2	34.5
Aug-76	14.5	29439.6	0	FALSE	TRUE	TRUE	TRUE	14.5	TRUE	-1272.7	14.5
Sep-76	7	29446.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1347	0
Oct-76	0	29446.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1421.3	0
Nov-76	25.5	29472.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1495.6	0
Dec-76	62	29534.1	62	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1433.6	62
Jan-77	13.5	29547.6	0	FALSE	TRUE	TRUE	TRUE	13.5	TRUE	-1420.1	13.5
Feb-77	43.5	29591.1	43.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1376.6	43.5
Mar-77	38.5	29629.6	38.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1338.1	38.5
Apr-77	115.5	29745.1	115.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1222.6	115.5
May-77	89.5	29834.6	89.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1133.1	89.5
Jun-77	17.5	29852.1	0	FALSE	TRUE	TRUE	TRUE	17.5	TRUE	-1115.6	17.5
Jul-77	16	29868.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1189.9	0
Aug-77	0	29868.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1264.2	0
Sep-77	0	29868.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1338.5	0
Oct-77	4	29872.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1412.8	0
Nov-77	90.5	29962.6	90.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1322.3	90.5
Dec-77	50	30012.6	50	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1272.3	50
Jan-78	37.5	30050.1	37.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1234.8	37.5
Feb-78	24	30074.1	0	FALSE	TRUE	TRUE	TRUE	24	TRUE	-1210.8	24
Mar-78	48.6	30122.7	48.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1162.2	48.6
Apr-78	45.5	30168.2	45.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1116.7	45.5
May-78	66.9	30235.1	66.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1049.8	66.9
Jun-78	123.4	30358.5	123.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-926.4	123.4
Jul-78	0	30358.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1000.7	0
Aug-78	2.2	30360.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1075	0
Sep-78	0	30360.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1149.3	0
Oct-78	14	30374.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1223.6	0
Nov-78	62.3	30437	62.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1161.3	62.3
Dec-78	0	30437	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1235.6	0
Jan-79	10.4	30447.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1309.9	0
Feb-79	9	30456.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1384.2	0
Mar-79	112.5	30568.9	112.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1271.7	112.5
Apr-79	106	30674.9	106	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1165.7	106
May-79	17	30691.9	0	FALSE	TRUE	TRUE	TRUE	17	TRUE	-1148.7	17

Jun-79	1.9	30693.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1223	0
Jul-79	1.9	30695.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1297.3	0
Aug-79	0	30695.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1371.6	0
Sep-79	51.8	30747.5	51.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1319.8	51.8
Oct-79	66.8	30814.3	66.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1253	66.8
Nov-79	0	30814.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1327.3	0
Dec-79	55.5	30869.8	55.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1271.8	55.5
Jan-80	38.3	30908.1	38.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1233.5	38.3
Feb-80	0	30908.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1307.8	0
Mar-80	20.5	30928.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1382.1	0
Apr-80	72	31000.6	72	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1310.1	72
May-80	33.3	31033.9	33.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1276.8	33.3
Jun-80	0	31033.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1351.1	0
Jul-80	0	31033.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1425.4	0
Aug-80	0	31033.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1499.7	0
Sep-80	3.5	31037.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1574	0
Oct-80	27	31064.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1648.3	0
Nov-80	63	31127.4	63	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1585.3	63
Dec-80	0	31127.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1659.6	0
Jan-81	155	31282.4	155	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1504.6	155
Feb-81	0	31282.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1578.9	0
Mar-81	96	31378.4	96	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1482.9	96
Apr-81	102	31480.4	102	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1380.9	102
May-81	75.5	31555.9	75.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1305.4	75.5
Jun-81	0	31555.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1379.7	0
Jul-81	0	31555.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1454	0
Aug-81	0	31555.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1528.3	0
Sep-81	0	31555.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1602.6	0
Oct-81	53.5	31609.4	53.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1549.1	53.5
Nov-81	0	31609.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1623.4	0
Dec-81	0	31609.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1697.7	0
Jan-82	0	31609.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1772	0
Feb-82	87.9	31697.3	87.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1684.1	87.9
Mar-82	27.2	31724.5	0	FALSE	TRUE	TRUE	TRUE	27.2	TRUE	-1656.9	27.2
Apr-82	43	31767.5	43	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1613.9	43
May-82	67	31834.5	67	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1546.9	67
Jun-82	59.3	31893.8	59.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1487.6	59.3
Jul-82	0	31893.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1561.9	0
Aug-82	22.5	31916.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1636.2	0
Sep-82	27.1	31943.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1710.5	0
Oct-82	0	31943.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1784.8	0
Nov-82	22	31965.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1859.1	0
Dec-82	0	31965.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1933.4	0
Jan-83	0	31965.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2007.7	0
Feb-83	2.5	31967.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2082	0
Mar-83	12	31979.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2156.3	0
Apr-83	21.5	32001.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2230.6	0
May-83	13.6	32015	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2304.9	0
Jun-83	0	32015	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2379.2	0
Jul-83	7.5	32022.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2453.5	0
Aug-83	19.5	32042	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2527.8	0
Sep-83	26	32068	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2602.1	0
Oct-83	0	32068	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2676.4	0
Nov-83	4	32072	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2750.7	0
Dec-83	25	32097	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2825	0
Jan-84	45	32142	45	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2780	45
Feb-84	44	32186	44	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2736	44
Mar-84	18	32204	0	FALSE	TRUE	TRUE	TRUE	18	TRUE	-2718	18
Apr-84	30.5	32234.5	30.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2687.5	30.5
May-84	64.7	32299.2	64.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2622.8	64.7
Jun-84	30	32329.2	30	FALSE	TRUE	TRUE	TRUE	30	TRUE	-2592.8	30
Jul-84	52.5	32381.7	52.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2540.3	52.5
Aug-84	0	32381.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2614.6	0
Sep-84	5	32386.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2688.9	0
Oct-84	12	32398.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2763.2	0
Nov-84	0	32398.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2837.5	0
Dec-84	33	32431.7	33	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2804.5	33
Jan-85	23.5	32455.2	0	FALSE	TRUE	TRUE	TRUE	23.5	TRUE	-2781	23.5
Feb-85	12	32467.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2855.3	0
Mar-85	65	32532.2	65	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2790.3	65

Apr-85	59	32591.2	59	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2731.3	59
May-85	0	32591.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2805.6	0
Jun-85	0	32591.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2879.9	0
Jul-85	0	32591.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2954.2	0
Aug-85	4	32595.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3028.5	0
Sep-85	0	32595.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3102.8	0
Oct-85	0	32595.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3177.1	0
Nov-85	0	32595.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3251.4	0
Dec-85	75	32670.2	75	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3176.4	75
Jan-86	51	32721.2	51	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3125.4	51
Feb-86	56.5	32777.7	56.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3068.9	56.5
Mar-86	18	32795.7	0	FALSE	TRUE	TRUE	TRUE	18	TRUE	-3050.9	18
Apr-86	24.8	32820.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3125.2	0
May-86	92.8	32913.3	92.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3032.4	92.8
Jun-86	13.1	32926.4	0	FALSE	TRUE	TRUE	TRUE	13.1	TRUE	-3019.3	13.1
Jul-86	0	32926.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3093.6	0
Aug-86	9.5	32935.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3167.9	0
Sep-86	0	32935.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3242.2	0
Oct-86	20.5	32956.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3316.5	0
Nov-86	6	32962.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3390.8	0
Dec-86	65.6	33028	65.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3325.2	65.6
Jan-87	71	33099	71	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3254.2	71
Feb-87	8	33107	0	FALSE	TRUE	TRUE	TRUE	8	TRUE	-3246.2	8
Mar-87	6	33113	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3320.5	0
Apr-87	33	33146	33	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3287.5	33
May-87	33.5	33179.5	33.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3254	33.5
Jun-87	54	33233.5	54	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3200	54
Jul-87	0	33233.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3274.3	0
Aug-87	0	33233.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3348.6	0
Sep-87	21	33254.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3422.9	0
Oct-87	40.5	33295	40.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3382.4	40.5
Nov-87	80	33375	80	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3302.4	80
Dec-87	14.5	33389.5	0	FALSE	TRUE	TRUE	TRUE	14.5	TRUE	-3287.9	14.5
Jan-88	102.5	33492	102.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3185.4	102.5
Feb-88	24	33516	0	FALSE	TRUE	TRUE	TRUE	24	TRUE	-3161.4	24
Mar-88	16	33532	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3235.7	0
Apr-88	381.1	33913.1	381.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2854.6	381.1
May-88	68.1	33981.2	68.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2786.5	68.1
Jun-88	139.5	34120.7	139.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2647	139.5
Jul-88	0	34120.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2721.3	0
Aug-88	15	34135.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2795.6	0
Sep-88	0	34135.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2869.9	0
Oct-88	0	34135.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2944.2	0
Nov-88	53	34188.7	53	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2891.2	53
Dec-88	63.1	34251.8	63.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2828.1	63.1
Jan-89	29	34280.8	0	FALSE	TRUE	TRUE	TRUE	29	TRUE	-2799.1	29
Feb-89	103	34383.8	103	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2696.1	103
Mar-89	87	34470.8	87	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2609.1	87
Apr-89	111	34581.8	111	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2498.1	111
May-89	47.5	34629.3	47.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2450.6	47.5
Jun-89	100.8	34730.1	100.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2349.8	100.8
Jul-89	23.5	34753.6	0	FALSE	TRUE	TRUE	TRUE	23.5	TRUE	-2326.3	23.5
Aug-89	0.4	34754	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2400.6	0
Sep-89	1.5	34755.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2474.9	0
Oct-89	0	34755.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2549.2	0
Nov-89	7.6	34763.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2623.5	0
Dec-89	22	34785.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2697.8	0
Jan-90	49.5	34834.6	49.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2648.3	49.5
Feb-90	31.9	34866.5	31.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2616.4	31.9
Mar-90	58	34924.5	58	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2558.4	58
Apr-90	106	35030.5	106	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2452.4	106
May-90	91.5	35122	91.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2360.9	91.5
Jun-90	55.8	35177.8	55.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2305.1	55.8
Jul-90	0	35177.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2379.4	0
Aug-90	13	35190.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2453.7	0
Sep-90	0	35190.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2528	0
Oct-90	7	35197.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2602.3	0
Nov-90	0	35197.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2676.6	0
Dec-90	0	35197.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2750.9	0
Jan-91	1	35198.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2825.2	0

Feb-91	29	35227.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2899.5	0
Mar-91	196	35423.8	196	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2703.5	196
Apr-91	10.7	35434.5	0	FALSE	TRUE	TRUE	TRUE	10.7	TRUE	-2692.8	10.7
May-91	140	35574.5	140	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2552.8	140
Jun-91	0	35574.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2627.1	0
Jul-91		35574.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2701.4	0
Aug-91	20	35594.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2775.7	0
Sep-91	3	35597.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2850	0
Oct-91	0	35597.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2924.3	0
Nov-91	25	35622.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2998.6	0
Dec-91	134.5	35757	134.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2864.1	134.5
Jan-92	45.5	35802.5	45.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2818.6	45.5
Feb-92	54	35856.5	54	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2764.6	54
Mar-92	7	35863.5	0	FALSE	TRUE	TRUE	TRUE	7	TRUE	-2757.6	7
Apr-92	10	35873.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2831.9	0
May-92	48.5	35922	48.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2783.4	48.5
Jun-92	23	35945	0	FALSE	TRUE	TRUE	TRUE	23	TRUE	-2760.4	23
Jul-92	0	35945	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2834.7	0
Aug-92	0	35945	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2909	0
Sep-92	0	35945	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2983.3	0
Oct-92	1.5	35946.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3057.6	0
Nov-92	0	35946.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3131.9	0
Dec-92	37	35983.5	37	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3094.9	37
Jan-93	73.5	36057	73.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3021.4	73.5
Feb-93	0	36057	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3095.7	0
Mar-93	40	36097	40	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3055.7	40
Apr-93	65.5	36162.5	65.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2990.2	65.5
May-93	8	36170.5	0	FALSE	TRUE	TRUE	TRUE	8	TRUE	-2982.2	8
Jun-93	51	36221.5	51	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2931.2	51
Jul-93	8	36229.5	0	FALSE	TRUE	TRUE	TRUE	8	TRUE	-2923.2	8
Aug-93	1	36230.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2997.5	0
Sep-93	0	36230.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3071.8	0
Oct-93	12	36242.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3146.1	0
Nov-93	0	36242.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3220.4	0
Dec-93	156	36398.5	156	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3064.4	156
Jan-94	50	36448.5	50	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3014.4	50
Feb-94	84	36532.5	84	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2930.4	84
Mar-94	88.5	36621	88.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2841.9	88.5
Apr-94	121	36742	121	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2720.9	121
May-94	101	36843	101	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2619.9	101
Jun-94	4	36847	0	FALSE	TRUE	TRUE	TRUE	4	TRUE	-2615.9	4
Jul-94	0	36847	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2690.2	0
Aug-94	1	36848	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2764.5	0
Sep-94	0	36848	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2838.8	0
Oct-94	0	36848	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2913.1	0
Nov-94	0	36848	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2987.4	0
Dec-94	0	36848	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3061.7	0
Jan-95	15	36863	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3136	0
Feb-95	6.5	36869.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3210.3	0
Mar-95	60	36929.5	60	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3150.3	60
Apr-95	38.5	36968	38.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3111.8	38.5
May-95	29	36997	0	FALSE	TRUE	TRUE	TRUE	29	TRUE	-3082.8	29
Jun-95	84	37081	84	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2998.8	84
Jul-95	47	37128	47	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2951.8	47
Aug-95	0	37128	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3026.1	0
Sep-95	0	37128	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3100.4	0
Oct-95	0	37128	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3174.7	0
Nov-95	14	37142	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3249	0
Dec-95	87	37229	87	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3162	87
Jan-96	15	37244	0	FALSE	TRUE	TRUE	TRUE	15	TRUE	-3147	15
Feb-96	73	37317	73	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3074	73
Mar-96	97	37414	97	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2977	97
Apr-96	69.5	37483.5	69.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2907.5	69.5
May-96	65.5	37549	65.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2842	65.5
Jun-96	28	37577	0	FALSE	TRUE	TRUE	TRUE	28	TRUE	-2814	28
Jul-96	7	37584	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2888.3	0
Aug-96	0	37584	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2962.6	0
Sep-96	15	37599	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3036.9	0
Oct-96	5	37604	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3111.2	0
Nov-96	5	37609	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3185.5	0

Dec-96	3	37612	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3259.8	0
Jan-97	88	37700	88	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3171.8	88
Feb-97	78	37778	78	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3093.8	78
Mar-97	125	37903	125	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2968.8	125
Apr-97	46	37949	46	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2922.8	46
May-97	73	38022	73	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2849.8	73
Jun-97	4	38026	0	FALSE	TRUE	TRUE	TRUE	4	TRUE	-2845.8	4
Jul-97	30	38056	30	FALSE	TRUE	FALSE	FALSE	0	TRUE	-2815.8	30
Aug-97	23	38079	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2890.1	0
Sep-97	13	38092	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2964.4	0
Oct-97	3	38095	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3038.7	0
Nov-97	0	38095	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3113	0
Dec-97	56	38151	56	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3057	56
Jan-98	5	38156	0	FALSE	TRUE	TRUE	TRUE	5	TRUE	-3052	5
Feb-98	46	38202	46	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3006	46
Mar-98	66	38268	66	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2940	66
Apr-98	155	38423	155	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2785	155
May-98	51.5	38474.5	51.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2733.5	51.5
Jun-98	26	38500.5	0	FALSE	TRUE	TRUE	TRUE	26	TRUE	-2707.5	26
Jul-98	0	38500.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2781.8	0
Aug-98	0	38500.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2856.1	0
Sep-98	14	38514.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2930.4	0
Oct-98	0	38514.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3004.7	0
Nov-98	15	38529.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3079	0
Dec-98	30	38559.5	30	FALSE	TRUE	FALSE	FALSE	0	TRUE	-3049	30
Jan-99	46	38605.5	46	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3003	46
Feb-99	9.5	38615	0	FALSE	TRUE	TRUE	TRUE	9.5	TRUE	-2993.5	9.5
Mar-99	66	38681	66	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2927.5	66
Apr-99	34.5	38715.5	34.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2893	34.5
May-99	20.5	38736	0	FALSE	TRUE	TRUE	TRUE	20.5	TRUE	-2872.5	20.5
Jun-99	22	38758	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2946.8	0
Jul-99	0	38758	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3021.1	0
Aug-99	0	38758	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3095.4	0
Sep-99	0	38758	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3169.7	0
Oct-99	0	38758	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3244	0
Nov-99	0	38758	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3318.3	0
Dec-99	0	38758	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3392.6	0
Jan-00	2	38760	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3466.9	0
Feb-00	95	38855	95	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3371.9	95
Mar-00	57	38912	57	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3314.9	57
Apr-00	110	39022	110	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3204.9	110
May-00	73	39095	73	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3131.9	73
Jun-00	3	39098	0	FALSE	TRUE	TRUE	TRUE	3	TRUE	-3128.9	3
Jul-00	0	39098	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3203.2	0
Aug-00	0	39098	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3277.5	0
Sep-00	0	39098	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3351.8	0
Oct-00		39098	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3426.1	0
Nov-00		39098	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3500.4	0
Dec-00		39098	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3574.7	0
Jan-01		39098	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3649	0
Feb-01	366	39464	366	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3283	366
Mar-01	11	39475	0	FALSE	TRUE	TRUE	TRUE	11	TRUE	-3272	11
Apr-01	95	39570	95	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3177	95
May-01	109	39679	109	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3068	109
Jun-01	15	39694	0	FALSE	TRUE	TRUE	TRUE	15	TRUE	-3053	15
Jul-01	25	39719	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3127.3	0
Aug-01	0	39719	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3201.6	0
Sep-01	13	39732	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3275.9	0
Oct-01	44	39776	44	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3231.9	44
Nov-01	60	39836	60	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3171.9	60
Dec-01	79	39915	79	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3092.9	79
Jan-02	103	40018	103	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2989.9	103
Feb-02	184	40202	184	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2805.9	184
Mar-02	41	40243	41	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2764.9	41
Apr-02	39.5	40282.5	39.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2725.4	39.5
May-02	11	40293.5	0	FALSE	TRUE	TRUE	TRUE	11	TRUE	-2714.4	11
Jun-02	54	40347.5	54	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2660.4	54
Jul-02	10	40357.5	0	FALSE	TRUE	TRUE	TRUE	10	TRUE	-2650.4	10
Aug-02	0	40357.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2724.7	0
Sep-02	86	40443.5	86	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2638.7	86
Oct-02	26	40469.5	0	FALSE	TRUE	TRUE	TRUE	26	TRUE	-2612.7	26
Nov-02	28	40497.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2687	0
TOTALS	**40497.5**	**22425715.6**	**35020.4**								**37286.4**

Adaption of CRD Method to allow for episodic recharge

Study area **Petrusburg**

Recharge via **Matrix**

		Excel formulas used
CRD_{ave} =	$CRD_i = P_i + CRD_{i-1} - P_{ave}$	
A =	Values above high threshold	if(P_i < high threshold, 0, P_i)
B =	Test to see whether Pi > high theshold	and(Pi > high theshold)
C =	Test to see whether Pi > low theshold	and(P_i > low threshold
D =	Test to see whether low threshold follows high threshold	and(C_i = true, B_{i-1} = true)
E =	Test to confirm thesholds are in correct order	and(B_{i-1} = true, B_i = false,C_i = true)
F =	Test to determine where sequential recharge occurs	if(E_i = true, E_i, 0)
G =	Test to see whether the high or low recharge threshold has been exceeded	or(A_i > 0,F_i > 0)
H =	Test to see whether CRDi = CRDi-1+Pi or CRDi = CRDi-1 - RF	if(G = true, CRD_{i-1} + P_i, CRD_{i-1} - RF)

Note: a) To obtain episodic CRD, plot Month versus "H (mm)";
b) RF must be adjusted until trendline through episodic CRD plot is horizontal;
c) "I (mm)" is used for averaging calculations only.

Average episodic threshold (low)	65	mm
Average episodic threshold (high)	335	mm
Total number of months	1134	months
No. of months above CRD2 threshold	3	months
Average (all values)	35.7	mm
Average CRD2 values	271.7	mm
% Recharge months	0.3	%
Recession Factor (RF)	0.28	mm/month

Month	Rain	CRD_{ave}(mm)	A (mm)	B	C	D	E	F (mm)	G	H (mm)	I (mm)
Jan-06	42.6	42.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-0.28	0
Feb-06	64.3	41.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-0.56	0
Mar-06	73.7	50.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-0.84	0
Apr-06	87.9	73.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1.12	0
May-06	88.8	97.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1.4	0
Jun-06	6.1	38.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1.68	0
Jul-06	12.9	-13.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1.96	0
Aug-06	17.8	-60.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2.24	0
Sep-06	0	-125.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2.52	0
Oct-06	0	-190.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2.8	0
Nov-06	2.5	-253.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3.08	0
Dec-06	81.8	-236.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3.36	0
Jan-07	132.5	-169.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-3.64	0
Feb-07	33.5	-200.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3.92	0
Mar-07	47.4	-218.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4.2	0
Apr-07	90.5	-192.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-4.48	0
May-07		-257.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-4.76	0
Jun-07		-322.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-5.04	0
Jul-07		-387.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-5.32	0
Aug-07		-452.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-5.6	0
Sep-07		-517.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-5.88	0
Oct-07		-582.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-6.16	0
Nov-07	15.2	-632.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-6.44	0
Dec-07	15.2	-682.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-6.72	0
Jan-08	0	-747.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-7	0
Feb-08	21.6	-790.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-7.28	0
Mar-08	0	-855.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-7.56	0
Apr-08	0	-920.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-7.84	0
May-08	43.1	-942.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-8.12	0
Jun-08	0	-1007.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-8.4	0
Jul-08	0	-1072.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-8.68	0
Aug-08	11.7	-1125.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-8.96	0
Sep-08	14.8	-1176.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-9.24	0
Oct-08	15.7	-1225.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-9.52	0
Nov-08	16	-1274.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-9.8	0
Dec-08	0	-1339.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-10.08	0
Jan-09	39.4	-1365	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-10.36	0
Feb-09	36.9	-1393.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-10.64	0
Mar-09	63.8	-1394.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-10.92	0
Apr-09	169.9	-1289.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-11.2	0
May-09	99.9	-1254.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-11.48	0

Jun-09	89.7	-1229.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-11.76	0
Jul-09	85.1	-1209.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-12.04	0
Aug-09	0	-1274.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-12.32	0
Sep-09	0	-1339.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-12.6	0
Oct-09		-1404.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-12.88	0
Nov-09	17.8	-1451.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-13.16	0
Dec-09	5	-1511.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-13.44	0
Jan-10	25.4	-1551.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-13.72	0
Feb-10	34.3	-1582.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-14	0
Mar-10	46.2	-1601	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-14.28	0
Apr-10		-1666	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-14.56	0
May-10	45.7	-1685.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-14.84	0
Jun-10		-1750.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-15.12	0
Jul-10		-1815.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-15.4	0
Aug-10		-1880.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-15.68	0
Sep-10		-1945.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-15.96	0
Oct-10		-2010.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-16.24	0
Nov-10		-2075.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-16.52	0
Dec-10	55.9	-2084.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-16.8	0
Jan-11	24.4	-2125	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-17.08	0
Feb-11	0	-2190	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-17.36	0
Mar-11	50.8	-2204.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-17.64	0
Apr-11	0	-2269.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-17.92	0
May-11	121.9	-2212.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-18.2	0
Jun-11	8.9	-2268.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-18.48	0
Jul-11	54.8	-2278.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-18.76	0
Aug-11	0	-2343.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-19.04	0
Sep-11	35.5	-2373.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-19.32	0
Oct-11	0	-2438.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-19.6	0
Nov-11	0	-2503.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-19.88	0
Dec-11	31.8	-2536.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-20.16	0
Jan-12	12.7	-2588.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-20.44	0
Feb-12	0	-2653.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-20.72	0
Mar-12	0	-2718.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-21	0
Apr-12	42	-2741.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-21.28	0
May-12	56	-2750.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-21.56	0
Jun-12	67.3	-2748.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-21.84	0
Jul-12	6.9	-2806.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-22.12	0
Aug-12	14	-2857.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-22.4	0
Sep-12	12.2	-2910.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-22.68	0
Oct-12	0	-2975.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-22.96	0
Nov-12	0	-3040.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-23.24	0
Dec-12	12.7	-3092.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-23.52	0
Jan-13	0	-3157.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-23.8	0
Feb-13	32.8	-3189.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-24.08	0
Mar-13	46.3	-3208.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-24.36	0
Apr-13	86.7	-3186.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-24.64	0
May-13	53.6	-3198.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-24.92	0
Jun-13	29.5	-3233.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-25.2	0
Jul-13	0	-3298.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-25.48	0
Aug-13	15	-3348.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-25.76	0
Sep-13	1.8	-3411.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-26.04	0
Oct-13	9.7	-3467.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-26.32	0
Nov-13	0	-3532.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-26.6	0
Dec-13	27.2	-3569.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-26.88	0
Jan-14	0	-3634.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-27.16	0
Feb-14	0	-3699.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-27.44	0
Mar-14	0	-3764.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-27.72	0
Apr-14	35.4	-3794.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-28	0
May-14	24.8	-3834.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-28.28	0
Jun-14	46.4	-3853.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-28.56	0
Jul-14	29.3	-3889	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-28.84	0
Aug-14	9.1	-3944.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-29.12	0
Sep-14	0	-4009.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-29.4	0
Oct-14	3.6	-4071.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-29.68	0
Nov-14	27.9	-4108.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-29.96	0
Dec-14	62.5	-4110.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-30.24	0
Jan-15	59.5	-4116.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-30.52	0
Feb-15	112.5	-4068.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-30.8	0
Mar-15	23.8	-4110.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-31.08	0

Apr-15	132.2	-4042.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-31.36	0
May-15	3.8	-4104.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-31.64	0
Jun-15	7.6	-4161.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-31.92	0
Jul-15	20.6	-4205.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-32.2	0
Aug-15	0	-4270.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-32.48	0
Sep-15	28.2	-4307.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-32.76	0
Oct-15	0	-4372.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-33.04	0
Nov-15	10.4	-4427.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-33.32	0
Dec-15	84.6	-4407.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-33.6	0
Jan-16	25.4	-4447.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-33.88	0
Feb-16	12.7	-4499.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-34.16	0
Mar-16	38.9	-4525.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-34.44	0
Apr-16	28.7	-4562	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-34.72	0
May-16	43.7	-4583.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-35	0
Jun-16	0	-4648.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-35.28	0
Jul-16	0	-4713.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-35.56	0
Aug-16	0	-4778.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-35.84	0
Sep-16	6.4	-4836.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-36.12	0
Oct-16	0	-4901.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-36.4	0
Nov-16	0	-4966.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-36.68	0
Dec-16		-5031.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-36.96	0
Jan-17		-5096.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-37.24	0
Feb-17	50.4	-5111.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-37.52	0
Mar-17	44	-5132.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-37.8	0
Apr-17	114.5	-5083	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-38.08	0
May-17	83.9	-5064.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-38.36	0
Jun-17	28.2	-5100.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-38.64	0
Jul-17	0	-5165.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-38.92	0
Aug-17	0	-5230.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-39.2	0
Sep-17	3.8	-5292.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-39.48	0
Oct-17	16.5	-5340.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-39.76	0
Nov-17	8.9	-5396.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-40.04	0
Dec-17	0	-5461.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-40.32	0
Jan-18	42.6	-5484.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-40.6	0
Feb-18	22.2	-5526.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-40.88	0
Mar-18	37.8	-5554.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-41.16	0
Apr-18	54.6	-5564.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-41.44	0
May-18	60.9	-5568.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-41.72	0
Jun-18	0	-5633.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-42	0
Jul-18	19.6	-5679	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-42.28	0
Aug-18	0	-5744	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-42.56	0
Sep-18	34.3	-5774.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-42.84	0
Oct-18	5.3	-5834.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-43.12	0
Nov-18	33.3	-5866.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-43.4	0
Dec-18	9.1	-5922	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-43.68	0
Jan-19	21.6	-5965.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-43.96	0
Feb-19	22.1	-6008.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-44.24	0
Mar-19		-6073.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-44.52	0
Apr-19	0	-6138.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-44.8	0
May-19	44.5	-6158.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-45.08	0
Jun-19	41.8	-6182	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-45.36	0
Jul-19	7.6	-6239.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-45.64	0
Aug-19	0	-6304.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-45.92	0
Sep-19	2.5	-6366.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-46.2	0
Oct-19	2.5	-6429.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-46.48	0
Nov-19		-6494.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-46.76	0
Dec-19	9.9	-6549.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-47.04	0
Jan-20	33.1	-6581.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-47.32	0
Feb-20	3.6	-6642.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-47.6	0
Mar-20	48.5	-6659.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-47.88	0
Apr-20	100.6	-6623.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-48.16	0
May-20	172.4	-6516.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-48.44	0
Jun-20	0	-6581.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-48.72	0
Jul-20	0	-6646.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-49	0
Aug-20	0	-6711.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-49.28	0
Sep-20		-6776.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-49.56	0
Oct-20	10.7	-6830.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-49.84	0
Nov-20	9.1	-6886.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-50.12	0
Dec-20	37.1	-6914.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-50.4	0
Jan-21	27.9	-6951.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-50.68	0

Feb-21	12.2	-7004.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-50.96	0
Mar-21	9.2	-7060.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-51.24	0
Apr-21	91.3	-7033.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-51.52	0
May-21	60.1	-7038.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-51.8	0
Jun-21	45.1	-7058.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-52.08	0
Jul-21	51.3	-7072.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-52.36	0
Aug-21	0	-7137.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-52.64	0
Sep-21	0	-7202.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-52.92	0
Oct-21		-7267.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-53.2	0
Nov-21	9.2	-7323.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-53.48	0
Dec-21	7.6	-7380.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-53.76	0
Jan-22	28	-7417.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-54.04	0
Feb-22	16	-7466.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-54.32	0
Mar-22	63	-7468.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-54.6	0
Apr-22	6	-7527.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-54.88	0
May-22		-7592.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-55.16	0
Jun-22	0	-7657.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-55.44	0
Jul-22	7.4	-7715.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-55.72	0
Aug-22	4.3	-7775.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-56	0
Sep-22	0	-7840.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-56.28	0
Oct-22	10.2	-7895.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-56.56	0
Nov-22	0	-7960.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-56.84	0
Dec-22	7.4	-8018.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-57.12	0
Jan-23	109.2	-7974	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-57.4	0
Feb-23	37.9	-8001.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-57.68	0
Mar-23	60.3	-8005.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-57.96	0
Apr-23	142.9	-7927.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-58.24	0
May-23	5.6	-7987.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-58.52	0
Jun-23	72.5	-7979.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-58.8	0
Jul-23	37.9	-8006.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-59.08	0
Aug-23	11.3	-8060.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-59.36	0
Sep-23	6.4	-8119.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-59.64	0
Oct-23	4.8	-8179.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-59.92	0
Nov-23	0	-8244.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-60.2	0
Dec-23	5.5	-8303.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-60.48	0
Jan-24	38.4	-8330.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-60.76	0
Feb-24	9.6	-8385.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-61.04	0
Mar-24	68.4	-8382.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-61.32	0
Apr-24	23.7	-8423.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-61.6	0
May-24	191.8	-8297	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-61.88	0
Jun-24	20.3	-8341.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-62.16	0
Jul-24	5.6	-8401.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-62.44	0
Aug-24	0	-8466.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-62.72	0
Sep-24	0	-8531.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-63	0
Oct-24	0	-8596.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-63.28	0
Nov-24	37.8	-8623.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-63.56	0
Dec-24	38.6	-8649.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-63.84	0
Jan-25	78.7	-8636	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-64.12	0
Feb-25	165.1	-8535.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-64.4	0
Mar-25	12.5	-8588.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-64.68	0
Apr-25	182.9	-8470.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-64.96	0
May-25	140.9	-8394.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-65.24	0
Jun-25	95.5	-8364.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-65.52	0
Jul-25	62.2	-8366.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-65.8	0
Aug-25	0	-8431.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-66.08	0
Sep-25	0	-8496.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-66.36	0
Oct-25	5.6	-8556.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-66.64	0
Nov-25	8.7	-8612.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-66.92	0
Dec-25	7.1	-8670.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-67.2	0
Jan-26	19.3	-8716.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-67.48	0
Feb-26	61.6	-8719.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-67.76	0
Mar-26	11.5	-8773.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-68.04	0
Apr-26	27.2	-8810.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-68.32	0
May-26	96.5	-8779.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-68.6	0
Jun-26	30	-8814.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-68.88	0
Jul-26	16.8	-8862.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-69.16	0
Aug-26	0	-8927.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-69.44	0
Sep-26	0	-8992.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-69.72	0
Oct-26	0	-9057.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-70	0
Nov-26	3.8	-9118.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-70.28	0

Dec-26	26.7	-9157.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-70.56	0
Jan-27	47.4	-9174.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-70.84	0
Feb-27	66.5	-9173.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-71.12	0
Mar-27	18.3	-9219.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-71.4	0
Apr-27	58.2	-9226.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-71.68	0
May-27	86.1	-9205.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-71.96	0
Jun-27	12.4	-9258.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-72.24	0
Jul-27	1.5	-9321.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-72.52	0
Aug-27	0	-9386.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-72.8	0
Sep-27	9.9	-9441.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-73.08	0
Oct-27	7.1	-9499.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-73.36	0
Nov-27	0	-9564.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-73.64	0
Dec-27	45.8	-9583.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-73.92	0
Jan-28	21.9	-9627	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-74.2	0
Feb-28	75.1	-9616.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-74.48	0
Mar-28	101.8	-9580.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-74.76	0
Apr-28	36.8	-9608.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-75.04	0
May-28	55.8	-9617.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-75.32	0
Jun-28	50.8	-9631.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-75.6	0
Jul-28	0	-9696.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-75.88	0
Aug-28	0	-9761.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-76.16	0
Sep-28	0	-9826.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-76.44	0
Oct-28	6.6	-9885.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-76.72	0
Nov-28	7.6	-9942.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-77	0
Dec-28	39.3	-9968.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-77.28	0
Jan-29	45.1	-9988.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-77.56	0
Feb-29	15.3	-10037.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-77.84	0
Mar-29	90.4	-10012.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-78.12	0
Apr-29	21.1	-10056.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-78.4	0
May-29		-10121.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-78.68	0
Jun-29	26.4	-10159.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-78.96	0
Jul-29	15.2	-10209.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-79.24	0
Aug-29	40.1	-10234.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-79.52	0
Sep-29	22.1	-10277.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-79.8	0
Oct-29	33.2	-10309.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-80.08	0
Nov-29	103.7	-10270.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-80.36	0
Dec-29	25.9	-10309.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-80.64	0
Jan-30	20.3	-10354.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-80.92	0
Feb-30	28.6	-10390.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-81.2	0
Mar-30	102.1	-10353.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-81.48	0
Apr-30	63	-10355.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-81.76	0
May-30	77.5	-10343.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-82.04	0
Jun-30	22.9	-10385.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-82.32	0
Jul-30	5.1	-10445.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-82.6	0
Aug-30		-10510.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-82.88	0
Sep-30	8.1	-10567.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-83.16	0
Oct-30	0	-10632.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-83.44	0
Nov-30	0	-10697.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-83.72	0
Dec-30	23.4	-10738.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-84	0
Jan-31	20.9	-10782.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-84.28	0
Feb-31	42.1	-10805.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-84.56	0
Mar-31	77.9	-10792.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-84.84	0
Apr-31	23.8	-10834	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-85.12	0
May-31	68.3	-10830.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-85.4	0
Jun-31	98.6	-10797.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-85.68	0
Jul-31	0	-10862.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-85.96	0
Aug-31	0	-10927.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-86.24	0
Sep-31	24.2	-10967.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-86.52	0
Oct-31	0	-11032.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-86.8	0
Nov-31	0	-11097.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-87.08	0
Dec-31	22.2	-11140.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-87.36	0
Jan-32	125.3	-11080.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-87.64	0
Feb-32	16.7	-11128.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-87.92	0
Mar-32	33.6	-11160.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-88.2	0
Apr-32	78.5	-11146.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-88.48	0
May-32	56.4	-11155.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-88.76	0
Jun-32	9.1	-11211.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-89.04	0
Jul-32	5.8	-11270.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-89.32	0
Aug-32	2.5	-11332.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-89.6	0
Sep-32	0	-11397.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-89.88	0

Oct-32	0	-11462.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-90.16	0
Nov-32	48.5	-11479.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-90.44	0
Dec-32	8.9	-11535.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-90.72	0
Jan-33	18	-11582.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-91	0
Feb-33	24	-11623.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-91.28	0
Mar-33	14.9	-11673.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-91.56	0
Apr-33	6.9	-11731.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-91.84	0
May-33	3.8	-11792.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-92.12	0
Jun-33	43.8	-11814	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-92.4	0
Jul-33	1.8	-11877.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-92.68	0
Aug-33	3.6	-11938.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-92.96	0
Sep-33	0	-12003.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-93.24	0
Oct-33	0	-12068.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-93.52	0
Nov-33	0	-12133.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-93.8	0
Dec-33	0	-12198.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-94.08	0
Jan-34	121.1	-12142.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-94.36	0
Feb-34	105	-12102.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-94.64	0
Mar-34	110.2	-12057.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-94.92	0
Apr-34	97.8	-12024.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-95.2	0
May-34	99.3	-11990.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-95.48	0
Jun-34	29.1	-12026.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-95.76	0
Jul-34	36.1	-12055	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-96.04	0
Aug-34	0	-12120	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-96.32	0
Sep-34	2.8	-12182.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-96.6	0
Oct-34	0	-12247.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-96.88	0
Nov-34	0	-12312.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-97.16	0
Dec-34	79.5	-12297.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-97.44	0
Jan-35	112.4	-12250.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-97.72	0
Feb-35	76	-12239.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-98	0
Mar-35	20.6	-12283.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-98.28	0
Apr-35	57.4	-12291.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-98.56	0
May-35	108.3	-12248	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-98.84	0
Jun-35	45.5	-12267.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-99.12	0
Jul-35	61	-12271.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-99.4	0
Aug-35	19.6	-12316.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-99.68	0
Sep-35	0	-12381.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-99.96	0
Oct-35	8.1	-12438.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-100.24	0
Nov-35	7.6	-12496.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-100.52	0
Dec-35	41.4	-12519.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-100.8	0
Jan-36	75.4	-12509.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-101.08	0
Feb-36	78.4	-12496	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-101.36	0
Mar-36	29.6	-12531.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-101.64	0
Apr-36	25.4	-12571	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-101.92	0
May-36	90.5	-12545.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-102.2	0
Jun-36	48.7	-12561.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-102.48	0
Jul-36	66.6	-12560.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-102.76	0
Aug-36	2	-12623.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-103.04	0
Sep-36	0	-12688.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-103.32	0
Oct-36	0	-12753.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-103.6	0
Nov-36	31.2	-12787	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-103.88	0
Dec-36	49.5	-12802.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-104.16	0
Jan-37	131.8	-12735.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-104.44	0
Feb-37	57.8	-12742.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-104.72	0
Mar-37	36.8	-12771.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-105	0
Apr-37	64.1	-12772	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-105.28	0
May-37	81.2	-12755.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-105.56	0
Jun-37	0	-12820.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-105.84	0
Jul-37	16.5	-12869.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-106.12	0
Aug-37	0	-12934.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-106.4	0
Sep-37	3.3	-12996	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-106.68	0
Oct-37	0	-13061	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-106.96	0
Nov-37	0	-13126	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-107.24	0
Dec-37	20.3	-13170.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-107.52	0
Jan-38	54.1	-13181.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-107.8	0
Feb-38	62	-13184.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-108.08	0
Mar-38	29.9	-13219.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-108.36	0
Apr-38	53.4	-13231.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-108.64	0
May-38	33.6	-13262.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-108.92	0
Jun-38	63.6	-13264.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-109.2	0
Jul-38	0	-13329.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-109.48	0

Aug-38	30.2	-13363.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-109.76	0
Sep-38	6.3	-13422.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-110.04	0
Oct-38	12.7	-13474.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-110.32	0
Nov-38	0	-13539.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-110.6	0
Dec-38	55.8	-13549.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-110.88	0
Jan-39	56.3	-13557.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-111.16	0
Feb-39	18.8	-13604	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-111.44	0
Mar-39	117.4	-13551.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-111.72	0
Apr-39	63.9	-13552.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-112	0
May-39	3	-13614.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-112.28	0
Jun-39	0	-13679.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-112.56	0
Jul-39	19.8	-13724.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-112.84	0
Aug-39	0	-13789.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-113.12	0
Sep-39	15.5	-13839.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-113.4	0
Oct-39	0	-13904.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-113.68	0
Nov-39	0	-13969.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-113.96	0
Dec-39	72.1	-13962.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-114.24	0
Jan-40	60.5	-13966.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-114.52	0
Feb-40	2.5	-14029.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-114.8	0
Mar-40	26.2	-14068.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-115.08	0
Apr-40	55	-14078.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-115.36	0
May-40	161.1	-13982	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-115.64	0
Jun-40	33.2	-14013.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-115.92	0
Jul-40	11.9	-14066.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-116.2	0
Aug-40	7.1	-14124.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-116.48	0
Sep-40	6.4	-14183.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-116.76	0
Oct-40	0	-14248.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-117.04	0
Nov-40	35.2	-14278.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-117.32	0
Dec-40	17.5	-14325.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-117.6	0
Jan-41	32.7	-14358	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-117.88	0
Feb-41	61.5	-14361.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-118.16	0
Mar-41	168.2	-14258.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-118.44	0
Apr-41	154.2	-14169.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-118.72	0
May-41	0	-14234.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-119	0
Jun-41	14.5	-14284.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-119.28	0
Jul-41	0	-14349.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-119.56	0
Aug-41	0	-14414.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-119.84	0
Sep-41	8.9	-14470.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-120.12	0
Oct-41	6.1	-14529.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-120.4	0
Nov-41	25.9	-14568.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-120.68	0
Dec-41	46.7	-14587	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-120.96	0
Jan-42	0	-14652	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-121.24	0
Feb-42	5.1	-14711.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-121.52	0
Mar-42		-14776.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-121.8	0
Apr-42	49.3	-14792.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-122.08	0
May-42	103.9	-14753.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-122.36	0
Jun-42	60.7	-14758	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-122.64	0
Jul-42	15.5	-14807.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-122.92	0
Aug-42	0	-14872.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-123.2	0
Sep-42	0	-14937.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-123.48	0
Oct-42	12.7	-14989.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-123.76	0
Nov-42	5.6	-15049.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-124.04	0
Dec-42	90	-15024.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-124.32	0
Jan-43	32.9	-15056.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-124.6	0
Feb-43	109.6	-15011.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-124.88	0
Mar-43	53.9	-15022.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-125.16	0
Apr-43	63.5	-15024.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-125.44	0
May-43	107.5	-14981.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-125.72	0
Jun-43	180.5	-14866.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-126	0
Jul-43	71.7	-14859.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-126.28	0
Aug-43	0	-14924.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-126.56	0
Sep-43	26.2	-14963.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-126.84	0
Oct-43	131.3	-14897.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-127.12	0
Nov-43	3	-14959.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-127.4	0
Dec-43	77.2	-14946.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-127.68	0
Jan-44	128.4	-14883.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-127.96	0
Feb-44	59.7	-14888.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-128.24	0
Mar-44	48.2	-14905.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-128.52	0
Apr-44	45	-14925.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-128.8	0
May-44	58.3	-14932.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-129.08	0

Apr-50	62.3	-17698.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-148.96	0
May-50	117.9	-17645.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-149.24	0
Jun-50	93.4	-17617.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-149.52	0
Jul-50	38.9	-17643.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-149.8	0
Aug-50	2.5	-17705.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-150.08	0
Sep-50	1	-17769.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-150.36	0
Oct-50	68.1	-17766.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-150.64	0
Nov-50	10.9	-17820.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-150.92	0
Dec-50	13.8	-17872.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-151.2	0
Jan-51	33.5	-17903.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-151.48	0
Feb-51	120.5	-17848.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-151.76	0
Mar-51	68.7	-17844.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-152.04	0
Apr-51	37.1	-17872.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-152.32	0
May-51	21.4	-17915.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-152.6	0
Jun-51	48	-17932.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-152.88	0
Jul-51	14.2	-17983.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-153.16	0
Aug-51	0	-18048.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-153.44	0
Sep-51	0	-18113.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-153.72	0
Oct-51	0	-18178.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-154	0
Nov-51	8.6	-18235.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-154.28	0
Dec-51	54.8	-18245.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-154.56	0
Jan-52	4.9	-18305.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-154.84	0
Feb-52	8.9	-18361.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-155.12	0
Mar-52	40.8	-18385.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-155.4	0
Apr-52	53.8	-18396.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-155.68	0
May-52	33.4	-18428.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-155.96	0
Jun-52	22.8	-18470.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-156.24	0
Jul-52	0	-18535.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-156.52	0
Aug-52	0	-18600.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-156.8	0
Sep-52	49.9	-18615.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-157.08	0
Oct-52	0	-18680.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-157.36	0
Nov-52	13.4	-18732.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-157.64	0
Dec-52	50.8	-18746.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-157.92	0
Jan-53	68.1	-18743.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-158.2	0
Feb-53	26	-18782.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-158.48	0
Mar-53	98.8	-18748.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-158.76	0
Apr-53	144.8	-18668.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-159.04	0
May-53	37.8	-18696.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-159.32	0
Jun-53	83.5	-18677.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-159.6	0
Jul-53	4.5	-18738.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-159.88	0
Aug-53	0	-18803.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-160.16	0
Sep-53	0	-18868.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-160.44	0
Oct-53	0	-18933.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-160.72	0
Nov-53	9	-18989.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-161	0
Dec-53	31	-19023.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-161.28	0
Jan-54	26	-19062.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-161.56	0
Feb-54	79.7	-19047.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-161.84	0
Mar-54	32.4	-19080	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-162.12	0
Apr-54	42.4	-19102.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-162.4	0
May-54	137.3	-19030.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-162.68	0
Jun-54	25	-19070.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-162.96	0
Jul-54	17	-19118.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-163.24	0
Aug-54	0	-19183.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-163.52	0
Sep-54	0	-19248.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-163.8	0
Oct-54	0	-19313.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-164.08	0
Nov-54	0	-19378.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-164.36	0
Dec-54	0	-19443.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-164.64	0
Jan-55	65.6	-19442.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-164.92	0
Feb-55	32.4	-19475.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-165.2	0
Mar-55	157.8	-19382.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-165.48	0
Apr-55	184.3	-19263.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-165.76	0
May-55	23.5	-19304.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-166.04	0
Jun-55	60.2	-19309.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-166.32	0
Jul-55	21	-19353.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-166.6	0
Aug-55	15.7	-19402.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-166.88	0
Sep-55	19.5	-19448.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-167.16	0
Oct-55	0	-19513.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-167.44	0
Nov-55	0.5	-19577.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-167.72	0
Dec-55	35.3	-19607.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-168	0
Jan-56	99	-19573.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-168.28	0

Feb-56	59.8	-19578.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-168.56	0
Mar-56	61.7	-19582	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-168.84	0
Apr-56	83.6	-19563.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-169.12	0
May-56	140.4	-19488	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-169.4	0
Jun-56	50.6	-19502.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-169.68	0
Jul-56	10.7	-19556.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-169.96	0
Aug-56	1.2	-19620.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-170.24	0
Sep-56	2.3	-19683.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-170.52	0
Oct-56	0	-19748.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-170.8	0
Nov-56	16	-19797.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-171.08	0
Dec-56	48.5	-19813.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-171.36	0
Jan-57	54.9	-19823.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-171.64	0
Feb-57	97.5	-19791.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-171.92	0
Mar-57	21.5	-19834.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-172.2	0
Apr-57	86.3	-19813.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-172.48	0
May-57	40.5	-19838	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-172.76	0
Jun-57	18.2	-19884.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-173.04	0
Jul-57	5	-19944.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-173.32	0
Aug-57	64.5	-19945.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-173.6	0
Sep-57	19.2	-19991.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-173.88	0
Oct-57	58.9	-19997.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-174.16	0
Nov-57	57.1	-20005.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-174.44	0
Dec-57	79.6	-19990.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-174.72	0
Jan-58	66.6	-19988.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-175	0
Feb-58	85.2	-19968.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-175.28	0
Mar-58	58.3	-19975.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-175.56	0
Apr-58	31.7	-20008.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-175.84	0
May-58	27.4	-20046.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-176.12	0
Jun-58	11.8	-20099.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-176.4	0
Jul-58	37.9	-20126.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-176.68	0
Aug-58	0	-20191.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-176.96	0
Sep-58	0	-20256.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-177.24	0
Oct-58	0	-20321.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-177.52	0
Nov-58	4.5	-20382.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-177.8	0
Dec-58	11.5	-20435.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-178.08	0
Jan-59	64.5	-20436.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-178.36	0
Feb-59	74.3	-20426.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-178.64	0
Mar-59	63.8	-20428	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-178.92	0
Apr-59	112	-20381	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-179.2	0
May-59	54.3	-20391.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-179.48	0
Jun-59	52.8	-20403.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-179.76	0
Jul-59	31.3	-20437.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-180.04	0
Aug-59	0	-20502.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-180.32	0
Sep-59	16.9	-20550.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-180.6	0
Oct-59	0	-20615.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-180.88	0
Nov-59	0	-20680.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-181.16	0
Dec-59	40.9	-20704.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-181.44	0
Jan-60	64.4	-20705.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-181.72	0
Feb-60	68	-20702.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-182	0
Mar-60	20.9	-20746.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-182.28	0
Apr-60	13.9	-20797.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-182.56	0
May-60	60.4	-20802.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-182.84	0
Jun-60	42.7	-20824.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-183.12	0
Jul-60	10.8	-20878.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-183.4	0
Aug-60	6.8	-20936.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-183.68	0
Sep-60	8.4	-20993.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-183.96	0
Oct-60	32.4	-21026.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-184.24	0
Nov-60	1.7	-21089.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-184.52	0
Dec-60	71.4	-21083	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-184.8	0
Jan-61	32.8	-21115.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-185.08	0
Feb-61	48.1	-21132.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-185.36	0
Mar-61	46.1	-21151	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-185.64	0
Apr-61	20	-21196	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-185.92	0
May-61	196.2	-21064.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-186.2	0
Jun-61	64.2	-21065.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-186.48	0
Jul-61	37	-21093.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-186.76	0
Aug-61	34.2	-21124.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-187.04	0
Sep-61	39.2	-21150.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-187.32	0
Oct-61	21	-21194.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-187.6	0
Nov-61	0	-21259.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-187.88	0

Dec-61	0	-21324.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-188.16	0
Jan-62	49.1	-21340.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-188.44	0
Feb-62	18.9	-21386.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-188.72	0
Mar-62	33	-21418.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-189	0
Apr-62	103	-21380.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-189.28	0
May-62	70	-21375.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-189.56	0
Jun-62	87	-21353.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-189.84	0
Jul-62	0	-21418.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-190.12	0
Aug-62	0	-21483.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-190.4	0
Sep-62	0	-21548.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-190.68	0
Oct-62	0	-21613.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-190.96	0
Nov-62	0	-21678.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-191.24	0
Dec-62	37.8	-21705.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-191.52	0
Jan-63	63.5	-21706.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-191.8	0
Feb-63	18	-21753.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-192.08	0
Mar-63	136.7	-21682.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-192.36	0
Apr-63	15	-21732.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-192.64	0
May-63	154	-21643.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-192.92	0
Jun-63	125.5	-21582.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-193.2	0
Jul-63	15.2	-21632.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-193.48	0
Aug-63	6	-21691.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-193.76	0
Sep-63	10	-21746.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-194.04	0
Oct-63	2	-21809.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-194.32	0
Nov-63	0	-21874.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-194.6	0
Dec-63	41.7	-21897.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-194.88	0
Jan-64	152	-21810.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-195.16	0
Feb-64	19.3	-21856.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-195.44	0
Mar-64	10.4	-21911.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-195.72	0
Apr-64	38	-21938.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-196	0
May-64	83.8	-21919.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-196.28	0
Jun-64	22.6	-21961.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-196.56	0
Jul-64	8.5	-22018.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-196.84	0
Aug-64	22.5	-22060.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-197.12	0
Sep-64	0	-22125.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-197.4	0
Oct-64	0	-22190.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-197.68	0
Nov-64	0	-22255.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-197.96	0
Dec-64	66.2	-22254.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-198.24	0
Jan-65	12	-22307.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-198.52	0
Feb-65	43.8	-22328.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-198.8	0
Mar-65	107.1	-22286.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-199.08	0
Apr-65	4	-22347.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-199.36	0
May-65	18.5	-22394.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-199.64	0
Jun-65	83.3	-22375.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-199.92	0
Jul-65	0	-22440.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-200.2	0
Aug-65	4.5	-22501.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-200.48	0
Sep-65	28	-22538.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-200.76	0
Oct-65	2	-22601.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-201.04	0
Nov-65	5.5	-22660.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-201.32	0
Dec-65	7.7	-22718.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-201.6	0
Jan-66	15	-22768.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-201.88	0
Feb-66	15.5	-22817.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-202.16	0
Mar-66	211.8	-22670.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-202.44	0
Apr-66	44.4	-22691.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-202.72	0
May-66	4	-22752.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-203	0
Jun-66	12.9	-22804.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-203.28	0
Jul-66	0	-22869.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-203.56	0
Aug-66	4.9	-22929.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-203.84	0
Sep-66	0	-22994.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-204.12	0
Oct-66	0	-23059.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-204.4	0
Nov-66	0	-23124.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-204.68	0
Dec-66	5.8	-23183.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-204.96	0
Jan-67	41.3	-23207.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-205.24	0
Feb-67	65.7	-23206.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-205.52	0
Mar-67	86.9	-23184.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-205.8	0
Apr-67	51.2	-23198.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-206.08	0
May-67	94.5	-23169.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-206.36	0
Jun-67	143.9	-23090.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-206.64	0
Jul-67	71.5	-23083.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-206.92	0
Aug-67	8.5	-23140.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-207.2	0
Sep-67	0	-23205.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-207.48	0

Oct-67	14	-23256.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-207.76	0
Nov-67	1	-23320.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-208.04	0
Dec-67	57	-23328.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-208.32	0
Jan-68	48.5	-23344.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-208.6	0
Feb-68	0	-23409.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-208.88	0
Mar-68	36.5	-23438.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-209.16	0
Apr-68	3	-23500.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-209.44	0
May-68	84	-23481.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-209.72	0
Jun-68	95	-23451.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-210	0
Jul-68	56.6	-23459.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-210.28	0
Aug-68	0	-23524.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-210.56	0
Sep-68	0	-23589.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-210.84	0
Oct-68	0	-23654.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-211.12	0
Nov-68	0	-23719.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-211.4	0
Dec-68	39.5	-23745.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-211.68	0
Jan-69	14.7	-23795.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-211.96	0
Feb-69	80.5	-23780	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-212.24	0
Mar-69	2	-23843	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-212.52	0
Apr-69	56.7	-23851.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-212.8	0
May-69	34.5	-23881.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-213.08	0
Jun-69	70	-23876.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-213.36	0
Jul-69	40.8	-23901	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-213.64	0
Aug-69	1.5	-23964.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-213.92	0
Sep-69	0	-24029.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-214.2	0
Oct-69	2	-24092.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-214.48	0
Nov-69	7.5	-24150	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-214.76	0
Dec-69	90.4	-24124.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-215.04	0
Jan-70	27	-24162.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-215.32	0
Feb-70	9	-24218.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-215.6	0
Mar-70	72	-24211.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-215.88	0
Apr-70	27	-24249.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-216.16	0
May-70	12	-24302.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-216.44	0
Jun-70	20.5	-24347.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-216.72	0
Jul-70	27.5	-24384.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-217	0
Aug-70	42	-24407.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-217.28	0
Sep-70	20.2	-24452.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-217.56	0
Oct-70	2.5	-24514.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-217.84	0
Nov-70	53	-24526.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-218.12	0
Dec-70	46	-24545.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-218.4	0
Jan-71	11	-24599.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-218.68	0
Feb-71	78.5	-24586.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-218.96	0
Mar-71	81.5	-24569.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-219.24	0
Apr-71	55	-24579.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-219.52	0
May-71	47	-24597.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-219.8	0
Jun-71	39	-24623.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-220.08	0
Jul-71	31.5	-24657.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-220.36	0
Aug-71	5.5	-24716.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-220.64	0
Sep-71	6.5	-24775.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-220.92	0
Oct-71	0	-24840.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-221.2	0
Nov-71	0	-24905.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-221.48	0
Dec-71	37.5	-24932.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-221.76	0
Jan-72	13	-24984.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-222.04	0
Feb-72	35	-25014.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-222.32	0
Mar-72	87.5	-24992.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-222.6	0
Apr-72	105.5	-24951.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-222.88	0
May-72	106.5	-24910.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-223.16	0
Jun-72	79	-24896.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-223.44	0
Jul-72	5.5	-24955.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-223.72	0
Aug-72	0	-25020.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-224	0
Sep-72	0	-25085.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-224.28	0
Oct-72	0	-25150.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-224.56	0
Nov-72	0	-25215.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-224.84	0
Dec-72	19	-25261.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-225.12	0
Jan-73	64	-25262.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-225.4	0
Feb-73	0	-25327.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-225.68	0
Mar-73	22	-25370.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-225.96	0
Apr-73	70.9	-25365	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-226.24	0
May-73	14	-25416	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-226.52	0
Jun-73	76.3	-25404.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-226.8	0
Jul-73	0	-25469.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-227.08	0

Jun-79	1.9	-26571.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-246.96	0
Jul-79	1.9	-26634.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-247.24	0
Aug-79	0	-26699.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-247.52	0
Sep-79	51.8	-26712.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-247.8	0
Oct-79	66.8	-26710.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-248.08	0
Nov-79	0	-26775.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-248.36	0
Dec-79	55.5	-26785.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-248.64	0
Jan-80	38.3	-26811.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-248.92	0
Feb-80	0	-26876.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-249.2	0
Mar-80	20.5	-26921.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-249.48	0
Apr-80	72	-26914.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-249.76	0
May-80	33.3	-26946.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-250.04	0
Jun-80	0	-27011.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-250.32	0
Jul-80	0	-27076.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-250.6	0
Aug-80	0	-27141.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-250.88	0
Sep-80	3.5	-27202.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-251.16	0
Oct-80	27	-27240.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-251.44	0
Nov-80	63	-27242.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-251.72	0
Dec-80	0	-27307.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-252	0
Jan-81	155	-27217.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-252.28	0
Feb-81	0	-27282.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-252.56	0
Mar-81	96	-27251.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-252.84	0
Apr-81	102	-27214.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-253.12	0
May-81	75.5	-27204.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-253.4	0
Jun-81	0	-27269.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-253.68	0
Jul-81	0	-27334.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-253.96	0
Aug-81	0	-27399.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-254.24	0
Sep-81	0	-27464.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-254.52	0
Oct-81	53.5	-27475.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-254.8	0
Nov-81	0	-27540.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-255.08	0
Dec-81	0	-27605.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-255.36	0
Jan-82	0	-27670.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-255.64	0
Feb-82	87.9	-27647.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-255.92	0
Mar-82	27.2	-27685.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-256.2	0
Apr-82	43	-27707.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-256.48	0
May-82	67	-27705.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-256.76	0
Jun-82	59.3	-27711.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-257.04	0
Jul-82	0	-27776.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-257.32	0
Aug-82	22.5	-27818.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-257.6	0
Sep-82	27.1	-27856.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-257.88	0
Oct-82	0	-27921.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-258.16	0
Nov-82	22	-27964.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-258.44	0
Dec-82	0	-28029.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-258.72	0
Jan-83	0	-28094.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-259	0
Feb-83	2.5	-28157.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-259.28	0
Mar-83	12	-28210.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-259.56	0
Apr-83	21.5	-28253.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-259.84	0
May-83	13.6	-28305	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-260.12	0
Jun-83	0	-28370	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-260.4	0
Jul-83	7.5	-28427.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-260.68	0
Aug-83	19.5	-28473	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-260.96	0
Sep-83	26	-28512	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-261.24	0
Oct-83	0	-28577	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-261.52	0
Nov-83	4	-28638	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-261.8	0
Dec-83	25	-28678	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-262.08	0
Jan-84	45	-28698	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-262.36	0
Feb-84	44	-28719	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-262.64	0
Mar-84	18	-28766	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-262.92	0
Apr-84	30.5	-28800.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-263.2	0
May-84	64.7	-28800.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-263.48	0
Jun-84	30	-28835.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-263.76	0
Jul-84	52.5	-28848.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-264.04	0
Aug-84	0	-28913.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-264.32	0
Sep-84	5	-28973.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-264.6	0
Oct-84	12	-29026.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-264.88	0
Nov-84	0	-29091.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-265.16	0
Dec-84	33	-29123.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-265.44	0
Jan-85	23.5	-29164.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-265.72	0
Feb-85	12	-29217.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-266	0
Mar-85	65	-29217.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-266.28	0

Apr-85	59	-29223.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-266.56	0
May-85	0	-29288.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-266.84	0
Jun-85	0	-29353.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-267.12	0
Jul-85	0	-29418.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-267.4	0
Aug-85	4	-29479.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-267.68	0
Sep-85	0	-29544.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-267.96	0
Oct-85	0	-29609.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-268.24	0
Nov-85	0	-29674.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-268.52	0
Dec-85	75	-29664.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-268.8	0
Jan-86	51	-29678.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-269.08	0
Feb-86	56.5	-29687.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-269.36	0
Mar-86	18	-29734.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-269.64	0
Apr-86	24.8	-29774.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-269.92	0
May-86	92.8	-29746.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-270.2	0
Jun-86	13.1	-29798.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-270.48	0
Jul-86	0	-29863.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-270.76	0
Aug-86	9.5	-29919.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-271.04	0
Sep-86	0	-29984.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-271.32	0
Oct-86	20.5	-30028.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-271.6	0
Nov-86	6	-30087.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-271.88	0
Dec-86	65.6	-30087	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-272.16	0
Jan-87	71	-30081	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-272.44	0
Feb-87	8	-30138	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-272.72	0
Mar-87	6	-30197	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-273	0
Apr-87	33	-30229	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-273.28	0
May-87	33.5	-30260.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-273.56	0
Jun-87	54	-30271.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-273.84	0
Jul-87	0	-30336.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-274.12	0
Aug-87	0	-30401.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-274.4	0
Sep-87	21	-30445.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-274.68	0
Oct-87	40.5	-30470	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-274.96	0
Nov-87	80	-30455	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-275.24	0
Dec-87	14.5	-30505.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-275.52	0
Jan-88	102.5	-30468	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-275.8	0
Feb-88	24	-30509	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-276.08	0
Mar-88	16	-30558	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-276.36	0
Apr-88	381.1	-30241.9	381.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	104.74	381.1
May-88	68.1	-30238.8	0	FALSE	TRUE	TRUE	TRUE	68.1	TRUE	172.84	68.1
Jun-88	139.5	-30164.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	172.56	0
Jul-88	0	-30229.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	172.28	0
Aug-88	15	-30279.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	172	0
Sep-88	0	-30344.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	171.72	0
Oct-88	0	-30409.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	171.44	0
Nov-88	53	-30421.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	171.16	0
Dec-88	63.1	-30423.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	170.88	0
Jan-89	29	-30459.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	170.6	0
Feb-89	103	-30421.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	170.32	0
Mar-89	87	-30399.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	170.04	0
Apr-89	111	-30353.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	169.76	0
May-89	47.5	-30370.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	169.48	0
Jun-89	100.8	-30334.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	169.2	0
Jul-89	23.5	-30376.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	168.92	0
Aug-89	0.4	-30441	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	168.64	0
Sep-89	1.5	-30504.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	168.36	0
Oct-89	0	-30569.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	168.08	0
Nov-89	7.6	-30626.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	167.8	0
Dec-89	22	-30669.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	167.52	0
Jan-90	49.5	-30685.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	167.24	0
Feb-90	31.9	-30718.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	166.96	0
Mar-90	58	-30725.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	166.68	0
Apr-90	106	-30684.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	166.4	0
May-90	91.5	-30658	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	166.12	0
Jun-90	55.8	-30667.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	165.84	0
Jul-90	0	-30732.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	165.56	0
Aug-90	13	-30784.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	165.28	0
Sep-90	0	-30849.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	165	0
Oct-90	7	-30907.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	164.72	0
Nov-90	0	-30972.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	164.44	0
Dec-90	0	-31037.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	164.16	0
Jan-91	1	-31101.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	163.88	0

Feb-91	29	-31137.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	163.6	0
Mar-91	196	-31006.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	163.32	0
Apr-91	10.7	-31060.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	163.04	0
May-91	140	-30985.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	162.76	0
Jun-91	0	-31050.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	162.48	0
Jul-91		-31115.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	162.2	0
Aug-91	20	-31160.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	161.92	0
Sep-91	3	-31222.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	161.64	0
Oct-91	0	-31287.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	161.36	0
Nov-91	25	-31327.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	161.08	0
Dec-91	134.5	-31258	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	160.8	0
Jan-92	45.5	-31277.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	160.52	0
Feb-92	54	-31288.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	160.24	0
Mar-92	7	-31346.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	159.96	0
Apr-92	10	-31401.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	159.68	0
May-92	48.5	-31418	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	159.4	0
Jun-92	23	-31460	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	159.12	0
Jul-92	0	-31525	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	158.84	0
Aug-92	0	-31590	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	158.56	0
Sep-92	0	-31655	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	158.28	0
Oct-92	1.5	-31718.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	158	0
Nov-92	0	-31783.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	157.72	0
Dec-92	37	-31811.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	157.44	0
Jan-93	73.5	-31803	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	157.16	0
Feb-93	0	-31868	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	156.88	0
Mar-93	40	-31893	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	156.6	0
Apr-93	65.5	-31892.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	156.32	0
May-93	8	-31949.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	156.04	0
Jun-93	51	-31963.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	155.76	0
Jul-93	8	-32020.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	155.48	0
Aug-93	1	-32084.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	155.2	0
Sep-93	0	-32149.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	154.92	0
Oct-93	12	-32202.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	154.64	0
Nov-93	0	-32267.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	154.36	0
Dec-93	156	-32176.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	154.08	0
Jan-94	50	-32191.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	153.8	0
Feb-94	84	-32172.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	153.52	0
Mar-94	88.5	-32149	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	153.24	0
Apr-94	121	-32093	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	152.96	0
May-94	101	-32057	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	152.68	0
Jun-94	4	-32118	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	152.4	0
Jul-94	0	-32183	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	152.12	0
Aug-94	1	-32247	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	151.84	0
Sep-94	0	-32312	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	151.56	0
Oct-94	0	-32377	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	151.28	0
Nov-94	0	-32442	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	151	0
Dec-94	0	-32507	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	150.72	0
Jan-95	15	-32557	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	150.44	0
Feb-95	6.5	-32615.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	150.16	0
Mar-95	60	-32620.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	149.88	0
Apr-95	38.5	-32647	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	149.6	0
May-95	29	-32683	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	149.32	0
Jun-95	84	-32664	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	149.04	0
Jul-95	47	-32682	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	148.76	0
Aug-95	0	-32747	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	148.48	0
Sep-95	0	-32812	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	148.2	0
Oct-95	0	-32877	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	147.92	0
Nov-95	14	-32928	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	147.64	0
Dec-95	87	-32906	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	147.36	0
Jan-96	15	-32956	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	147.08	0
Feb-96	73	-32948	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	146.8	0
Mar-96	97	-32916	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	146.52	0
Apr-96	69.5	-32911.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	146.24	0
May-96	65.5	-32911	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	145.96	0
Jun-96	28	-32948	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	145.68	0
Jul-96	7	-33006	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	145.4	0
Aug-96	0	-33071	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	145.12	0
Sep-96	15	-33121	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	144.84	0
Oct-96	5	-33181	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	144.56	0
Nov-96	5	-33241	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	144.28	0

Dec-96	3	-33303	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	144	0
Jan-97	88	-33280	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	143.72	0
Feb-97	78	-33267	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	143.44	0
Mar-97	125	-33207	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	143.16	0
Apr-97	46	-33226	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	142.88	0
May-97	73	-33218	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	142.6	0
Jun-97	4	-33279	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	142.32	0
Jul-97	30	-33314	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	142.04	0
Aug-97	23	-33356	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	141.76	0
Sep-97	13	-33408	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	141.48	0
Oct-97	3	-33470	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	141.2	0
Nov-97	0	-33535	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	140.92	0
Dec-97	56	-33544	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	140.64	0
Jan-98	5	-33604	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	140.36	0
Feb-98	46	-33623	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	140.08	0
Mar-98	66	-33622	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	139.8	0
Apr-98	155	-33532	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	139.52	0
May-98	51.5	-33545.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	139.24	0
Jun-98	26	-33584.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	138.96	0
Jul-98	0	-33649.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	138.68	0
Aug-98	0	-33714.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	138.4	0
Sep-98	14	-33765.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	138.12	0
Oct-98	0	-33830.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	137.84	0
Nov-98	15	-33880.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	137.56	0
Dec-98	30	-33915.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	137.28	0
Jan-99	46	-33934.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	137	0
Feb-99	9.5	-33990	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	136.72	0
Mar-99	66	-33989	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	136.44	0
Apr-99	34.5	-34019.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	136.16	0
May-99	20.5	-34064	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	135.88	0
Jun-99	22	-34107	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	135.6	0
Jul-99	0	-34172	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	135.32	0
Aug-99	0	-34237	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	135.04	0
Sep-99	0	-34302	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	134.76	0
Oct-99	0	-34367	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	134.48	0
Nov-99	0	-34432	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	134.2	0
Dec-99	0	-34497	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	133.92	0
Jan-00	2	-34560	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	133.64	0
Feb-00	95	-34530	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	133.36	0
Mar-00	57	-34538	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	133.08	0
Apr-00	110	-34493	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	132.8	0
May-00	73	-34485	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	132.52	0
Jun-00	3	-34547	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	132.24	0
Jul-00	0	-34612	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	131.96	0
Aug-00	0	-34677	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	131.68	0
Sep-00	0	-34742	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	131.4	0
Oct-00		-34807	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	131.12	0
Nov-00		-34872	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	130.84	0
Dec-00		-34937	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	130.56	0
Jan-01		-35002	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	130.28	0
Feb-01	366	-34701	366	TRUE	TRUE	FALSE	FALSE	0	TRUE	496.28	366
Mar-01	11	-34755	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	496	0
Apr-01	95	-34725	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	495.72	0
May-01	109	-34681	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	495.44	0
Jun-01	15	-34731	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	495.16	0
Jul-01	25	-34771	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	494.88	0
Aug-01	0	-34836	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	494.6	0
Sep-01	13	-34888	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	494.32	0
Oct-01	44	-34909	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	494.04	0
Nov-01	60	-34914	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	493.76	0
Dec-01	79	-34900	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	493.48	0
Jan-02	103	-34862	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	493.2	0
Feb-02	184	-34743	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	492.92	0
Mar-02	41	-34767	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	492.64	0
Apr-02	39.5	-34792.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	492.36	0
May-02	11	-34846.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	492.08	0
Jun-02	54	-34857.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	491.8	0
Jul-02	10	-34912.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	491.52	0
Aug-02	0	-34977.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	491.24	0
Sep-02	86	-34956.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	490.96	0
Oct-02	26	-34995.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	490.68	0
Nov-02	28	-35032.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	490.4	0
TOTALS	**40497.5**	**-21494979.4**	**747.1**								**815.2**

Adaption of CRD Method to allow for episodic recharge

Study area **Hotazel**
Recharge via **Preferential pathways**

CRD_{ave} =	$CRD_i = P_i + CRD_{i-1} - P_{ave}$	Excel formulas used
A =	Values above high threshold	if(P_i < high threshold, 0, P_i)
B =	Test to see whether Pi > high theshold	and(Pi > high theshold)
C =	Test to see whether Pi > low theshold	and(P_i > low threshold
D =	Test to see whether low threshold follows high threshold	and(C_i = true, B_{i-1} = true)
E =	Test to confirm thesholds are in correct order	and(B_{i-1} = true, B_i = false,C_i = true)
F =	Test to determine where sequential recharge occurs	if(E_i = true, E_i, 0)
G =	Test to see whether the high or low recharge threshold has been exceeded	or(A_i > 0,F_i > 0)
H =	Test to see whether CRDi = CRDi-1+Pi or CRDi = CRDi-1 - RF	if(G = true, $CRD_{i-1} + P_i$, CRD_{i-1} - RF)

Note: a) To obtain episodic CRD, plot Month versus "H (mm)";
b) RF must be adjusted until trendline through episodic CRD plot is horizontal;
c) "I (mm)" is used for averaging calculations only.

Average episodic threshold (low)	10	mm
Average episodic threshold (high)	55	mm
Total number of months	508	months
No. of months above CRD2 threshold	138	months
Average (all values)	30.4	mm
Average CRD2 values	83.7	mm
% Recharge months	27.2	%
Recession Factor (RF)	28.9	mm/month

Month	Rain	CRD_{ave}(mm)	A (mm)	B	C	D	E	F (mm)	G	H (mm)	I (mm)
Aug-60	9	9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-28.9	0
Sep-60	0	-1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-57.8	0
Oct-60	0	-11	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-86.7	0
Nov-60	56.5	35.5	56.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-30.2	56.5
Dec-60	19	44.5	0	FALSE	TRUE	TRUE	TRUE	19	TRUE	-11.2	19
Jan-61	37	71.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-40.1	0
Feb-61	60	121.5	60	TRUE	TRUE	FALSE	FALSE	0	TRUE	19.9	60
Mar-61	113.5	225	113.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	133.4	113.5
Apr-61	190	405	190	TRUE	TRUE	TRUE	FALSE	0	TRUE	323.4	190
May-61	34.5	429.5	0	FALSE	TRUE	TRUE	TRUE	34.5	TRUE	357.9	34.5
Jun-61	51.5	471	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	329	0
Jul-61	32.5	493.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	300.1	0
Aug-61	0	483.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	271.2	0
Sep-61	0	473.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	242.3	0
Oct-61	0	463.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	213.4	0
Nov-61	97	550.5	97	TRUE	TRUE	FALSE	FALSE	0	TRUE	310.4	97
Dec-61	30	570.5	0	FALSE	TRUE	TRUE	TRUE	30	TRUE	340.4	30
Jan-62	12	572.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	311.5	0
Feb-62	64	626.5	64	TRUE	TRUE	FALSE	FALSE	0	TRUE	375.5	64
Mar-62	26.3	642.8	0	FALSE	TRUE	TRUE	TRUE	26.3	TRUE	401.8	26.3
Apr-62	23	655.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	372.9	0
May-62	0	645.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	344	0
Jun-62	0	635.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	315.1	0
Jul-62	0	625.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	286.2	0
Aug-62	1	616.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	257.3	0
Sep-62	0	606.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	228.4	0
Oct-62	3.5	600.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	199.5	0
Nov-62	83	673.3	83	TRUE	TRUE	FALSE	FALSE	0	TRUE	282.5	83
Dec-62	47	710.3	0	FALSE	TRUE	TRUE	TRUE	47	TRUE	329.5	47
Jan-63	91.2	791.5	91.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	420.7	91.2
Feb-63	21.25	802.75	0	FALSE	TRUE	TRUE	TRUE	21.25	TRUE	441.95	21.25
Mar-63	109.25	902	109.25	TRUE	TRUE	FALSE	FALSE	0	TRUE	551.2	109.25
Apr-63	44.3	936.3	0	FALSE	TRUE	TRUE	TRUE	44.3	TRUE	595.5	44.3
May-63	61.75	988.05	61.75	TRUE	TRUE	FALSE	FALSE	0	TRUE	657.25	61.75
Jun-63	26	1004.05	0	FALSE	TRUE	TRUE	TRUE	26	TRUE	683.25	26
Jul-63	0	994.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	654.35	0
Aug-63	0.75	984.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	625.45	0
Sep-63	0	974.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	596.55	0
Oct-63	27.75	992.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	567.65	0
Nov-63	66.5	1049.05	66.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	634.15	66.5
Dec-63	40	1079.05	0	FALSE	TRUE	TRUE	TRUE	40	TRUE	674.15	40

Jan-64	0	1069.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	645.25	0
Feb-64	19.5	1078.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	616.35	0
Mar-64	10	1078.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	587.45	0
Apr-64	4.25	1072.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	558.55	0
May-64	0	1062.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	529.65	0
Jun-64	6.5	1059.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	500.75	0
Jul-64	0	1049.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	471.85	0
Aug-64	1	1040.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	442.95	0
Sep-64	0	1030.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	414.05	0
Oct-64	61.5	1081.8	61.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	475.55	61.5
Nov-64	3.5	1075.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	446.65	0
Dec-64	10.25	1075.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	417.75	0
Jan-65	10	1075.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	388.85	0
Feb-65	8.75	1074.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	359.95	0
Mar-65	22.25	1086.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	331.05	0
Apr-65	28.5	1105.05	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	302.15	0
May-65	0	1095.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	273.25	0
Jun-65	0	1085.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	244.35	0
Jul-65	2	1077.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	215.45	0
Aug-65	0	1067.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	186.55	0
Sep-65	1.75	1058.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	157.65	0
Oct-65	0	1048.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	128.75	0
Nov-65	11.5	1050.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	99.85	0
Dec-65	0	1040.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	70.95	0
Jan-66	67	1097.3	67	TRUE	TRUE	FALSE	FALSE	0	TRUE	137.95	67
Feb-66	59.25	1146.55	59.25	TRUE	TRUE	TRUE	FALSE	0	TRUE	197.2	59.25
Mar-66	1	1137.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	168.3	0
Apr-66	5	1132.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	139.4	0
May-66	0.5	1123.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	110.5	0
Jun-66	11.5	1124.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	81.6	0
Jul-66	0	1114.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	52.7	0
Aug-66	0	1104.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	23.8	0
Sep-66	16	1110.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-5.1	0
Oct-66	60	1160.55	60	TRUE	TRUE	FALSE	FALSE	0	TRUE	54.9	60
Nov-66	0	1150.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	26	0
Dec-66	33	1173.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2.9	0
Jan-67	69	1232.55	69	TRUE	TRUE	FALSE	FALSE	0	TRUE	66.1	69
Feb-67	33.75	1256.3	0	FALSE	TRUE	TRUE	TRUE	33.75	TRUE	99.85	33.75
Mar-67	28	1274.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	70.95	0
Apr-67	58.5	1322.8	58.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	129.45	58.5
May-67	36	1348.8	0	FALSE	TRUE	TRUE	TRUE	36	TRUE	165.45	36
Jun-67	0	1338.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	136.55	0
Jul-67	0	1328.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	107.65	0
Aug-67	0	1318.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	78.75	0
Sep-67	7.75	1316.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	49.85	0
Oct-67	10	1316.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	20.95	0
Nov-67	20	1326.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-7.95	0
Dec-67	2	1318.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-36.85	0
Jan-68	0	1308.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-65.75	0
Feb-68	0	1298.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-94.65	0
Mar-68	86	1374.55	86	TRUE	TRUE	FALSE	FALSE	0	TRUE	-8.65	86
Apr-68	21.5	1386.05	0	FALSE	TRUE	TRUE	TRUE	21.5	TRUE	12.85	21.5
May-68	56.5	1432.55	56.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	69.35	56.5
Jun-68	0	1422.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	40.45	0
Jul-68	0	1412.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	11.55	0
Aug-68	0	1402.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-17.35	0
Sep-68	0	1392.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-46.25	0
Oct-68	32	1414.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-75.15	0
Nov-68	0	1404.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-104.05	0
Dec-68	7	1401.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-132.95	0
Jan-69	0	1391.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-161.85	0
Feb-69	61.5	1443.05	61.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-100.35	61.5
Mar-69	9	1442.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-129.25	0
Apr-69	44	1476.05	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-158.15	0
May-69	21	1487.05	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-187.05	0
Jun-69	0	1477.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-215.95	0
Jul-69	0	1467.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-244.85	0
Aug-69	0	1457.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-273.75	0
Sep-69	0	1447.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-302.65	0
Oct-69	13.75	1450.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-331.55	0

Nov-69	5.25	1446.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-360.45	0
Dec-69	23.5	1459.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-389.35	0
Jan-70	17	1466.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-418.25	0
Feb-70	23	1479.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-447.15	0
Mar-70	0	1469.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-476.05	0
Apr-70	23	1482.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-504.95	0
May-70	17	1489.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-533.85	0
Jun-70	5.5	1485.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-562.75	0
Jul-70	0	1475.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-591.65	0
Aug-70	0	1465.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-620.55	0
Sep-70	0	1455.05	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-649.45	0
Oct-70	8.5	1453.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-678.35	0
Nov-70	17.25	1460.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-707.25	0
Dec-70	41	1491.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-736.15	0
Jan-71	34.5	1516.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-765.05	0
Feb-71	105	1611.3	105	TRUE	TRUE	FALSE	FALSE	0	TRUE	-660.05	105
Mar-71	0	1601.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-688.95	0
Apr-71	28.5	1619.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-717.85	0
May-71	34.75	1644.55	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-746.75	0
Jun-71	0	1634.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-775.65	0
Jul-71	0	1624.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-804.55	0
Aug-71	0	1614.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-833.45	0
Sep-71	0	1604.55	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-862.35	0
Oct-71	24.25	1618.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-891.25	0
Nov-71	7.5	1616.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-920.15	0
Dec-71	29	1635.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-949.05	0
Jan-72	155.5	1780.8	155.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-793.55	155.5
Feb-72	11	1781.8	0	FALSE	TRUE	TRUE	TRUE	11	TRUE	-782.55	11
Mar-72	144	1915.8	144	TRUE	TRUE	FALSE	FALSE	0	TRUE	-638.55	144
Apr-72	35	1940.8	0	FALSE	TRUE	TRUE	TRUE	35	TRUE	-603.55	35
May-72	0	1930.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-632.45	0
Jun-72	0	1920.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-661.35	0
Jul-72	0	1910.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-690.25	0
Aug-72	0	1900.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-719.15	0
Sep-72	0	1890.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-748.05	0
Oct-72	7	1887.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-776.95	0
Nov-72	47	1924.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-805.85	0
Dec-72	5.5	1920.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-834.75	0
Jan-73	6.5	1916.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-863.65	0
Feb-73	136.5	2043.3	136.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-727.15	136.5
Mar-73	90.55	2123.85	90.55	TRUE	TRUE	TRUE	FALSE	0	TRUE	-636.6	90.55
Apr-73	65	2178.85	65	TRUE	TRUE	TRUE	FALSE	0	TRUE	-571.6	65
May-73	0	2168.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-600.5	0
Jun-73	0	2158.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-629.4	0
Jul-73	0	2148.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-658.3	0
Aug-73	0	2138.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-687.2	0
Sep-73	3.5	2132.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-716.1	0
Oct-73	37	2159.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-745	0
Nov-73	33.5	2182.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-773.9	0
Dec-73	243	2415.85	243	TRUE	TRUE	FALSE	FALSE	0	TRUE	-530.9	243
Jan-74	258.5	2664.35	258.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-272.4	258.5
Feb-74	107	2761.35	107	TRUE	TRUE	TRUE	FALSE	0	TRUE	-165.4	107
Mar-74	288.5	3039.85	288.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	123.1	288.5
Apr-74	21	3050.85	0	FALSE	TRUE	TRUE	TRUE	21	TRUE	144.1	21
May-74	0	3040.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	115.2	0
Jun-74	0	3030.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	86.3	0
Jul-74	0	3020.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	57.4	0
Aug-74	37	3047.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	28.5	0
Sep-74	5.5	3043.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-0.4	0
Oct-74	25	3058.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-29.3	0
Nov-74	44.5	3092.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-58.2	0
Dec-74	34	3116.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-87.1	0
Jan-75	107	3213.85	107	TRUE	TRUE	FALSE	FALSE	0	TRUE	19.9	107
Feb-75	53	3256.85	0	FALSE	TRUE	TRUE	TRUE	53	TRUE	72.9	53
Mar-75	137	3383.85	137	TRUE	TRUE	FALSE	FALSE	0	TRUE	209.9	137
Apr-75	65	3438.85	65	TRUE	TRUE	TRUE	FALSE	0	TRUE	274.9	65
May-75	0	3428.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	246	0
Jun-75	0	3418.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	217.1	0
Jul-75	0	3408.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	188.2	0
Aug-75	0	3398.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	159.3	0

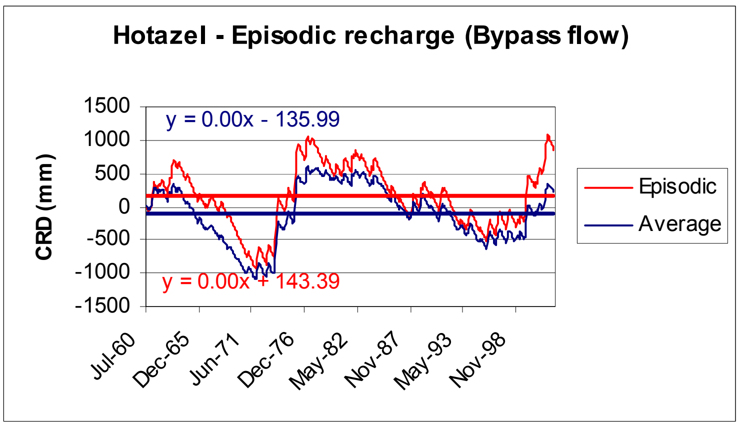
Sep-75	0	3388.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	130.4	0
Oct-75	3.5	3382.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	101.5	0
Nov-75	51	3423.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	72.6	0
Dec-75	189	3602.35	189	TRUE	TRUE	FALSE	FALSE	0	TRUE	261.6	189
Jan-76	268.5	3860.85	268.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	530.1	268.5
Feb-76	108	3958.85	108	TRUE	TRUE	TRUE	FALSE	0	TRUE	638.1	108
Mar-76	185	4133.85	185	TRUE	TRUE	TRUE	FALSE	0	TRUE	823.1	185
Apr-76	99	4222.85	99	TRUE	TRUE	TRUE	FALSE	0	TRUE	922.1	99
May-76	11	4223.85	0	FALSE	TRUE	TRUE	TRUE	11	TRUE	933.1	11
Jun-76	5	4218.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	904.2	0
Jul-76	0	4208.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	875.3	0
Aug-76	0	4198.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	846.4	0
Sep-76	30	4218.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	817.5	0
Oct-76	34.5	4243.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	788.6	0
Nov-76	8	4241.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	759.7	0
Dec-76	15.5	4246.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	730.8	0
Jan-77	53	4289.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	701.9	0
Feb-77	66	4345.85	66	TRUE	TRUE	FALSE	FALSE	0	TRUE	767.9	66
Mar-77	237.5	4573.35	237.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	1005.4	237.5
Apr-77	49	4612.35	0	FALSE	TRUE	TRUE	TRUE	49	TRUE	1054.4	49
May-77	0	4602.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	1025.5	0
Jun-77	0	4592.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	996.6	0
Jul-77	0	4582.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	967.7	0
Aug-77	0	4572.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	938.8	0
Sep-77	77.5	4639.85	77.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	1016.3	77.5
Oct-77	20	4649.85	0	FALSE	TRUE	TRUE	TRUE	20	TRUE	1036.3	20
Nov-77	46	4685.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	1007.4	0
Dec-77	42	4717.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	978.5	0
Jan-78	32	4739.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	949.6	0
Feb-78	49	4778.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	920.7	0
Mar-78	25	4793.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	891.8	0
Apr-78	20	4803.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	862.9	0
May-78	51	4844.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	834	0
Jun-78	0	4834.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	805.1	0
Jul-78	0	4824.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	776.2	0
Aug-78	5	4819.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	747.3	0
Sep-78	6	4815.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	718.4	0
Oct-78	32	4837.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	689.5	0
Nov-78	10	4837.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	660.6	0
Dec-78	30	4857.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	631.7	0
Jan-79	34.5	4882.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	602.8	0
Feb-79	110.5	4982.85	110.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	713.3	110.5
Mar-79	31	5003.85	0	FALSE	TRUE	TRUE	TRUE	31	TRUE	744.3	31
Apr-79	2.5	4996.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	715.4	0
May-79	18	5004.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	686.5	0
Jun-79	2	4996.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	657.6	0
Jul-79	0	4986.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	628.7	0
Aug-79	24	5000.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	599.8	0
Sep-79	0	4990.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	570.9	0
Oct-79	49	5029.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	542	0
Nov-79	15	5034.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	513.1	0
Dec-79	38	5062.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	484.2	0
Jan-80	1	5053.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	455.3	0
Feb-80	79	5122.35	79	TRUE	TRUE	FALSE	FALSE	0	TRUE	534.3	79
Mar-80	26.5	5138.85	0	FALSE	TRUE	TRUE	TRUE	26.5	TRUE	560.8	26.5
Apr-80	65	5193.85	65	TRUE	TRUE	FALSE	FALSE	0	TRUE	625.8	65
May-80	0	5183.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	596.9	0
Jun-80	0	5173.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	568	0
Jul-80	0	5163.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	539.1	0
Aug-80	13.5	5167.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	510.2	0
Sep-80	41	5198.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	481.3	0
Oct-80	6	5194.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	452.4	0
Nov-80	71	5255.35	71	TRUE	TRUE	FALSE	FALSE	0	TRUE	523.4	71
Dec-80	32	5277.35	0	FALSE	TRUE	TRUE	TRUE	32	TRUE	555.4	32
Jan-81	90	5357.35	90	TRUE	TRUE	FALSE	FALSE	0	TRUE	645.4	90
Feb-81	66	5413.35	66	TRUE	TRUE	TRUE	FALSE	0	TRUE	711.4	66
Mar-81	24	5427.35	0	FALSE	TRUE	TRUE	TRUE	24	TRUE	735.4	24
Apr-81	0	5417.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	706.5	0
May-81	0	5407.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	677.6	0
Jun-81	0	5397.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	648.7	0

Jul-81	0	5387.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	619.8	0
Aug-81	30	5407.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	590.9	0
Sep-81	7	5404.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	562	0
Oct-81	3	5397.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	533.1	0
Nov-81	92	5479.35	92	TRUE	TRUE	FALSE	FALSE	0	TRUE	625.1	92
Dec-81	144	5613.35	144	TRUE	TRUE	TRUE	FALSE	0	TRUE	769.1	144
Jan-82	10	5613.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	740.2	0
Feb-82	55	5658.35	55	FALSE	TRUE	FALSE	FALSE	0	TRUE	795.2	55
Mar-82	48	5696.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	766.3	0
Apr-82	77	5763.35	77	TRUE	TRUE	FALSE	FALSE	0	TRUE	843.3	77
May-82	0	5753.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	814.4	0
Jun-82	15	5758.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	785.5	0
Jul-82	0	5748.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	756.6	0
Aug-82	0	5738.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	727.7	0
Sep-82	0	5728.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	698.8	0
Oct-82	101	5819.35	101	TRUE	TRUE	FALSE	FALSE	0	TRUE	799.8	101
Nov-82	6	5815.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	770.9	0
Dec-82	41	5846.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	742	0
Jan-83	49	5885.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	713.1	0
Feb-83	6	5881.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	684.2	0
Mar-83	36	5907.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	655.3	0
Apr-83	13	5910.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	626.4	0
May-83	0	5900.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	597.5	0
Jun-83	0	5890.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	568.6	0
Jul-83	0	5880.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	539.7	0
Aug-83	0	5870.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	510.8	0
Sep-83	7	5867.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	481.9	0
Oct-83	3	5860.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	453	0
Nov-83	68	5918.35	68	TRUE	TRUE	FALSE	FALSE	0	TRUE	521	68
Dec-83	91.5	5999.85	91.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	612.5	91.5
Jan-84	0	5989.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	583.6	0
Feb-84	11	5990.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	554.7	0
Mar-84	146	6126.85	146	TRUE	TRUE	FALSE	FALSE	0	TRUE	700.7	146
Apr-84	29	6145.85	0	FALSE	TRUE	TRUE	TRUE	29	TRUE	729.7	29
May-84	22	6157.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	700.8	0
Jun-84	0	6147.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	671.9	0
Jul-84	0	6137.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	643	0
Aug-84	0	6127.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	614.1	0
Sep-84	0	6117.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	585.2	0
Oct-84	31	6138.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	556.3	0
Nov-84	31	6159.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	527.4	0
Dec-84	12	6161.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	498.5	0
Jan-85	34	6185.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	469.6	0
Feb-85	6	6181.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	440.7	0
Mar-85	19.5	6191.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	411.8	0
Apr-85	0	6181.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	382.9	0
May-85	0	6171.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	354	0
Jun-85	0	6161.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	325.1	0
Jul-85	0	6151.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	296.2	0
Aug-85	0	6141.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	267.3	0
Sep-85	15	6146.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	238.4	0
Oct-85	10	6146.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	209.5	0
Nov-85	11	6147.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	180.6	0
Dec-85	116	6253.35	116	TRUE	TRUE	FALSE	FALSE	0	TRUE	296.6	116
Jan-86	25	6268.35	0	FALSE	TRUE	TRUE	TRUE	25	TRUE	321.6	25
Feb-86	19	6277.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	292.7	0
Mar-86	24.5	6291.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	263.8	0
Apr-86	0	6281.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	234.9	0
May-86	0	6271.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	206	0
Jun-86	0	6261.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	177.1	0
Jul-86	0	6251.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	148.2	0
Aug-86	0	6241.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	119.3	0
Sep-86	3	6234.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	90.4	0
Oct-86	20	6244.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	61.5	0
Nov-86	83	6317.85	83	TRUE	TRUE	FALSE	FALSE	0	TRUE	144.5	83
Dec-86	8	6315.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	115.6	0
Jan-87	10	6315.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	86.7	0
Feb-87	21	6326.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	57.8	0
Mar-87	10	6326.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	28.9	0
Apr-87	30	6346.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	3.2E-12	0

May-87	0	6336.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-28.9	0
Jun-87	0	6326.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-57.8	0
Jul-87	5	6321.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-86.7	0
Aug-87	0	6311.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-115.6	0
Sep-87	40	6341.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-144.5	0
Oct-87	16	6347.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-173.4	0
Nov-87	18	6355.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-202.3	0
Dec-87	62	6407.85	62	TRUE	TRUE	FALSE	FALSE	0	TRUE	-140.3	62
Jan-88	34	6431.85	0	FALSE	TRUE	TRUE	TRUE	34	TRUE	-106.3	34
Feb-88	113	6534.85	113	TRUE	TRUE	FALSE	FALSE	0	TRUE	6.7	113
Mar-88	97	6621.85	97	TRUE	TRUE	TRUE	FALSE	0	TRUE	103.7	97
Apr-88	93	6704.85	93	TRUE	TRUE	TRUE	FALSE	0	TRUE	196.7	93
May-88	6	6700.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	167.8	0
Jun-88	0	6690.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	138.9	0
Jul-88	0	6680.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	110	0
Aug-88	0	6670.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	81.1	0
Sep-88	33	6693.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	52.2	0
Oct-88	15	6698.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	23.3	0
Nov-88	18	6706.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-5.6	0
Dec-88	106	6802.85	106	TRUE	TRUE	FALSE	FALSE	0	TRUE	100.4	106
Jan-89	139	6931.85	139	TRUE	TRUE	TRUE	FALSE	0	TRUE	239.4	139
Feb-89	50	6971.85	0	FALSE	TRUE	TRUE	TRUE	50	TRUE	289.4	50
Mar-89	19	6980.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	260.5	0
Apr-89	89	7059.85	89	TRUE	TRUE	FALSE	FALSE	0	TRUE	349.5	89
May-89	20	7069.85	0	FALSE	TRUE	TRUE	TRUE	20	TRUE	369.5	20
Jun-89	0	7059.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	340.6	0
Jul-89	0	7049.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	311.7	0
Aug-89	0	7039.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	282.8	0
Sep-89	0	7029.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	253.9	0
Oct-89	0	7019.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	225	0
Nov-89	25	7034.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	196.1	0
Dec-89	0	7024.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	167.2	0
Jan-90	16	7030.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	138.3	0
Feb-90	78	7098.85	78	TRUE	TRUE	FALSE	FALSE	0	TRUE	216.3	78
Mar-90	9	7097.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	187.4	0
Apr-90	20	7107.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	158.5	0
May-90	0	7097.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	129.6	0
Jun-90	0	7087.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	100.7	0
Jul-90	0	7077.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	71.8	0
Aug-90	0	7067.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	42.9	0
Sep-90	0	7057.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	14	0
Oct-90	3	7050.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-14.9	0
Nov-90	11	7051.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-43.8	0
Dec-90	15	7056.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-72.7	0
Jan-91	171	7217.85	171	TRUE	TRUE	FALSE	FALSE	0	TRUE	98.3	171
Feb-91	71	7278.85	71	TRUE	TRUE	TRUE	FALSE	0	TRUE	169.3	71
Mar-91	107.5	7376.35	107.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	276.8	107.5
Apr-91	0	7366.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	247.9	0
May-91	0	7356.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	219	0
Jun-91	57	7403.35	57	TRUE	TRUE	FALSE	FALSE	0	TRUE	276	57
Jul-91	0	7393.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	247.1	0
Aug-91	0	7383.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	218.2	0
Sep-91	3.5	7376.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	189.3	0
Oct-91	49.5	7416.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	160.4	0
Nov-91	20	7426.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	131.5	0
Dec-91	40	7456.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	102.6	0
Jan-92	12	7458.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	73.7	0
Feb-92	13	7461.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	44.8	0
Mar-92	5	7456.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	15.9	0
Apr-92	0	7446.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-13	0
May-92	0	7436.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-41.9	0
Jun-92	0	7426.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-70.8	0
Jul-92	0	7416.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-99.7	0
Aug-92	1.5	7407.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-128.6	0
Sep-92	0	7397.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-157.5	0
Oct-92	4.5	7392.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-186.4	0
Nov-92	26.5	7408.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-215.3	0
Dec-92	29	7427.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-244.2	0
Jan-93	43.5	7461.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-273.1	0
Feb-93	69	7520.35	69	TRUE	TRUE	FALSE	FALSE	0	TRUE	-204.1	69

Mar-93	23.5	7533.85	0	FALSE	TRUE	TRUE	TRUE	23.5	TRUE	-180.6	23.5
Apr-93	24	7547.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-209.5	0
May-93	0	7537.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-238.4	0
Jun-93	0	7527.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-267.3	0
Jul-93	0	7517.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-296.2	0
Aug-93	2	7509.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-325.1	0
Sep-93	0	7499.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-354	0
Oct-93	75	7564.85	75	TRUE	TRUE	FALSE	FALSE	0	TRUE	-279	75
Nov-93	24.5	7579.35	0	FALSE	TRUE	TRUE	TRUE	24.5	TRUE	-254.5	24.5
Dec-93	39	7608.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-283.4	0
Jan-94	76.5	7674.85	76.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-206.9	76.5
Feb-94	88.5	7753.35	88.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-118.4	88.5
Mar-94	61.5	7804.85	61.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-56.9	61.5
Apr-94	0	7794.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-85.8	0
May-94	6	7790.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-114.7	0
Jun-94	0	7780.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-143.6	0
Jul-94	0	7770.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-172.5	0
Aug-94	0	7760.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-201.4	0
Sep-94	0	7750.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-230.3	0
Oct-94	2	7742.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-259.2	0
Nov-94	6	7738.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-288.1	0
Dec-94	0	7728.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-317	0
Jan-95	13	7731.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-345.9	0
Feb-95	26.5	7748.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-374.8	0
Mar-95	73.5	7811.85	73.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-301.3	73.5
Apr-95	9	7810.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-330.2	0
May-95	36	7836.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-359.1	0
Jun-95	0	7826.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-388	0
Jul-95	0	7816.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-416.9	0
Aug-95	0	7806.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-445.8	0
Sep-95	0	7796.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-474.7	0
Oct-95	12	7798.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-503.6	0
Nov-95	38	7826.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-532.5	0
Dec-95	134.5	7951.35	134.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-398	134.5
Jan-96	60.5	8001.85	60.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-337.5	60.5
Feb-96	142.5	8134.35	142.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-195	142.5
Mar-96	0	8124.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-223.9	0
Apr-96	14.5	8128.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-252.8	0
May-96	42	8160.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-281.7	0
Jun-96	0	8150.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-310.6	0
Jul-96	0	8140.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-339.5	0
Aug-96	0	8130.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-368.4	0
Sep-96	1.5	8122.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-397.3	0
Oct-96	2.5	8114.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-426.2	0
Nov-96	113	8217.85	113	TRUE	TRUE	FALSE	FALSE	0	TRUE	-313.2	113
Dec-96	55.5	8263.35	55.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-257.7	55.5
Jan-97	86.5	8339.85	86.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-171.2	86.5
Feb-97	30	8359.85	0	FALSE	TRUE	TRUE	TRUE	30	TRUE	-141.2	30
Mar-97	74.5	8424.35	74.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-66.7	74.5
Apr-97	6.5	8420.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-95.6	0
May-97	44.5	8455.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-124.5	0
Jun-97	1.5	8446.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-153.4	0
Jul-97	1.5	8438.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-182.3	0
Aug-97	0	8428.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-211.2	0
Sep-97	3.5	8421.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-240.1	0
Oct-97	21	8432.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-269	0
Nov-97	4	8426.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-297.9	0
Dec-97	3.5	8420.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-326.8	0
Jan-98	119.5	8529.85	119.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-207.3	119.5
Feb-98	106	8625.85	106	TRUE	TRUE	TRUE	FALSE	0	TRUE	-101.3	106
Mar-98	44.5	8660.35	0	FALSE	TRUE	TRUE	TRUE	44.5	TRUE	-56.8	44.5
Apr-98	11	8661.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-85.7	0
May-98	0	8651.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-114.6	0
Jun-98	0	8641.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-143.5	0
Jul-98	1	8632.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-172.4	0
Aug-98	2	8624.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-201.3	0
Sep-98	12.5	8626.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-230.2	0
Oct-98	46	8662.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-259.1	0
Nov-98	24	8676.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-288	0
Dec-98	29.5	8696.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-316.9	0

Jan-99	89.5	8775.85	89.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-227.4	89.5
Feb-99	27	8792.85	0	FALSE	TRUE	TRUE	TRUE	27	TRUE	-200.4	27
Mar-99	28	8810.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-229.3	0
Apr-99	2	8802.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-258.2	0
May-99	142.5	8935.35	142.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-115.7	142.5
Jun-99	0	8925.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-144.6	0
Jul-99	0	8915.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-173.5	0
Aug-99	0	8905.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-202.4	0
Sep-99	0	8895.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-231.3	0
Oct-99	62	8947.35	62	TRUE	TRUE	FALSE	FALSE	0	TRUE	-169.3	62
Nov-99	27	8964.35	0	FALSE	TRUE	TRUE	TRUE	27	TRUE	-142.3	27
Dec-99	275	9229.35	275	TRUE	TRUE	FALSE	FALSE	0	TRUE	132.7	275
Jan-00	195	9414.35	195	TRUE	TRUE	TRUE	FALSE	0	TRUE	327.7	195
Feb-00	36	9440.35	0	FALSE	TRUE	TRUE	TRUE	36	TRUE	363.7	36
Mar-00	93	9523.35	93	TRUE	TRUE	FALSE	FALSE	0	TRUE	456.7	93
Apr-00	16	9529.35	0	FALSE	TRUE	TRUE	TRUE	16	TRUE	472.7	16
May-00	5	9524.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	443.8	0
Jun-00	0	9514.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	414.9	0
Jul-00	0	9504.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	386	0
Aug-00	0	9494.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	357.1	0
Sep-00	30	9514.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	328.2	0
Oct-00	14	9518.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	299.3	0
Nov-00	30	9538.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	270.4	0
Dec-00	92	9620.35	92	TRUE	TRUE	FALSE	FALSE	0	TRUE	362.4	92
Jan-01	5	9615.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	333.5	0
Feb-01	56	9661.35	56	TRUE	TRUE	FALSE	FALSE	0	TRUE	389.5	56
Mar-01	27	9678.35	0	FALSE	TRUE	TRUE	TRUE	27	TRUE	416.5	27
Apr-01	131	9799.35	131	TRUE	TRUE	FALSE	FALSE	0	TRUE	547.5	131
May-01	25	9814.35	0	FALSE	TRUE	TRUE	TRUE	25	TRUE	572.5	25
Jun-01	0	9804.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	543.6	0
Jul-01	0	9794.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	514.7	0
Aug-01	4.5	9788.85	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	485.8	0
Sep-01	58	9836.85	58	TRUE	TRUE	FALSE	FALSE	0	TRUE	543.8	58
Oct-01	32	9858.85	0	FALSE	TRUE	TRUE	TRUE	32	TRUE	575.8	32
Nov-01	162	10010.85	162	TRUE	TRUE	FALSE	FALSE	0	TRUE	737.8	162
Dec-01	73	10073.85	73	TRUE	TRUE	TRUE	FALSE	0	TRUE	810.8	73
Jan-02	122	10185.85	122	TRUE	TRUE	TRUE	FALSE	0	TRUE	932.8	122
Feb-02	70	10245.85	70	TRUE	TRUE	TRUE	FALSE	0	TRUE	1002.8	70
Mar-02	80	10315.85	80	TRUE	TRUE	TRUE	FALSE	0	TRUE	1082.8	80
Apr-02	8.5	10314.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	1053.9	0
May-02	40	10344.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	1025	0
Jun-02	14	10348.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	996.1	0
Jul-02	0	10338.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	967.2	0
Aug-02	30	10358.35	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	938.3	0
Sep-02	8	10356.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	909.4	0
Oct-02	8	10354.35	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	880.5	0
Nov-02	27.5	10371.85	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	851.6	0
TOTALS	**15441.85**	**2522147.15**	**10381**								**11544.6**



Note: Since no monthly rainfall values exceed 430 mm, Episodic CRD_{uzm} cannot be determined.

Appendix 8: Hydrological investigations undertaken previously at Kriel and Matla Power Stations

Note:

1. This list includes correspondence and supporting documentation relating to hydrological studies undertaken at the site;

2. Geo-Hydro Technologies (GHT) has prepared numerous water quality-monitoring reports for the site. These have not been listed here.

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Appendix 9: Chemical and isotopic composition of water samples taken at Kriel and Matla Power Stations

Table A9-1a: Stable isotope results for surface and groundwater samples taken in February and March 2001. Results are listed sequentially from lowest to highest values for the respective power station sites so that the transition from meteoric to evaporated water (a relative ^{18}O content between -3.2 and 2.5‰) can be more easily observed. Note that "s" and "d" denotes shallow and deep piezometers, respectively.

Site	^{18}O (‰)	^{2}H (‰)
KB30	-5.14	-25
KB34	-4.93	-27.1
KB33	-4.83	-24.2
KB18d	-4.8	-23.1
KB6d	-4.72	-19.6
KB32	-4.58	-20.4
KB8s	-4.49	-21.7
KB10d	-4.47	-22.5
KB5d	-4.44	-22.1
KB27d	-4.34	-22.3
KB10s	-4.31	-20.1
KB6s	-4.28	-19.1
KB7s	-4.15	-18.2
KB36	-4.1	-14.6
KB28	-4.07	-19.3
KB7d	-3.87	-18.7
KB27s	-3.86	-17.8
KB24	-3.83	-14.9
KB23	-3.62	-17.4
KB16	-3.39	-15.3
KB18s	-3.19	-12.4
KB29	-3.11	-11.2
KB12	-2.43	-10.4
KB8d	-2.4	-9.5
KB38	-1.84	-4.4
KB5s	-1.66	-4.5
R15	-1.03	1.7
KB22	-0.8	-1.8
KB39	-0.76	-0.1
KB40d	0.41	5
KB40s	0.46	5.6

Table A9-1b: Stable isotope results for surface and groundwater samples taken in February and March 2001 (continued).

Site	^{18}O (‰)	^{2}H (‰)
R11	0.86	10.4
KP5	1.37	10.9
KB20	1.4	10.7
KB42	1.76	14.3
KP14	2.51	16.8
KB35d	2.92	22
KB35s	3.91	27
KP9	3.99	25.3
KP3	4.2	29
KP8	4.49	30.8
KP11	4.66	25.6
KB19	5.29	36.5
KB41	5.59	40.6
MB35	-4.58	-22.3
MB31d	-4.57	-21.9
MB5	-4.38	-21.2
MB4	-4.27	-21
MB34	-4.26	-17.8
MB29	-4.05	-16.6
MB31	-4.05	-17.1
MB33	-4.02	-17.9
MB17	-4	-20.6
MB3	-3.96	-22.1
MB16	-3.69	-18.5
MB32	-3.39	-15.3
MB30d	-3.1	-11.2
MB30s	-2.89	-11.2
MB1	-1.82	-5.7
R1	-1.31	-4.3
MB2	2.68	17
MP11	3.49	20.7
MP6	3.74	22.5
MP13	3.95	19.8
MC1	4.4	23.8
MP7	4.53	24.9
MP4	4.75	26.3

Table A9-2a: Results of laboratory testing on water samples taken in February and March 2001.

Site	EC mS/m	pH	Na mg/L	K mg/L	Mg mg/L	Ca mg/L	Cl mg/L	SO_4 mg/L	M. Alk. mg/L
KB5D	66.5	8	76	5.9	19.4	50.5	2.4	1.7	455.7
KB5S	42.9	8	14	3.4	21.4	52.1	23.5	52.6	201.2
KB6D	60.4	8.6	134.5	3.3	8.3	15.2	12.5	0.7	4.27
KB6S	40.7	7.8	40.6	4	16.9	30.4	5.7	2.2	278.7
KB7D	60	7.7	70.6	6.2	15.1	54.5	17	16.6	388.4
KB7S	74.8	7.4	109	6.5	18.5	52.1	29.9	31.7	459.1
KB8D	60.5	7.7	26	4.9	29.6	65.7	27.4	70.3	288.8
KB8S	29.7	7.7	31	4.1	9.2	22.4	5.3	0.7	193
KB10D	38.6	8.1	71	4.2	4.4	16.8	10.8	4.2	244.3
KB10S	36.2	7.5	33.1	5.9	11.2	35.3	10.7	4.7	236.3
KB12	152	7.4	87	8.1	93.6	126.2	67.9	4.8	974.5541
KB16	49	7.5	72	4.8	9.2	27.3	17.2	30.3	259.8
KB18D	148	8	315	4.2	5.3	3.2	111.4	1.4	685.3
KB18S	285	8	328	14.6	91.1	132.3	562.9	366	319.6
KB19	270	7.5	203	35.2	70.5	386.8	25	1458.2	229.7
KB20	319	7.6	183	29.2	194.4	414.8	24.5	1664	613.8
KB22	20.7	5.6	6.7	1.5	11.2	15.2	5.2	73.3	20.6
KB23	24.7	6.8	17	7.8	8.1	16.6	20.6	3.5	108.6
KB24	28.8	6.6	32.4	8.1	5.3	10.4	46.6	45.7	18.6
KB27	27	8.26	25.8	2.1	6.9	19.4	1.94	1.5	167.8
KB28	23.7	6.9	18.3	4.2	14.6	19.2	10.3	100.7	41.2
KB29	180	7.8	179	14.3	85.1	122.2	204.4	474.3	342.2
KB30	186	8.74	470	3.4	1.06	2.5	38.4	0.8	1201.7
KB32	35	8.56	41.9	6.1	8.4	20.7	14.1	1	198.3
KB33	11	7.54	10.4	3.9	2.5	5.2	0.83	0.38	54.9
KB34	39	7.84	24.5	56	10.2	31.8	5.62	77.4	143.4
KB35	103	7.73	127	5.9	27.5	37.5	44.2	367.4	85.4
KB36	6.9	7.2	6.5	2.6	3.4	6.4	7.3	5.5	38.3
KB38	280	7.6	73	16	196.8	388.7	36.7	1388.3	563.1251
KB39	332		426	15.1	116.7	277	43.2	1399.9	628.3
KB40	228	7.59	97.9	19.34	127.3	288	18.2	1001.6	500.2
KB41	186	11.17	140	70.6	0.94	126	45	572.8	73.2
KB42	331	7.8	190	22.1	172.5	419	31.9	1823.6	500.2

Table A9-2b: Results of laboratory testing on water samples taken in February and March 2001.

Site	EC mS/m	pH	Na mg/L	K mg/L	Mg mg/L	Ca mg/L	Cl mg/L	SO_4 mg/L	M. Alk. mg/L
MB01	382	7.28	90.6	29.6	348.7	408	95.6	2617.2	67.1
MB02	155	8.1	205	15.3	30.9	60	128	320	335.5
MB03	42	8.43	41	3.5	12.1	31.5	13.8	19.5	216.6
MB04	31	7.71	36.1	2.3	7.5	15.2	5.22	38.8	115.9
MB05	23	7.97	17.9	2	6.7	16.6	0.86	19.5	112.9
MB17	13	7.75	10.5	3.1	3.7	6.9	1.9	1.9	64.1
MB27	26	8.12	17.3	8.5	7.1	21.1	13.3	9.8	125.1
MB29	18	7.68	5.4	5.5	6.5	16	8.8	4.6	21.4
MB30	81	8.27	132	6.7	13.1	35.2	19.8	116.9	350.8
MB31	92	8.25	207	4.3	4.6	9	29.1	4.4	591.7
MB32	34	8.06	15.5	4.9	9.6	29.4	13.7	20.2	143.4
MB33	39	8.23	59.8	3.4	6.6	15.9	7.1	6.8	244
MB34	65	7.84	65.5	5.1	24.3	33.2	21.9	96.2	247.1
MB35	24	8.26	13.3	4.5	10.5	16.3	1		152.5
KP03	117.8	9	159	49	15.8	66.1	42.3	495.7	46
KP05	67	7.4	54	14.6	11.7	72.1	27.8	159.9	192
KP08	89.6	7.5	68.2	21.1	29.6	85.8	47.9	289.1	158
KP09	599	13.2	150.1	51	121.5	434.8	20.8	662.4	-
KP11	281	8.5	176	26.3	202.9	270.5	24.2	1671	177
KP14	197	8.1	102	16.2	127.6	224.4	15	1015	248
KP17	213	12.3	135	47.2	8.5	136.3	44.6	514.3	-
R11	58.4	7.5	35	7.9	22.8	61.7	29.9	61.2	262
R15	36.5	7.7	37	1.9	15.5	36.1	8.1	37.1	218

Table A9-3: Stable isotope results for groundwater samples taken 28 and 29 November 2002.

Site	^{18}O (‰)	^{2}H (‰)
KB45	-3.7	-19
KB46	-4.1	-21
KB47	-4.2	-21
KB48	-3.6	-19
KN49	-3.7	-19
KB50	-4.2	-21
KB51	-3.5	-17
KB52	-3.3	-16
KB53	-4.0	-21
KB54	-3.8	-20
KB55	-3.6	-19
KB56	-3.4	-18
KB59	-4.0	-21
F2	-3.5	-18

Table A9-4: Laboratory test results for groundwater samples, taken 28 and 29 November 2002.

Site	EC mS/m	pH	Na mg/L	K mg/L	Mg mg/L	Ca mg/L	Cl mg/L	SO_4 mg/L	M. Alk mg/L
KB45	17.7	6.59	14	5.1	2	17	6.12	1.5	47
KB46	29	7.72	12	5.1	6	42	5.62	10.6	128
KB47	46.9	7.82	58	4.5	15	36	14.21	1.7	248
KB48	14	6.73	9	4.0	4	13	3.9	0.6	40
KN49	47.5	7.52	12	7.0	22	51	16.13	86.0	82
KB50	60	8.82	145	2.3	2	9	15.07	0.5	318
KB51	23.2	7.30	10	3.2	5	28	13.82	1.1	69
KB52	78.1	6.30	37	10.6	36	63	129.7	3.5	28
KB53	26.6	7.84	21	3.7	9	28	6.69	7.6	135
KB54	30.6	7.66	20	3.4	10	37	7.24	9.5	156
KB56	14.6	7.36	13	4.1	4	9	3.36	4.3	54
KB59	41.4	8.28	45	7.4	16	35	7.56	8.0	230
F2	20.4	6.99	13	5.4	4	22	4.11	1.0	80

Appendix 10: CRD calculations for Witbank

Adaption of CRD Method to allow for episodic recharge

Study area **Witbank**
Recharge via **Preferential pathways**

CRD_{ave} =	$CRD_i = P_i + CRD_{i-1} - P_{ave}$	~~Excel formulas used~~
A =	Values above high threshold	if(P_i < high threshold, 0, P_i)
B =	Test to see whether Pi > high theshold	and(Pi > high theshold)
C =	Test to see whether Pi > low theshold	and(P_i > low threshold
D =	Test to see whether low threshold follows high threshold	and(C_i = true, B_{i-1} = true)
E =	Test to confirm thesholds are in correct order	and(B_{i-1} = true, B_i = false,C_i = true)
F =	Test to determine where sequential recharge occurs	if(E_i = true, E_i, 0)
G =	Test to see whether the high or low recharge threshold has been exceeded	or(A_i > 0,F_i > 0)
H =	Test to see whether CRDi = CRDi-1+Pi or CRDi = CRDi-1 - RF	if(G = true, $CRD_{i-1} + P_i$, CRD_{i-1} - RF)

~~Note:~~ a) To obtain episodic CRD, plot Month versus "H (mm)";
b) RF must be adjusted until trendline through episodic CRD plot is horizontal;
c) "I (mm)" is used for averaging calculations only.

Average episodic threshold (low)	30	mm
Average episodic threshold (high)	80	mm
Total number of months	639	months
No. of months above CRD2 threshold	286	months
Average (all values)	60.0	mm
Average CRD2 values	112.8	mm
% Recharge months	44.8	%
Recession Factor (RF)	89.5	mm/month

Month	Rain	CRD_{ave}(mm)	A (mm)	B	C	D	E	F (mm)	G	H (mm)	I (mm)
Jan-48	173.7	173.7	173.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	173.7	173.7
Feb-48	54.9	198.6	0	FALSE	TRUE	TRUE	TRUE	54.9	TRUE	228.6	54.9
Mar-48	81.1	249.7	81.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	309.7	81.1
Apr-48		219.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	220.2	0
May-48		189.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	130.7	0
Jun-48		159.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	41.2	0
Jul-48		129.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-48.3	0
Aug-48		99.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-137.8	0
Sep-48		69.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-227.3	0
Oct-48	99.1	138.8	99.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-128.2	99.1
Nov-48	149.3	258.1	149.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	21.1	149.3
Dec-48		228.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-68.4	0
Jan-49	179.5	377.6	179.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	111.1	179.5
Feb-49	64.1	411.7	0	FALSE	TRUE	TRUE	TRUE	64.1	TRUE	175.2	64.1
Mar-49	96.9	478.6	96.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	272.1	96.9
Apr-49	32.7	481.3	0	FALSE	TRUE	TRUE	TRUE	32.7	TRUE	304.8	32.7
May-49	16.2	467.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	215.3	0
Jun-49	4.6	442.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	125.8	0
Jul-49	0	412.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	36.3	0
Aug-49	0	382.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-53.2	0
Sep-49		352.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-142.7	0
Oct-49		322.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-232.2	0
Nov-49		292.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-321.7	0
Dec-49		262.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-411.2	0
Jan-50	35.8	267.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-500.7	0
Feb-50	24.1	262	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-590.2	0
Mar-50	27	259	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-679.7	0
Apr-50	30.3	259.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-769.2	0
May-50	7	236.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-858.7	0
Jun-50	0	206.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-948.2	0
Jul-50	0.4	176.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1037.7	0
Aug-50	0.1	146.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1127.2	0
Sep-50	4.1	120.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1216.7	0
Oct-50	13	103.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1306.2	0
Nov-50	29.7	103.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1395.7	0
Dec-50	28.2	101.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1485.2	0
Jan-51	91.7	163.5	91.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1393.5	91.7
Feb-51	65.2	198.7	0	FALSE	TRUE	TRUE	TRUE	65.2	TRUE	-1328.3	65.2
Mar-51	114.8	283.5	114.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1213.5	114.8
Apr-51	103.9	357.4	103.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1109.6	103.9
May-51	50.2	377.6	0	FALSE	TRUE	TRUE	TRUE	50.2	TRUE	-1059.4	50.2

Jun-51	2.3	349.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1148.9	0
Jul-51	0	319.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1238.4	0
Aug-51	29.4	319.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1327.9	0
Sep-51	2.3	291.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1417.4	0
Oct-51	96	357.6	96	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1321.4	96
Nov-51	19.7	347.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1410.9	0
Dec-51	146	463.3	146	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1264.9	146
Jan-52	107	540.3	107	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1157.9	107
Feb-52	92.3	602.6	92.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1065.6	92.3
Mar-52	43.4	616	0	FALSE	TRUE	TRUE	TRUE	43.4	TRUE	-1022.2	43.4
Apr-52	48.9	634.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1111.7	0
May-52	10.7	615.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1201.2	0
Jun-52	3.1	588.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1290.7	0
Jul-52	11.5	570.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1380.2	0
Aug-52	0.5	540.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1469.7	0
Sep-52	8.1	518.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1559.2	0
Oct-52	39.7	528.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1648.7	0
Nov-52	135.6	634.1	135.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1513.1	135.6
Dec-52	129.2	733.3	129.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1383.9	129.2
Jan-53	89	792.3	89	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1294.9	89
Feb-53	186.1	948.4	186.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1108.8	186.1
Mar-53	162.7	1081.1	162.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-946.1	162.7
Apr-53	43.7	1094.8	0	FALSE	TRUE	TRUE	TRUE	43.7	TRUE	-902.4	43.7
May-53	23.2	1088	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-991.9	0
Jun-53	0.4	1058.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1081.4	0
Jul-53	0	1028.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1170.9	0
Aug-53	2.4	1000.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1260.4	0
Sep-53	13.2	984	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1349.9	0
Oct-53	25.5	979.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1439.4	0
Nov-53	202.9	1152.4	202.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1236.5	202.9
Dec-53	130.7	1253.1	130.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1105.8	130.7
Jan-54	90.8	1313.9	90.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1015	90.8
Feb-54	95.4	1379.3	95.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-919.6	95.4
Mar-54	76.7	1426	0	FALSE	TRUE	TRUE	TRUE	76.7	TRUE	-842.9	76.7
Apr-54	53	1449	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-932.4	0
May-54	12.3	1431.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1021.9	0
Jun-54	0	1401.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1111.4	0
Jul-54	0	1371.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1200.9	0
Aug-54	0.1	1341.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1290.4	0
Sep-54	28.8	1340.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1379.9	0
Oct-54	30.1	1340.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1469.4	0
Nov-54	140.1	1450.4	140.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1329.3	140.1
Dec-54	69.3	1489.7	0	FALSE	TRUE	TRUE	TRUE	69.3	TRUE	-1260	69.3
Jan-55	205	1664.7	205	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1055	205
Feb-55	209.2	1843.9	209.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-845.8	209.2
Mar-55	71.9	1885.8	0	FALSE	TRUE	TRUE	TRUE	71.9	TRUE	-773.9	71.9
Apr-55	80.4	1936.2	80.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-693.5	80.4
May-55	7	1913.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-783	0
Jun-55	8.7	1891.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-872.5	0
Jul-55	0	1861.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-962	0
Aug-55	0.7	1832.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1051.5	0
Sep-55	1.7	1804.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1141	0
Oct-55	66.4	1840.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1230.5	0
Nov-55	111.7	1922.4	111.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1118.8	111.7
Dec-55	245.4	2137.8	245.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-873.4	245.4
Jan-56	46.6	2154.4	0	FALSE	TRUE	TRUE	TRUE	46.6	TRUE	-826.8	46.6
Feb-56	131.9	2256.3	131.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-694.9	131.9
Mar-56	26.8	2253.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-784.4	0
Apr-56	6	2229.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-873.9	0
May-56	113.9	2313	113.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-760	113.9
Jun-56	12.3	2295.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-849.5	0
Jul-56	4.3	2269.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-939	0
Aug-56	0	2239.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1028.5	0
Sep-56	81.3	2290.9	81.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-947.2	81.3
Oct-56	72.4	2333.3	0	FALSE	TRUE	TRUE	TRUE	72.4	TRUE	-874.8	72.4
Nov-56	80.7	2384	80.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-794.1	80.7
Dec-56	92.5	2446.5	92.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-701.6	92.5
Jan-57	73.1	2489.6	0	FALSE	TRUE	TRUE	TRUE	73.1	TRUE	-628.5	73.1
Feb-57	122.7	2582.3	122.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-505.8	122.7
Mar-57	58.1	2610.4	0	FALSE	TRUE	TRUE	TRUE	58.1	TRUE	-447.7	58.1

Apr-57	30.4	2610.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-537.2	0
May-57	10.1	2590.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-626.7	0
Jun-57	31.7	2592.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-716.2	0
Jul-57	69.8	2632.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-805.7	0
Aug-57	24.1	2626.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-895.2	0
Sep-57	79	2675.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-984.7	0
Oct-57	87.7	2733.2	87.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-897	87.7
Nov-57	51.6	2754.8	0	FALSE	TRUE	TRUE	TRUE	51.6	TRUE	-845.4	51.6
Dec-57	79.9	2804.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-934.9	0
Jan-58	149.7	2924.4	149.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-785.2	149.7
Feb-58	35.3	2929.7	0	FALSE	TRUE	TRUE	TRUE	35.3	TRUE	-749.9	35.3
Mar-58	71.3	2971	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-839.4	0
Apr-58	115.7	3056.7	115.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-723.7	115.7
May-58	9.7	3036.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-813.2	0
Jun-58	0.7	3007.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-902.7	0
Jul-58	0	2977.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-992.2	0
Aug-58	0	2947.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1081.7	0
Sep-58	91.4	3008.5	91.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-990.3	91.4
Oct-58	134	3112.5	134	TRUE	TRUE	TRUE	FALSE	0	TRUE	-856.3	134
Nov-58	74.2	3156.7	0	FALSE	TRUE	TRUE	TRUE	74.2	TRUE	-782.1	74.2
Dec-58	152.1	3278.8	152.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-630	152.1
Jan-59	122.1	3370.9	122.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-507.9	122.1
Feb-59	79	3419.9	0	FALSE	TRUE	TRUE	TRUE	79	TRUE	-428.9	79
Mar-59	43	3432.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-518.4	0
Apr-59	49	3451.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-607.9	0
May-59	21.3	3443.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-697.4	0
Jun-59	1.8	3415	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-786.9	0
Jul-59	17.4	3402.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-876.4	0
Aug-59	0	3372.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-965.9	0
Sep-59	8.4	3350.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1055.4	0
Oct-59	27.1	3347.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1144.9	0
Nov-59	255.5	3573.4	255.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-889.4	255.5
Dec-59	72.8	3616.2	0	FALSE	TRUE	TRUE	TRUE	72.8	TRUE	-816.6	72.8
Jan-60	80	3666.2	80	FALSE	TRUE	FALSE	FALSE	0	TRUE	-736.6	80
Feb-60	51.3	3687.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-826.1	0
Mar-60	66.6	3724.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-915.6	0
Apr-60	111.5	3805.6	111.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-804.1	111.5
May-60	4	3779.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-893.6	0
Jun-60	7.2	3756.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-983.1	0
Jul-60	0.9	3727.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1072.6	0
Aug-60	12.2	3709.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1162.1	0
Sep-60	8.1	3688	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1251.6	0
Oct-60	59.8	3717.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1341.1	0
Nov-60	111.1	3798.9	111.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1230	111.1
Dec-60	138.3	3907.2	138.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1091.7	138.3
Jan-61	80.9	3958.1	80.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1010.8	80.9
Feb-61		3928.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1100.3	0
Mar-61	90.2	3988.3	90.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1010.1	90.2
Apr-61	63.7	4022	0	FALSE	TRUE	TRUE	TRUE	63.7	TRUE	-946.4	63.7
May-61	10.1	4002.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1035.9	0
Jun-61	16.5	3988.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1125.4	0
Jul-61	5	3963.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1214.9	0
Aug-61	1.5	3935.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1304.4	0
Sep-61	52	3957.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1393.9	0
Oct-61	63.7	3990.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1483.4	0
Nov-61		3960.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1572.9	0
Dec-61	130.9	4061.7	130.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1442	130.9
Jan-62	100.6	4132.3	100.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1341.4	100.6
Feb-62	73	4175.3	0	FALSE	TRUE	TRUE	TRUE	73	TRUE	-1268.4	73
Mar-62	98.9	4244.2	98.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1169.5	98.9
Apr-62	68.9	4283.1	0	FALSE	TRUE	TRUE	TRUE	68.9	TRUE	-1100.6	68.9
May-62	0	4253.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1190.1	0
Jun-62	7	4230.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1279.6	0
Jul-62		4200.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1369.1	0
Aug-62	14.5	4184.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1458.6	0
Sep-62	14	4168.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1548.1	0
Oct-62	54.2	4192.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1637.6	0
Nov-62	184.9	4347.7	184.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1452.7	184.9
Dec-62	126.5	4444.2	126.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1326.2	126.5
Jan-63	142.9	4557.1	142.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1183.3	142.9

Feb-63	15.4	4542.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1272.8	0
Mar-63	27.1	4539.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1362.3	0
Apr-63	54.6	4564.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1451.8	0
May-63	20.6	4554.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1541.3	0
Jun-63	70.4	4595.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1630.8	0
Jul-63	19	4584.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1720.3	0
Aug-63	0	4554.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1809.8	0
Sep-63	0	4524.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1899.3	0
Oct-63	72.3	4566.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1988.8	0
Nov-63	133.8	4670.3	133.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1855	133.8
Dec-63	32.2	4672.5	0	FALSE	TRUE	TRUE	TRUE	32.2	TRUE	-1822.8	32.2
Jan-64	178.5	4821	178.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1644.3	178.5
Feb-64	52.9	4843.9	0	FALSE	TRUE	TRUE	TRUE	52.9	TRUE	-1591.4	52.9
Mar-64	35.5	4849.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1680.9	0
Apr-64	24.5	4843.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1770.4	0
May-64	3.5	4817.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1859.9	0
Jun-64	0.4	4787.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1949.4	0
Jul-64	0	4757.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2038.9	0
Aug-64	13.6	4741.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2128.4	0
Sep-64	6.5	4717.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2217.9	0
Oct-64	161	4848.9	161	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2056.9	161
Nov-64	88.5	4907.4	88.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1968.4	88.5
Dec-64	101.2	4978.6	101.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1867.2	101.2
Jan-65	64.2	5012.8	0	FALSE	TRUE	TRUE	TRUE	64.2	TRUE	-1803	64.2
Feb-65	27.8	5010.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1892.5	0
Mar-65	16	4996.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1982	0
Apr-65	55.4	5022	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2071.5	0
May-65	8.1	5000.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2161	0
Jun-65	0	4970.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2250.5	0
Jul-65	6.5	4946.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2340	0
Aug-65	4.4	4921	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2429.5	0
Sep-65	1.8	4892.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2519	0
Oct-65	21.4	4884.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2608.5	0
Nov-65	59.6	4913.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2698	0
Dec-65	119.2	5003	119.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2578.8	119.2
Jan-66	57.8	5030.8	0	FALSE	TRUE	TRUE	TRUE	57.8	TRUE	-2521	57.8
Feb-66	62.7	5063.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2610.5	0
Mar-66	4.6	5038.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2700	0
Apr-66	57.7	5065.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2789.5	0
May-66	10.9	5046.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2879	0
Jun-66	10.2	5026.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2968.5	0
Jul-66	0	4996.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3058	0
Aug-66	1	4967.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3147.5	0
Sep-66	5.2	4943.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3237	0
Oct-66	116	5029.1	116	TRUE	TRUE	FALSE	FALSE	0	TRUE	-3121	116
Nov-66	100.6	5099.7	100.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-3020.4	100.6
Dec-66	93.1	5162.8	93.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2927.3	93.1
Jan-67	213.1	5345.9	213.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2714.2	213.1
Feb-67	121.6	5437.5	121.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2592.6	121.6
Mar-67	70.5	5478	0	FALSE	TRUE	TRUE	TRUE	70.5	TRUE	-2522.1	70.5
Apr-67	105.6	5553.6	105.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2416.5	105.6
May-67	15.7	5539.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2506	0
Jun-67	0	5509.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2595.5	0
Jul-67	6.5	5485.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2685	0
Aug-67	10.1	5465.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2774.5	0
Sep-67	1.7	5437.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2864	0
Oct-67	112.8	5520.4	112.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2751.2	112.8
Nov-67	134.1	5624.5	134.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2617.1	134.1
Dec-67	98.8	5693.3	98.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2518.3	98.8
Jan-68	93.7	5757	93.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2424.6	93.7
Feb-68	61.1	5788.1	0	FALSE	TRUE	TRUE	TRUE	61.1	TRUE	-2363.5	61.1
Mar-68	104.6	5862.7	104.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2258.9	104.6
Apr-68	34.8	5867.5	0	FALSE	TRUE	TRUE	TRUE	34.8	TRUE	-2224.1	34.8
May-68	24.3	5861.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2313.6	0
Jun-68	0	5831.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2403.1	0
Jul-68		5801.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2492.6	0
Aug-68	13.3	5785.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2582.1	0
Sep-68	10	5765.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2671.6	0
Oct-68	15.4	5750.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2761.1	0
Nov-68	150.2	5870.7	150.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2610.9	150.2

Dec-68	77.9	5918.6	0	FALSE	TRUE	TRUE	TRUE	77.9	TRUE	-2533	77.9
Jan-69	121.2	6009.8	121.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2411.8	121.2
Feb-69	112.8	6092.6	112.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2299	112.8
Mar-69	202.5	6265.1	202.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2096.5	202.5
Apr-69	54.1	6289.2	0	FALSE	TRUE	TRUE	TRUE	54.1	TRUE	-2042.4	54.1
May-69		6259.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2131.9	0
Jun-69	0	6229.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2221.4	0
Jul-69	0	6199.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2310.9	0
Aug-69		6169.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2400.4	0
Sep-69	10.8	6150	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2489.9	0
Oct-69	165.4	6285.4	165.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2324.5	165.4
Nov-69	128.1	6383.5	128.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2196.4	128.1
Dec-69	139.6	6493.1	139.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2056.8	139.6
Jan-70	106.9	6570	106.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1949.9	106.9
Feb-70	88.4	6628.4	88.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1861.5	88.4
Mar-70	38.5	6636.9	0	FALSE	TRUE	TRUE	TRUE	38.5	TRUE	-1823	38.5
Apr-70		6606.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1912.5	0
May-70	16.8	6593.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2002	0
Jun-70		6563.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2091.5	0
Jul-70	3	6536.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2181	0
Aug-70	6.8	6513.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2270.5	0
Sep-70	19	6502.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2360	0
Oct-70	97	6569.5	97	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2263	97
Nov-70	117.5	6657	117.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2145.5	117.5
Dec-70	100.6	6727.6	100.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2044.9	100.6
Jan-71	106.1	6803.7	106.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1938.8	106.1
Feb-71	71	6844.7	0	FALSE	TRUE	TRUE	TRUE	71	TRUE	-1867.8	71
Mar-71	70.4	6885.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1957.3	0
Apr-71	103.7	6958.8	103.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1853.6	103.7
May-71	19.9	6948.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1943.1	0
Jun-71	6	6924.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2032.6	0
Jul-71		6894.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2122.1	0
Aug-71	0.3	6865	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2211.6	0
Sep-71	42.4	6877.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2301.1	0
Oct-71	75	6922.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2390.6	0
Nov-71	144.4	7036.8	144.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2246.2	144.4
Dec-71	131.8	7138.6	131.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2114.4	131.8
Jan-72	224.8	7333.4	224.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1889.6	224.8
Feb-72	61	7364.4	0	FALSE	TRUE	TRUE	TRUE	61	TRUE	-1828.6	61
Mar-72	139.5	7473.9	139.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1689.1	139.5
Apr-72	17.2	7461.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1778.6	0
May-72	14.3	7445.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1868.1	0
Jun-72	0.7	7416.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1957.6	0
Jul-72	0	7386.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2047.1	0
Aug-72	5.4	7361.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2136.6	0
Sep-72	42.8	7374.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2226.1	0
Oct-72	74.8	7419.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2315.6	0
Nov-72	131.4	7520.5	131.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2184.2	131.4
Dec-72	60.9	7551.4	0	FALSE	TRUE	TRUE	TRUE	60.9	TRUE	-2123.3	60.9
Jan-73	88.6	7610	88.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2034.7	88.6
Feb-73	43.7	7623.7	0	FALSE	TRUE	TRUE	TRUE	43.7	TRUE	-1991	43.7
Mar-73	99.3	7693	99.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1891.7	99.3
Apr-73	76.6	7739.6	0	FALSE	TRUE	TRUE	TRUE	76.6	TRUE	-1815.1	76.6
May-73	0.5	7710.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1904.6	0
Jun-73	0	7680.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1994.1	0
Jul-73	0	7650.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2083.6	0
Aug-73	4.1	7624.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2173.1	0
Sep-73	57.4	7651.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2262.6	0
Oct-73	106.9	7728.5	106.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2155.7	106.9
Nov-73	63.9	7762.4	0	FALSE	TRUE	TRUE	TRUE	63.9	TRUE	-2091.8	63.9
Dec-73	151.9	7884.3	151.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1939.9	151.9
Jan-74	123.9	7978.2	123.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1816	123.9
Feb-74	57.3	8005.5	0	FALSE	TRUE	TRUE	TRUE	57.3	TRUE	-1758.7	57.3
Mar-74	24.4	7999.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1848.2	0
Apr-74	77.7	8047.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1937.7	0
May-74	6.8	8024.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2027.2	0
Jun-74	0.8	7995.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2116.7	0
Jul-74	15.5	7980.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2206.2	0
Aug-74	2	7952.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2295.7	0
Sep-74	14.4	7937.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2385.2	0

Oct-74	19.4	7926.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2474.7	0
Nov-74	112.1	8008.6	112.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2362.6	112.1
Dec-74	90.2	8068.8	90.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2272.4	90.2
Jan-75	277.5	8316.3	277.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1994.9	277.5
Feb-75	170	8456.3	170	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1824.9	170
Mar-75	108	8534.3	108	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1716.9	108
Apr-75	84.4	8588.7	84.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1632.5	84.4
May-75	11.4	8570.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1722	0
Jun-75	6.8	8546.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1811.5	0
Jul-75	0.7	8517.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1901	0
Aug-75	0	8487.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1990.5	0
Sep-75	3.5	8461.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2080	0
Oct-75	60.5	8491.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2169.5	0
Nov-75	219.4	8681	219.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1950.1	219.4
Dec-75	145.5	8796.5	145.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1804.6	145.5
Jan-76	112.4	8878.9	112.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1692.2	112.4
Feb-76	64	8912.9	0	FALSE	TRUE	TRUE	TRUE	64	TRUE	-1628.2	64
Mar-76	79.2	8962.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1717.7	0
Apr-76	23.2	8955.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1807.2	0
May-76	59.9	8985.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1896.7	0
Jun-76	0	8955.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1986.2	0
Jul-76	0	8925.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2075.7	0
Aug-76	2.5	8897.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2165.2	0
Sep-76	7.8	8875.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2254.7	0
Oct-76	126.7	8972.2	126.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2128	126.7
Nov-76	101.9	9044.1	101.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2026.1	101.9
Dec-76	136.6	9150.7	136.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1889.5	136.6
Jan-77	103.9	9224.6	103.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1785.6	103.9
Feb-77	8.5	9203.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1875.1	0
Mar-77	129.5	9302.6	129.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1745.6	129.5
Apr-77	37.7	9310.3	0	FALSE	TRUE	TRUE	TRUE	37.7	TRUE	-1707.9	37.7
May-77	12.9	9293.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1797.4	0
Jun-77	0	9263.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1886.9	0
Jul-77	0	9233.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1976.4	0
Aug-77	10.5	9213.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2065.9	0
Sep-77	30.4	9214.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2155.4	0
Oct-77	52.1	9236.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-2244.9	0
Nov-77	110.8	9317	110.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2134.1	110.8
Dec-77	82.5	9369.5	82.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-2051.6	82.5
Jan-78	374.4	9713.9	374.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1677.2	374.4
Feb-78	188.6	9872.5	188.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1488.6	188.6
Mar-78	64.6	9907.1	0	FALSE	TRUE	TRUE	TRUE	64.6	TRUE	-1424	64.6
Apr-78	25	9902.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1513.5	0
May-78	3	9875.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1603	0
Jun-78	0	9845.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1692.5	0
Jul-78	0.2	9815.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1782	0
Aug-78	19.6	9804.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1871.5	0
Sep-78	50.9	9825.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1961	0
Oct-78	100.2	9896	100.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1860.8	100.2
Nov-78	96.1	9962.1	96.1	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1764.7	96.1
Dec-78	46.3	9978.4	0	FALSE	TRUE	TRUE	TRUE	46.3	TRUE	-1718.4	46.3
Jan-79	55.9	10004.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1807.9	0
Feb-79	98.7	10073	98.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1709.2	98.7
Mar-79	73	10116	0	FALSE	TRUE	TRUE	TRUE	73	TRUE	-1636.2	73
Apr-79	19.8	10105.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1725.7	0
May-79	4.5	10080.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1815.2	0
Jun-79	0	10050.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1904.7	0
Jul-79	12.8	10033.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1994.2	0
Aug-79	10.8	10013.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2083.7	0
Sep-79	16.2	10000.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-2173.2	0
Oct-79	135.1	10105.2	135.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-2038.1	135.1
Nov-79	169.2	10244.4	169.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1868.9	169.2
Dec-79	72.7	10287.1	0	FALSE	TRUE	TRUE	TRUE	72.7	TRUE	-1796.2	72.7
Jan-80	183.7	10440.8	183.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1612.5	183.7
Feb-80	176.4	10587.2	176.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1436.1	176.4
Mar-80	71.5	10628.7	0	FALSE	TRUE	TRUE	TRUE	71.5	TRUE	-1364.6	71.5
Apr-80	28.7	10627.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1454.1	0
May-80	4.7	10602.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1543.6	0
Jun-80	0	10572.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1633.1	0
Jul-80	0	10542.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1722.6	0

Aug-80	0	10512.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1812.1	0
Sep-80	22.3	10504.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1901.6	0
Oct-80	26.5	10500.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1991.1	0
Nov-80	204.4	10675.3	204.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1786.7	204.4
Dec-80	113.6	10758.9	113.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1673.1	113.6
Jan-81	231.2	10960.1	231.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1441.9	231.2
Feb-81	114.3	11044.4	114.3	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1327.6	114.3
Mar-81	50.7	11065.1	0	FALSE	TRUE	TRUE	TRUE	50.7	TRUE	-1276.9	50.7
Apr-81	38.5	11073.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1366.4	0
May-81	0	11043.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1455.9	0
Jun-81	7	11020.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1545.4	0
Jul-81	0	10990.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1634.9	0
Aug-81	15.2	10975.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1724.4	0
Sep-81	51	10996.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1813.9	0
Oct-81	134	11100.8	134	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1679.9	134
Nov-81	41.3	11112.1	0	FALSE	TRUE	TRUE	TRUE	41.3	TRUE	-1638.6	41.3
Dec-81	91.8	11173.9	91.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1546.8	91.8
Jan-82	138	11281.9	138	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1408.8	138
Feb-82	51.6	11303.5	0	FALSE	TRUE	TRUE	TRUE	51.6	TRUE	-1357.2	51.6
Mar-82	132	11405.5	132	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1225.2	132
Apr-82	14.1	11389.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1314.7	0
May-82	0	11359.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1404.2	0
Jun-82	0	11329.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1493.7	0
Jul-82	10.7	11310.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1583.2	0
Aug-82	0	11280.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1672.7	0
Sep-82	4	11254.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1762.2	0
Oct-82	84.7	11309	84.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1677.5	84.7
Nov-82	89.4	11368.4	89.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1588.1	89.4
Dec-82	29.5	11367.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1677.6	0
Jan-83	186	11523.9	186	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1491.6	186
Feb-83	35.5	11529.4	0	FALSE	TRUE	TRUE	TRUE	35.5	TRUE	-1456.1	35.5
Mar-83	89.6	11589	89.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1366.5	89.6
Apr-83	31.3	11590.3	0	FALSE	TRUE	TRUE	TRUE	31.3	TRUE	-1335.2	31.3
May-83	15.3	11575.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1424.7	0
Jun-83	20.5	11566.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1514.2	0
Jul-83	23	11559.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1603.7	0
Aug-83	38	11567.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1693.2	0
Sep-83	2.5	11539.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1782.7	0
Oct-83	82.8	11592.4	82.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1699.9	82.8
Nov-83	251	11813.4	251	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1448.9	251
Dec-83	89.2	11872.6	89.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1359.7	89.2
Jan-84	121	11963.6	121	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1238.7	121
Feb-84	115	12048.6	115	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1123.7	115
Mar-84	85.5	12104.1	85.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1038.2	85.5
Apr-84	7	12081.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1127.7	0
May-84	0	12051.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1217.2	0
Jun-84	20	12041.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1306.7	0
Jul-84	15.3	12026.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1396.2	0
Aug-84	6	12002.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1485.7	0
Sep-84	13.5	11985.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1575.2	0
Oct-84	111.8	12067.7	111.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1463.4	111.8
Nov-84	71.2	12108.9	0	FALSE	TRUE	TRUE	TRUE	71.2	TRUE	-1392.2	71.2
Dec-84	81.5	12160.4	81.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1310.7	81.5
Jan-85	77.7	12208.1	0	FALSE	TRUE	TRUE	TRUE	77.7	TRUE	-1233	77.7
Feb-85	170.5	12348.6	170.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1062.5	170.5
Mar-85	89	12407.6	89	TRUE	TRUE	TRUE	FALSE	0	TRUE	-973.5	89
Apr-85	0	12377.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1063	0
May-85	16.7	12364.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1152.5	0
Jun-85	0	12334.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1242	0
Jul-85	0	12304.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1331.5	0
Aug-85	0	12274.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1421	0
Sep-85	49	12293.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1510.5	0
Oct-85	83	12346.3	83	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1427.5	83
Nov-85	65	12381.3	0	FALSE	TRUE	TRUE	TRUE	65	TRUE	-1362.5	65
Dec-85	94.3	12445.6	94.3	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1268.2	94.3
Jan-86	119.4	12535	119.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1148.8	119.4
Feb-86	66.2	12571.2	0	FALSE	TRUE	TRUE	TRUE	66.2	TRUE	-1082.6	66.2
Mar-86	78.3	12619.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1172.1	0
Apr-86	28	12617.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1261.6	0
May-86	0	12587.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1351.1	0

Jun-86	8.2	12565.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1440.6	0
Jul-86	0	12535.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1530.1	0
Aug-86	0	12505.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1619.6	0
Sep-86	5.8	12481.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1709.1	0
Oct-86	80	12531.5	80	FALSE	TRUE	FALSE	FALSE	0	TRUE	-1629.1	80
Nov-86	154.5	12656	154.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1474.6	154.5
Dec-86	137.9	12763.9	137.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1336.7	137.9
Jan-87	147	12880.9	147	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1189.7	147
Feb-87	80.7	12931.6	80.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1109	80.7
Mar-87	112.5	13014.1	112.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-996.5	112.5
Apr-87	23	13007.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1086	0
May-87	12.5	12989.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1175.5	0
Jun-87	0	12959.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1265	0
Jul-87	0	12929.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1354.5	0
Aug-87	39.5	12939.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1444	0
Sep-87	135.5	13044.6	135.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1308.5	135.5
Oct-87	71	13085.6	0	FALSE	TRUE	TRUE	TRUE	71	TRUE	-1237.5	71
Nov-87	221	13276.6	221	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1016.5	221
Dec-87	117.2	13363.8	117.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-899.3	117.2
Jan-88	84.5	13418.3	84.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-814.8	84.5
Feb-88	67	13455.3	0	FALSE	TRUE	TRUE	TRUE	67	TRUE	-747.8	67
Mar-88	88.5	13513.8	88.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-659.3	88.5
Apr-88	42	13525.8	0	FALSE	TRUE	TRUE	TRUE	42	TRUE	-617.3	42
May-88	1	13496.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-706.8	0
Jun-88	14.5	13481.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-796.3	0
Jul-88	1	13452.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-885.8	0
Aug-88	3	13425.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-975.3	0
Sep-88	48	13443.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1064.8	0
Oct-88	104	13517.3	104	TRUE	TRUE	FALSE	FALSE	0	TRUE	-960.8	104
Nov-88	76.5	13563.8	0	FALSE	TRUE	TRUE	TRUE	76.5	TRUE	-884.3	76.5
Dec-88	113	13646.8	113	TRUE	TRUE	FALSE	FALSE	0	TRUE	-771.3	113
Jan-89	136.4	13753.2	136.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-634.9	136.4
Feb-89	218.7	13941.9	218.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	-416.2	218.7
Mar-89	72	13983.9	0	FALSE	TRUE	TRUE	TRUE	72	TRUE	-344.2	72
Apr-89	29.5	13983.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-433.7	0
May-89	4	13957.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-523.2	0
Jun-89	59	13986.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-612.7	0
Jul-89	0	13956.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-702.2	0
Aug-89	13	13939.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-791.7	0
Sep-89	7	13916.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-881.2	0
Oct-89	62.6	13949	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-970.7	0
Nov-89	170	14089	170	TRUE	TRUE	FALSE	FALSE	0	TRUE	-800.7	170
Dec-89	156.8	14215.8	156.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-643.9	156.8
Jan-90	71	14256.8	0	FALSE	TRUE	TRUE	TRUE	71	TRUE	-572.9	71
Feb-90	88.5	14315.3	88.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-484.4	88.5
Mar-90	81	14366.3	81	TRUE	TRUE	TRUE	FALSE	0	TRUE	-403.4	81
Apr-90	112.5	14448.8	112.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-290.9	112.5
May-90	20.5	14439.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-380.4	0
Jun-90	0	14409.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-469.9	0
Jul-90	5	14384.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-559.4	0
Aug-90	0	14354.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-648.9	0
Sep-90	7.1	14331.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-738.4	0
Oct-90	42	14343.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-827.9	0
Nov-90	92.5	14405.9	92.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-735.4	92.5
Dec-90	140.9	14516.8	140.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-594.5	140.9
Jan-91	351.4	14838.2	351.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-243.1	351.4
Feb-91	90.5	14898.7	90.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-152.6	90.5
Mar-91	173.7	15042.4	173.7	TRUE	TRUE	TRUE	FALSE	0	TRUE	21.1	173.7
Apr-91	0	15012.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-68.4	0
May-91	10.3	14992.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-157.9	0
Jun-91	21.5	14984.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-247.4	0
Jul-91		14954.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-336.9	0
Aug-91	0	14924.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-426.4	0
Sep-91	4	14898.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-515.9	0
Oct-91	56	14924.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-605.4	0
Nov-91	28.3	14922.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-694.9	0
Dec-91	111.6	15004.1	111.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-583.3	111.6
Jan-92	96	15070.1	96	TRUE	TRUE	TRUE	FALSE	0	TRUE	-487.3	96
Feb-92	92.5	15132.6	92.5	TRUE	TRUE	TRUE	FALSE	0	TRUE	-394.8	92.5
Mar-92	62	15164.6	0	FALSE	TRUE	TRUE	TRUE	62	TRUE	-332.8	62

Apr-92	22.5	15157.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-422.3	0
May-92	0	15127.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-511.8	0
Jun-92	0	15097.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-601.3	0
Jul-92	0	15067.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-690.8	0
Aug-92	19.2	15056.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-780.3	0
Sep-92	8.5	15034.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-869.8	0
Oct-92	47	15051.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-959.3	0
Nov-92	112	15133.8	112	TRUE	TRUE	FALSE	FALSE	0	TRUE	-847.3	112
Dec-92	105.9	15209.7	105.9	TRUE	TRUE	TRUE	FALSE	0	TRUE	-741.4	105.9
Jan-93	42.9	15222.6	0	FALSE	TRUE	TRUE	TRUE	42.9	TRUE	-698.5	42.9
Feb-93		15192.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-788	0
Mar-93		15162.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-877.5	0
Apr-93		15132.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-967	0
May-93	13.5	15116.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1056.5	0
Jun-93	0	15086.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1146	0
Jul-93		15056.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1235.5	0
Aug-93		15026.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1325	0
Sep-93	58.5	15054.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1414.5	0
Oct-93	122	15146.6	122	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1292.5	122
Nov-93	142.2	15258.8	142.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1150.3	142.2
Dec-93	78.6	15307.4	0	FALSE	TRUE	TRUE	TRUE	78.6	TRUE	-1071.7	78.6
Jan-94	102.8	15380.2	102.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-968.9	102.8
Feb-94	95.2	15445.4	95.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-873.7	95.2
Mar-94	48	15463.4	0	FALSE	TRUE	TRUE	TRUE	48	TRUE	-825.7	48
Apr-94	2.2	15435.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-915.2	0
May-94	0	15405.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1004.7	0
Jun-94	0.2	15375.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1094.2	0
Jul-94	0	15345.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1183.7	0
Aug-94	0.2	15316	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1273.2	0
Sep-94	8.6	15294.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1362.7	0
Oct-94	49.6	15314.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1452.2	0
Nov-94	63	15347.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1541.7	0
Dec-94	125.8	15443	125.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1415.9	125.8
Jan-95	129.2	15542.2	129.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1286.7	129.2
Feb-95	27.8	15540	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1376.2	0
Mar-95	90.6	15600.6	90.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1285.6	90.6
Apr-95	67.6	15638.2	0	FALSE	TRUE	TRUE	TRUE	67.6	TRUE	-1218	67.6
May-95	6.6	15614.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1307.5	0
Jun-95	0	15584.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1397	0
Jul-95	0	15554.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1486.5	0
Aug-95	8.8	15533.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1576	0
Sep-95	2.8	15506.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1665.5	0
Oct-95	71	15547.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1755	0
Nov-95	138	15655.4	138	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1617	138
Dec-95	153.4	15778.8	153.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1463.6	153.4
Jan-96	189.4	15938.2	189.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1274.2	189.4
Feb-96	271.2	16179.4	271.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1003	271.2
Mar-96	85.6	16235	85.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-917.4	85.6
Apr-96	58.4	16263.4	0	FALSE	TRUE	TRUE	TRUE	58.4	TRUE	-859	58.4
May-96	8.2	16241.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-948.5	0
Jun-96	0.4	16212	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1038	0
Jul-96	3	16185	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1127.5	0
Aug-96	10.4	16165.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1217	0
Sep-96	0.8	16136.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1306.5	0
Oct-96	140.6	16246.8	140.6	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1165.9	140.6
Nov-96	45.4	16262.2	0	FALSE	TRUE	TRUE	TRUE	45.4	TRUE	-1120.5	45.4
Dec-96	128.8	16361	128.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-991.7	128.8
Jan-97	50.8	16381.8	0	FALSE	TRUE	TRUE	TRUE	50.8	TRUE	-940.9	50.8
Feb-97	36.4	16388.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1030.4	0
Mar-97	214.2	16572.4	214.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-816.2	214.2
Apr-97	17.4	16559.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-905.7	0
May-97	71.2	16601	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-995.2	0
Jun-97	2.2	16573.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1084.7	0
Jul-97	6.6	16549.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1174.2	0
Aug-97	4.2	16524	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1263.7	0
Sep-97	26.4	16520.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1353.2	0
Oct-97	138.2	16628.6	138.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1215	138.2
Nov-97	151.8	16750.4	151.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1063.2	151.8
Dec-97	108	16828.4	108	TRUE	TRUE	TRUE	FALSE	0	TRUE	-955.2	108
Jan-98	71.4	16869.8	0	FALSE	TRUE	TRUE	TRUE	71.4	TRUE	-883.8	71.4

Feb-98	41.2	16881	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-973.3	0
Mar-98	34.4	16885.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1062.8	0
Apr-98	0	16855.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1152.3	0
May-98	0.2	16825.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1241.8	0
Jun-98	0.2	16795.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1331.3	0
Jul-98	0	16765.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1420.8	0
Aug-98	0	16735.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1510.3	0
Sep-98	61.6	16767.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1599.8	0
Oct-98	110.4	16847.8	110.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1489.4	110.4
Nov-98	212	17029.8	212	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1277.4	212
Dec-98	160.6	17160.4	160.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1116.8	160.6
Jan-99	183.8	17314.2	183.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-933	183.8
Feb-99	18.2	17302.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1022.5	0
Mar-99	27.6	17300	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1112	0
Apr-99	31.8	17301.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1201.5	0
May-99	47.8	17319.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1291	0
Jun-99	13	17302.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1380.5	0
Jul-99	0	17272.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1470	0
Aug-99	1	17243.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1559.5	0
Sep-99	0	17213.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1649	0
Oct-99	0	17183.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1738.5	0
Nov-99	0	17153.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1828	0
Dec-99	230.8	17354.4	230.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1597.2	230.8
Jan-00	242.8	17567.2	242.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1354.4	242.8
Feb-00	110.6	17647.8	110.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1243.8	110.6
Mar-00	156.4	17774.2	156.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1087.4	156.4
Apr-00	68.6	17812.8	0	FALSE	TRUE	TRUE	TRUE	68.6	TRUE	-1018.8	68.6
May-00	15.6	17798.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1108.3	0
Jun-00	10.2	17778.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1197.8	0
Jul-00	0	17748.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1287.3	0
Aug-00	2.2	17720.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1376.8	0
Sep-00	0	17690.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1466.3	0
Oct-00	106.8	17767.6	106.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1359.5	106.8
Nov-00	123.4	17861	123.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1236.1	123.4
Dec-00	115.8	17946.8	115.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1120.3	115.8
Jan-01	220.4	18137.2	220.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-899.9	220.4
Feb-01	84.4	18191.6	84.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-815.5	84.4
Mar-01	31	18192.6	0	FALSE	TRUE	TRUE	TRUE	31	TRUE	-784.5	31
Apr-01	13	18175.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-874	0
May-01	31.4	18177	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-963.5	0
Jun-01	5.4	18152.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1053	0
Jul-01	2.2	18124.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1142.5	0
Aug-01	1.4	18096	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1232	0
Sep-01	3	18069	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1321.5	0
Oct-01	93.8	18132.8	93.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1227.7	93.8
Nov-01	128.6	18231.4	128.6	TRUE	TRUE	TRUE	FALSE	0	TRUE	-1099.1	128.6
Dec-01	140.4	18341.8	140.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-958.7	140.4
Jan-02	82	18393.8	82	TRUE	TRUE	TRUE	FALSE	0	TRUE	-876.7	82
Feb-02	111.4	18475.2	111.4	TRUE	TRUE	TRUE	FALSE	0	TRUE	-765.3	111.4
Mar-02	32.6	18477.8	0	FALSE	TRUE	TRUE	TRUE	32.6	TRUE	-732.7	32.6
Apr-02	22	18469.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-822.2	0
May-02	28.4	18468.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-911.7	0
Jun-02	9.8	18448	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1001.2	0
Jul-02	0.2	18418.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1090.7	0
Aug-02	39.2	18427.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1180.2	0
Sep-02	1.8	18399.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1269.7	0
Oct-02	35	18404.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1359.2	0
Nov-02	9.6	18383.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1448.7	0
Dec-02	35.8	18389.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1538.2	0
Jan-03	6.6	18366.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1627.7	0
Feb-03	106.4	18442.6	106.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1521.3	106.4
Mar-03	33.2	18445.8	0	FALSE	TRUE	TRUE	TRUE	33.2	TRUE	-1488.1	33.2
Apr-03	47.6	18463.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1577.6	0
May-03	0	18433.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1667.1	0
TOTALS	**38353.4**	**5894639.2**	**27923.9**								**32253.4**

Adaption of CRD Method to allow for episodic recharge

Study area **Witbank**
Recharge via **Matrix**

CRD_{ave} =	$CRD_i = P_i + CRD_{i-1} - P_{ave}$	Excel formulas used
A =	Values above high threshold	if(P_i < high threshold, 0, P_i)
B =	Test to see whether Pi > high theshold	and(Pi > high theshold)
C =	Test to see whether Pi > low theshold	and(P_i > low threshold
D =	Test to see whether low threshold follows high threshold	and(C_i = true, B_{i-1} = true)
E =	Test to confirm thesholds are in correct order	and(B_{i-1} = true, B_i = false,C_i = true)
F =	Test to determine where sequential recharge occurs	if(E_i = true, E_i, 0)
G =	Test to see whether the high or low recharge threshold has been exceeded	or(A_i > 0,F_i > 0)
H =	Test to see whether CRDi = CRDi-1+Pi or CRDi = CRDi-1 - RF	if(G = true, $CRD_{i-1} + P_i$, CRD_{i-1} - RF)

Note: a) To obtain episodic CRD, plot Month versus "H (mm)";
b) RF must be adjusted until trendline through episodic CRD plot is horizontal;
c) "I (mm)" is used for averaging calculations only.

Average episodic threshold (low)	90	mm
Average episodic threshold (high)	190	mm
Total number of months	639	months
No. of months above CRD2 threshold	34	months
Average (all values)	60.0	mm
Average CRD2 values	204.8	mm
% Recharge months	5.3	%
Recession Factor (RF)	11.4	mm/month

Month	Rain	CRD_{ave}(mm)	A (mm)	B	C	D	E	F (mm)	G	H (mm)	I (mm)
Jan-48	173.7	173.7	0	FALSE	TRUE	TRUE	FALSE	0	FALSE	-11.4	0
Feb-48	54.9	138.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-22.8	0
Mar-48	81.1	129.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-34.2	0
Apr-48		39.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-45.6	0
May-48		-50.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-57	0
Jun-48		-140.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-68.4	0
Jul-48		-230.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-79.8	0
Aug-48		-320.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-91.2	0
Sep-48		-410.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-102.6	0
Oct-48	99.1	-401.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-114	0
Nov-48	149.3	-341.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-125.4	0
Dec-48		-431.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-136.8	0
Jan-49	179.5	-342.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-148.2	0
Feb-49	64.1	-368.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-159.6	0
Mar-49	96.9	-361.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-171	0
Apr-49	32.7	-418.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-182.4	0
May-49	16.2	-492.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-193.8	0
Jun-49	4.6	-577.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-205.2	0
Jul-49	0	-667.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-216.6	0
Aug-49	0	-757.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-228	0
Sep-49		-847.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-239.4	0
Oct-49		-937.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-250.8	0
Nov-49		-1027.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-262.2	0
Dec-49		-1117.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-273.6	0
Jan-50	35.8	-1172.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-285	0
Feb-50	24.1	-1238	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-296.4	0
Mar-50	27	-1301	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-307.8	0
Apr-50	30.3	-1360.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-319.2	0
May-50	7	-1443.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-330.6	0
Jun-50	0	-1533.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-342	0
Jul-50	0.4	-1623.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-353.4	0
Aug-50	0.1	-1713.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-364.8	0
Sep-50	4.1	-1799.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-376.2	0
Oct-50	13	-1876.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-387.6	0
Nov-50	29.7	-1936.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-399	0
Dec-50	28.2	-1998.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-410.4	0
Jan-51	91.7	-1996.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-421.8	0
Feb-51	65.2	-2021.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-433.2	0
Mar-51	114.8	-1996.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-444.6	0
Apr-51	103.9	-1982.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-456	0
May-51	50.2	-2022.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-467.4	0

Jun-51	2.3	-2110.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-478.8	0
Jul-51	0	-2200.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-490.2	0
Aug-51	29.4	-2260.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-501.6	0
Sep-51	2.3	-2348.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-513	0
Oct-51	96	-2342.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-524.4	0
Nov-51	19.7	-2412.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-535.8	0
Dec-51	146	-2356.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-547.2	0
Jan-52	107	-2339.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-558.6	0
Feb-52	92.3	-2337.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-570	0
Mar-52	43.4	-2384	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-581.4	0
Apr-52	48.9	-2425.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-592.8	0
May-52	10.7	-2504.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-604.2	0
Jun-52	3.1	-2591.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-615.6	0
Jul-52	11.5	-2669.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-627	0
Aug-52	0.5	-2759.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-638.4	0
Sep-52	8.1	-2841.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-649.8	0
Oct-52	39.7	-2891.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-661.2	0
Nov-52	135.6	-2845.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-672.6	0
Dec-52	129.2	-2806.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-684	0
Jan-53	89	-2807.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-695.4	0
Feb-53	186.1	-2711.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-706.8	0
Mar-53	162.7	-2638.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-718.2	0
Apr-53	43.7	-2685.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-729.6	0
May-53	23.2	-2752	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-741	0
Jun-53	0.4	-2841.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-752.4	0
Jul-53	0	-2931.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-763.8	0
Aug-53	2.4	-3019.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-775.2	0
Sep-53	13.2	-3096	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-786.6	0
Oct-53	25.5	-3160.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-798	0
Nov-53	202.9	-3047.6	202.9	TRUE	TRUE	FALSE	FALSE	0	TRUE	-595.1	202.9
Dec-53	130.7	-3006.9	0	FALSE	TRUE	TRUE	TRUE	130.7	TRUE	-464.4	130.7
Jan-54	90.8	-3006.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-475.8	0
Feb-54	95.4	-3000.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-487.2	0
Mar-54	76.7	-3014	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-498.6	0
Apr-54	53	-3051	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-510	0
May-54	12.3	-3128.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-521.4	0
Jun-54	0	-3218.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-532.8	0
Jul-54	0	-3308.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-544.2	0
Aug-54	0.1	-3398.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-555.6	0
Sep-54	28.8	-3459.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-567	0
Oct-54	30.1	-3519.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-578.4	0
Nov-54	140.1	-3469.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-589.8	0
Dec-54	69.3	-3490.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-601.2	0
Jan-55	205	-3375.3	205	TRUE	TRUE	FALSE	FALSE	0	TRUE	-396.2	205
Feb-55	209.2	-3256.1	209.2	TRUE	TRUE	TRUE	FALSE	0	TRUE	-187	209.2
Mar-55	71.9	-3274.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-198.4	0
Apr-55	80.4	-3283.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-209.8	0
May-55	7	-3366.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-221.2	0
Jun-55	8.7	-3448.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-232.6	0
Jul-55	0	-3538.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-244	0
Aug-55	0.7	-3627.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-255.4	0
Sep-55	1.7	-3715.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-266.8	0
Oct-55	66.4	-3739.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-278.2	0
Nov-55	111.7	-3717.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-289.6	0
Dec-55	245.4	-3562.2	245.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-44.2	245.4
Jan-56	46.6	-3605.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-55.6	0
Feb-56	131.9	-3563.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-67	0
Mar-56	26.8	-3626.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-78.4	0
Apr-56	6	-3710.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-89.8	0
May-56	113.9	-3687	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-101.2	0
Jun-56	12.3	-3764.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-112.6	0
Jul-56	4.3	-3850.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-124	0
Aug-56	0	-3940.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-135.4	0
Sep-56	81.3	-3949.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-146.8	0
Oct-56	72.4	-3966.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-158.2	0
Nov-56	80.7	-3976	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-169.6	0
Dec-56	92.5	-3973.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-181	0
Jan-57	73.1	-3990.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-192.4	0
Feb-57	122.7	-3957.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-203.8	0
Mar-57	58.1	-3989.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-215.2	0

Feb-63	15.4	-6317.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-757.7	0
Mar-63	27.1	-6380.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-769.1	0
Apr-63	54.6	-6415.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-780.5	0
May-63	20.6	-6485.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-791.9	0
Jun-63	70.4	-6504.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-803.3	0
Jul-63	19	-6575.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-814.7	0
Aug-63	0	-6665.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-826.1	0
Sep-63	0	-6755.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-837.5	0
Oct-63	72.3	-6773.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-848.9	0
Nov-63	133.8	-6729.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-860.3	0
Dec-63	32.2	-6787.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-871.7	0
Jan-64	178.5	-6699	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-883.1	0
Feb-64	52.9	-6736.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-894.5	0
Mar-64	35.5	-6790.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-905.9	0
Apr-64	24.5	-6856.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-917.3	0
May-64	3.5	-6942.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-928.7	0
Jun-64	0.4	-7032.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-940.1	0
Jul-64	0	-7122.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-951.5	0
Aug-64	13.6	-7198.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-962.9	0
Sep-64	6.5	-7282.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-974.3	0
Oct-64	161	-7211.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-985.7	0
Nov-64	88.5	-7212.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-997.1	0
Dec-64	101.2	-7201.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1008.5	0
Jan-65	64.2	-7227.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1019.9	0
Feb-65	27.8	-7289.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1031.3	0
Mar-65	16	-7363.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1042.7	0
Apr-65	55.4	-7398	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1054.1	0
May-65	8.1	-7479.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1065.5	0
Jun-65	0	-7569.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1076.9	0
Jul-65	6.5	-7653.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1088.3	0
Aug-65	4.4	-7739	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1099.7	0
Sep-65	1.8	-7827.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1111.1	0
Oct-65	21.4	-7895.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1122.5	0
Nov-65	59.6	-7926.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1133.9	0
Dec-65	119.2	-7897	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1145.3	0
Jan-66	57.8	-7929.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1156.7	0
Feb-66	62.7	-7956.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1168.1	0
Mar-66	4.6	-8041.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1179.5	0
Apr-66	57.7	-8074.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1190.9	0
May-66	10.9	-8153.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1202.3	0
Jun-66	10.2	-8233.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1213.7	0
Jul-66	0	-8323.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1225.1	0
Aug-66	1	-8412.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1236.5	0
Sep-66	5.2	-8496.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1247.9	0
Oct-66	116	-8470.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1259.3	0
Nov-66	100.6	-8460.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1270.7	0
Dec-66	93.1	-8457.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1282.1	0
Jan-67	213.1	-8334.1	213.1	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1069	213.1
Feb-67	121.6	-8302.5	0	FALSE	TRUE	TRUE	TRUE	121.6	TRUE	-947.4	121.6
Mar-67	70.5	-8322	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-958.8	0
Apr-67	105.6	-8306.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-970.2	0
May-67	15.7	-8380.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-981.6	0
Jun-67	0	-8470.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-993	0
Jul-67	6.5	-8554.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1004.4	0
Aug-67	10.1	-8634.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1015.8	0
Sep-67	1.7	-8722.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1027.2	0
Oct-67	112.8	-8699.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1038.6	0
Nov-67	134.1	-8655.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1050	0
Dec-67	98.8	-8646.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1061.4	0
Jan-68	93.7	-8643	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1072.8	0
Feb-68	61.1	-8671.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1084.2	0
Mar-68	104.6	-8657.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1095.6	0
Apr-68	34.8	-8712.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1107	0
May-68	24.3	-8778.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1118.4	0
Jun-68	0	-8868.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1129.8	0
Jul-68		-8958.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1141.2	0
Aug-68	13.3	-9034.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1152.6	0
Sep-68	10	-9114.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1164	0
Oct-68	15.4	-9189.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1175.4	0
Nov-68	150.2	-9129.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1186.8	0

Dec-68	77.9	-9141.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1198.2	0
Jan-69	121.2	-9110.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1209.6	0
Feb-69	112.8	-9087.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1221	0
Mar-69	202.5	-8974.9	202.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1018.5	202.5
Apr-69	54.1	-9010.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1029.9	0
May-69		-9100.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1041.3	0
Jun-69	0	-9190.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1052.7	0
Jul-69	0	-9280.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1064.1	0
Aug-69		-9370.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1075.5	0
Sep-69	10.8	-9450	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1086.9	0
Oct-69	165.4	-9374.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1098.3	0
Nov-69	128.1	-9336.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1109.7	0
Dec-69	139.6	-9286.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1121.1	0
Jan-70	106.9	-9270	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1132.5	0
Feb-70	88.4	-9271.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1143.9	0
Mar-70	38.5	-9323.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1155.3	0
Apr-70		-9413.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1166.7	0
May-70	16.8	-9486.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1178.1	0
Jun-70		-9576.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1189.5	0
Jul-70	3	-9663.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1200.9	0
Aug-70	6.8	-9746.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1212.3	0
Sep-70	19	-9817.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1223.7	0
Oct-70	97	-9810.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1235.1	0
Nov-70	117.5	-9783	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1246.5	0
Dec-70	100.6	-9772.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1257.9	0
Jan-71	106.1	-9756.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1269.3	0
Feb-71	71	-9775.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1280.7	0
Mar-71	70.4	-9794.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1292.1	0
Apr-71	103.7	-9781.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1303.5	0
May-71	19.9	-9851.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1314.9	0
Jun-71	6	-9935.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1326.3	0
Jul-71		-10025.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1337.7	0
Aug-71	0.3	-10115	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1349.1	0
Sep-71	42.4	-10162.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1360.5	0
Oct-71	75	-10177.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1371.9	0
Nov-71	144.4	-10123.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1383.3	0
Dec-71	131.8	-10081.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1394.7	0
Jan-72	224.8	-9946.6	224.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1169.9	224.8
Feb-72	61	-9975.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1181.3	0
Mar-72	139.5	-9926.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1192.7	0
Apr-72	17.2	-9998.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1204.1	0
May-72	14.3	-10074.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1215.5	0
Jun-72	0.7	-10163.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1226.9	0
Jul-72	0	-10253.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1238.3	0
Aug-72	5.4	-10338.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1249.7	0
Sep-72	42.8	-10385.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1261.1	0
Oct-72	74.8	-10400.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1272.5	0
Nov-72	131.4	-10359.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1283.9	0
Dec-72	60.9	-10388.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1295.3	0
Jan-73	88.6	-10390	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1306.7	0
Feb-73	43.7	-10436.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1318.1	0
Mar-73	99.3	-10427	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1329.5	0
Apr-73	76.6	-10440.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1340.9	0
May-73	0.5	-10529.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1352.3	0
Jun-73	0	-10619.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1363.7	0
Jul-73	0	-10709.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1375.1	0
Aug-73	4.1	-10795.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1386.5	0
Sep-73	57.4	-10828.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1397.9	0
Oct-73	106.9	-10811.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1409.3	0
Nov-73	63.9	-10837.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1420.7	0
Dec-73	151.9	-10775.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1432.1	0
Jan-74	123.9	-10741.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1443.5	0
Feb-74	57.3	-10774.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1454.9	0
Mar-74	24.4	-10840.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1466.3	0
Apr-74	77.7	-10852.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1477.7	0
May-74	6.8	-10935.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1489.1	0
Jun-74	0.8	-11024.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1500.5	0
Jul-74	15.5	-11099.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1511.9	0
Aug-74	2	-11187.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1523.3	0
Sep-74	14.4	-11262.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1534.7	0

Oct-74	19.4	-11333.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1546.1	0
Nov-74	112.1	-11311.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1557.5	0
Dec-74	90.2	-11311.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1568.9	0
Jan-75	277.5	-11123.7	277.5	TRUE	TRUE	FALSE	FALSE	0	TRUE	-1291.4	277.5
Feb-75	170	-11043.7	0	FALSE	TRUE	TRUE	TRUE	170	TRUE	-1121.4	170
Mar-75	108	-11025.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1132.8	0
Apr-75	84.4	-11031.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1144.2	0
May-75	11.4	-11109.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1155.6	0
Jun-75	6.8	-11193.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1167	0
Jul-75	0.7	-11282.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1178.4	0
Aug-75	0	-11372.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1189.8	0
Sep-75	3.5	-11458.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1201.2	0
Oct-75	60.5	-11488.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1212.6	0
Nov-75	219.4	-11359	219.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-993.2	219.4
Dec-75	145.5	-11303.5	0	FALSE	TRUE	TRUE	TRUE	145.5	TRUE	-847.7	145.5
Jan-76	112.4	-11281.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-859.1	0
Feb-76	64	-11307.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-870.5	0
Mar-76	79.2	-11317.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-881.9	0
Apr-76	23.2	-11384.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-893.3	0
May-76	59.9	-11414.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-904.7	0
Jun-76	0	-11504.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-916.1	0
Jul-76	0	-11594.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-927.5	0
Aug-76	2.5	-11682.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-938.9	0
Sep-76	7.8	-11764.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-950.3	0
Oct-76	126.7	-11727.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-961.7	0
Nov-76	101.9	-11715.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-973.1	0
Dec-76	136.6	-11669.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-984.5	0
Jan-77	103.9	-11655.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-995.9	0
Feb-77	8.5	-11736.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1007.3	0
Mar-77	129.5	-11697.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1018.7	0
Apr-77	37.7	-11749.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1030.1	0
May-77	12.9	-11826.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1041.5	0
Jun-77	0	-11916.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1052.9	0
Jul-77	0	-12006.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1064.3	0
Aug-77	10.5	-12086.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1075.7	0
Sep-77	30.4	-12145.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1087.1	0
Oct-77	52.1	-12183.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1098.5	0
Nov-77	110.8	-12163	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-1109.9	0
Dec-77	82.5	-12170.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-1121.3	0
Jan-78	374.4	-11886.1	374.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-746.9	374.4
Feb-78	188.6	-11787.5	0	FALSE	TRUE	TRUE	TRUE	188.6	TRUE	-558.3	188.6
Mar-78	64.6	-11812.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-569.7	0
Apr-78	25	-11877.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-581.1	0
May-78	3	-11964.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-592.5	0
Jun-78	0	-12054.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-603.9	0
Jul-78	0.2	-12144.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-615.3	0
Aug-78	19.6	-12215.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-626.7	0
Sep-78	50.9	-12254.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-638.1	0
Oct-78	100.2	-12244	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-649.5	0
Nov-78	96.1	-12237.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-660.9	0
Dec-78	46.3	-12281.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-672.3	0
Jan-79	55.9	-12315.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-683.7	0
Feb-79	98.7	-12307	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-695.1	0
Mar-79	73	-12324	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-706.5	0
Apr-79	19.8	-12394.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-717.9	0
May-79	4.5	-12479.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-729.3	0
Jun-79	0	-12569.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-740.7	0
Jul-79	12.8	-12646.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-752.1	0
Aug-79	10.8	-12726.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-763.5	0
Sep-79	16.2	-12799.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-774.9	0
Oct-79	135.1	-12754.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-786.3	0
Nov-79	169.2	-12675.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-797.7	0
Dec-79	72.7	-12692.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-809.1	0
Jan-80	183.7	-12599.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-820.5	0
Feb-80	176.4	-12512.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-831.9	0
Mar-80	71.5	-12531.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-843.3	0
Apr-80	28.7	-12592.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-854.7	0
May-80	4.7	-12677.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-866.1	0
Jun-80	0	-12767.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-877.5	0
Jul-80	0	-12857.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-888.9	0

Aug-80	0	-12947.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-900.3	0
Sep-80	22.3	-13015.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-911.7	0
Oct-80	26.5	-13079.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-923.1	0
Nov-80	204.4	-12964.7	204.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-718.7	204.4
Dec-80	113.6	-12941.1	0	FALSE	TRUE	TRUE	TRUE	113.6	TRUE	-605.1	113.6
Jan-81	231.2	-12799.9	231.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-373.9	231.2
Feb-81	114.3	-12775.6	0	FALSE	TRUE	TRUE	TRUE	114.3	TRUE	-259.6	114.3
Mar-81	50.7	-12814.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-271	0
Apr-81	38.5	-12866.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-282.4	0
May-81	0	-12956.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-293.8	0
Jun-81	7	-13039.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-305.2	0
Jul-81	0	-13129.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-316.6	0
Aug-81	15.2	-13204.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-328	0
Sep-81	51	-13243.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-339.4	0
Oct-81	134	-13199.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-350.8	0
Nov-81	41.3	-13247.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-362.2	0
Dec-81	91.8	-13246.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-373.6	0
Jan-82	138	-13198.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-385	0
Feb-82	51.6	-13236.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-396.4	0
Mar-82	132	-13194.5	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-407.8	0
Apr-82	14.1	-13270.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-419.2	0
May-82	0	-13360.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-430.6	0
Jun-82	0	-13450.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-442	0
Jul-82	10.7	-13529.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-453.4	0
Aug-82	0	-13619.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-464.8	0
Sep-82	4	-13705.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-476.2	0
Oct-82	84.7	-13711	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-487.6	0
Nov-82	89.4	-13711.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-499	0
Dec-82	29.5	-13772.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-510.4	0
Jan-83	186	-13676.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-521.8	0
Feb-83	35.5	-13730.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-533.2	0
Mar-83	89.6	-13731	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-544.6	0
Apr-83	31.3	-13789.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-556	0
May-83	15.3	-13864.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-567.4	0
Jun-83	20.5	-13933.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-578.8	0
Jul-83	23	-14000.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-590.2	0
Aug-83	38	-14052.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-601.6	0
Sep-83	2.5	-14140.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-613	0
Oct-83	82.8	-14147.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-624.4	0
Nov-83	251	-13986.6	251	TRUE	TRUE	FALSE	FALSE	0	TRUE	-373.4	251
Dec-83	89.2	-13987.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-384.8	0
Jan-84	121	-13956.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-396.2	0
Feb-84	115	-13931.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-407.6	0
Mar-84	85.5	-13935.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-419	0
Apr-84	7	-14018.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-430.4	0
May-84	0	-14108.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-441.8	0
Jun-84	20	-14178.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-453.2	0
Jul-84	15.3	-14253.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-464.6	0
Aug-84	6	-14337.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-476	0
Sep-84	13.5	-14414.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-487.4	0
Oct-84	111.8	-14392.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-498.8	0
Nov-84	71.2	-14411.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-510.2	0
Dec-84	81.5	-14419.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-521.6	0
Jan-85	77.7	-14431.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-533	0
Feb-85	170.5	-14351.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-544.4	0
Mar-85	89	-14352.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-555.8	0
Apr-85	0	-14442.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-567.2	0
May-85	16.7	-14515.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-578.6	0
Jun-85	0	-14605.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-590	0
Jul-85	0	-14695.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-601.4	0
Aug-85	0	-14785.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-612.8	0
Sep-85	49	-14826.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-624.2	0
Oct-85	83	-14833.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-635.6	0
Nov-85	65	-14858.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-647	0
Dec-85	94.3	-14854.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-658.4	0
Jan-86	119.4	-14825	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-669.8	0
Feb-86	66.2	-14848.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-681.2	0
Mar-86	78.3	-14860.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-692.6	0
Apr-86	28	-14922.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-704	0
May-86	0	-15012.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-715.4	0

Jun-86	8.2	-15094.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-726.8	0
Jul-86	0	-15184.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-738.2	0
Aug-86	0	-15274.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-749.6	0
Sep-86	5.8	-15358.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-761	0
Oct-86	80	-15368.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-772.4	0
Nov-86	154.5	-15304	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-783.8	0
Dec-86	137.9	-15256.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-795.2	0
Jan-87	147	-15199.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-806.6	0
Feb-87	80.7	-15208.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-818	0
Mar-87	112.5	-15185.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-829.4	0
Apr-87	23	-15252.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-840.8	0
May-87	12.5	-15330.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-852.2	0
Jun-87	0	-15420.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-863.6	0
Jul-87	0	-15510.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-875	0
Aug-87	39.5	-15560.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-886.4	0
Sep-87	135.5	-15515.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-897.8	0
Oct-87	71	-15534.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-909.2	0
Nov-87	221	-15403.4	221	TRUE	TRUE	FALSE	FALSE	0	TRUE	-688.2	221
Dec-87	117.2	-15376.2	0	FALSE	TRUE	TRUE	TRUE	117.2	TRUE	-571	117.2
Jan-88	84.5	-15381.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-582.4	0
Feb-88	67	-15404.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-593.8	0
Mar-88	88.5	-15406.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-605.2	0
Apr-88	42	-15454.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-616.6	0
May-88	1	-15543.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-628	0
Jun-88	14.5	-15618.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-639.4	0
Jul-88	1	-15707.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-650.8	0
Aug-88	3	-15794.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-662.2	0
Sep-88	48	-15836.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-673.6	0
Oct-88	104	-15822.7	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-685	0
Nov-88	76.5	-15836.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-696.4	0
Dec-88	113	-15813.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-707.8	0
Jan-89	136.4	-15766.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-719.2	0
Feb-89	218.7	-15638.1	218.7	TRUE	TRUE	FALSE	FALSE	0	TRUE	-500.5	218.7
Mar-89	72	-15656.1	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-511.9	0
Apr-89	29.5	-15716.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-523.3	0
May-89	4	-15802.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-534.7	0
Jun-89	59	-15833.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-546.1	0
Jul-89	0	-15923.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-557.5	0
Aug-89	13	-16000.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-568.9	0
Sep-89	7	-16083.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-580.3	0
Oct-89	62.6	-16111	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-591.7	0
Nov-89	170	-16031	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-603.1	0
Dec-89	156.8	-15964.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-614.5	0
Jan-90	71	-15983.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-625.9	0
Feb-90	88.5	-15984.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-637.3	0
Mar-90	81	-15993.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-648.7	0
Apr-90	112.5	-15971.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-660.1	0
May-90	20.5	-16040.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-671.5	0
Jun-90	0	-16130.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-682.9	0
Jul-90	5	-16215.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-694.3	0
Aug-90	0	-16305.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-705.7	0
Sep-90	7.1	-16388.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-717.1	0
Oct-90	42	-16436.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-728.5	0
Nov-90	92.5	-16434.1	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-739.9	0
Dec-90	140.9	-16383.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-751.3	0
Jan-91	351.4	-16121.8	351.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	-399.9	351.4
Feb-91	90.5	-16121.3	0	FALSE	TRUE	TRUE	TRUE	90.5	TRUE	-309.4	90.5
Mar-91	173.7	-16037.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-320.8	0
Apr-91	0	-16127.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-332.2	0
May-91	10.3	-16207.3	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-343.6	0
Jun-91	21.5	-16275.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-355	0
Jul-91		-16365.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-366.4	0
Aug-91	0	-16455.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-377.8	0
Sep-91	4	-16541.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-389.2	0
Oct-91	56	-16575.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-400.6	0
Nov-91	28.3	-16637.5	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-412	0
Dec-91	111.6	-16615.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-423.4	0
Jan-92	96	-16609.9	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-434.8	0
Feb-92	92.5	-16607.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-446.2	0
Mar-92	62	-16635.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-457.6	0

Apr-92	22.5	-16702.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-469	0
May-92	0	-16792.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-480.4	0
Jun-92	0	-16882.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-491.8	0
Jul-92	0	-16972.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-503.2	0
Aug-92	19.2	-17043.7	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-514.6	0
Sep-92	8.5	-17125.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-526	0
Oct-92	47	-17168.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-537.4	0
Nov-92	112	-17146.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-548.8	0
Dec-92	105.9	-17130.3	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-560.2	0
Jan-93	42.9	-17177.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-571.6	0
Feb-93		-17267.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-583	0
Mar-93		-17357.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-594.4	0
Apr-93		-17447.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-605.8	0
May-93	13.5	-17523.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-617.2	0
Jun-93	0	-17613.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-628.6	0
Jul-93		-17703.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-640	0
Aug-93		-17793.9	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-651.4	0
Sep-93	58.5	-17825.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-662.8	0
Oct-93	122	-17793.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-674.2	0
Nov-93	142.2	-17741.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-685.6	0
Dec-93	78.6	-17752.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-697	0
Jan-94	102.8	-17739.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-708.4	0
Feb-94	95.2	-17734.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-719.8	0
Mar-94	48	-17776.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-731.2	0
Apr-94	2.2	-17864.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-742.6	0
May-94	0	-17954.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-754	0
Jun-94	0.2	-18044.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-765.4	0
Jul-94	0	-18134.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-776.8	0
Aug-94	0.2	-18224	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-788.2	0
Sep-94	8.6	-18305.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-799.6	0
Oct-94	49.6	-18345.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-811	0
Nov-94	63	-18372.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-822.4	0
Dec-94	125.8	-18337	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-833.8	0
Jan-95	129.2	-18297.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-845.2	0
Feb-95	27.8	-18360	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-856.6	0
Mar-95	90.6	-18359.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-868	0
Apr-95	67.6	-18381.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-879.4	0
May-95	6.6	-18465.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-890.8	0
Jun-95	0	-18555.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-902.2	0
Jul-95	0	-18645.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-913.6	0
Aug-95	8.8	-18726.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-925	0
Sep-95	2.8	-18813.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-936.4	0
Oct-95	71	-18832.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-947.8	0
Nov-95	138	-18784.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-959.2	0
Dec-95	153.4	-18721.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-970.6	0
Jan-96	189.4	-18621.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-982	0
Feb-96	271.2	-18440.6	271.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-710.8	271.2
Mar-96	85.6	-18445	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-722.2	0
Apr-96	58.4	-18476.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-733.6	0
May-96	8.2	-18558.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-745	0
Jun-96	0.4	-18648	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-756.4	0
Jul-96	3	-18735	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-767.8	0
Aug-96	10.4	-18814.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-779.2	0
Sep-96	0.8	-18903.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-790.6	0
Oct-96	140.6	-18853.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-802	0
Nov-96	45.4	-18897.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-813.4	0
Dec-96	128.8	-18859	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-824.8	0
Jan-97	50.8	-18898.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-836.2	0
Feb-97	36.4	-18951.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-847.6	0
Mar-97	214.2	-18827.6	214.2	TRUE	TRUE	FALSE	FALSE	0	TRUE	-633.4	214.2
Apr-97	17.4	-18900.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-644.8	0
May-97	71.2	-18919	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-656.2	0
Jun-97	2.2	-19006.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-667.6	0
Jul-97	6.6	-19090.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-679	0
Aug-97	4.2	-19176	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-690.4	0
Sep-97	26.4	-19239.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-701.8	0
Oct-97	138.2	-19191.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-713.2	0
Nov-97	151.8	-19129.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-724.6	0
Dec-97	108	-19111.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-736	0
Jan-98	71.4	-19130.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-747.4	0

Feb-98	41.2	-19179	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-758.8	0
Mar-98	34.4	-19234.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-770.2	0
Apr-98	0	-19324.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-781.6	0
May-98	0.2	-19414.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-793	0
Jun-98	0.2	-19504.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-804.4	0
Jul-98	0	-19594.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-815.8	0
Aug-98	0	-19684.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-827.2	0
Sep-98	61.6	-19712.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-838.6	0
Oct-98	110.4	-19692.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-850	0
Nov-98	212	-19570.2	212	TRUE	TRUE	FALSE	FALSE	0	TRUE	-638	212
Dec-98	160.6	-19499.6	0	FALSE	TRUE	TRUE	TRUE	160.6	TRUE	-477.4	160.6
Jan-99	183.8	-19405.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-488.8	0
Feb-99	18.2	-19477.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-500.2	0
Mar-99	27.6	-19540	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-511.6	0
Apr-99	31.8	-19598.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-523	0
May-99	47.8	-19640.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-534.4	0
Jun-99	13	-19717.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-545.8	0
Jul-99	0	-19807.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-557.2	0
Aug-99	1	-19896.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-568.6	0
Sep-99	0	-19986.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-580	0
Oct-99	0	-20076.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-591.4	0
Nov-99	0	-20166.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-602.8	0
Dec-99	230.8	-20025.6	230.8	TRUE	TRUE	FALSE	FALSE	0	TRUE	-372	230.8
Jan-00	242.8	-19872.8	242.8	TRUE	TRUE	TRUE	FALSE	0	TRUE	-129.2	242.8
Feb-00	110.6	-19852.2	0	FALSE	TRUE	TRUE	TRUE	110.6	TRUE	-18.6	110.6
Mar-00	156.4	-19785.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-30	0
Apr-00	68.6	-19807.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-41.4	0
May-00	15.6	-19881.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-52.8	0
Jun-00	10.2	-19961.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-64.2	0
Jul-00	0	-20051.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-75.6	0
Aug-00	2.2	-20139.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-87	0
Sep-00	0	-20229.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-98.4	0
Oct-00	106.8	-20212.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-109.8	0
Nov-00	123.4	-20179	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-121.2	0
Dec-00	115.8	-20153.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-132.6	0
Jan-01	220.4	-20022.8	220.4	TRUE	TRUE	FALSE	FALSE	0	TRUE	87.8	220.4
Feb-01	84.4	-20028.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	76.4	0
Mar-01	31	-20087.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	65	0
Apr-01	13	-20164.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	53.6	0
May-01	31.4	-20223	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	42.2	0
Jun-01	5.4	-20307.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	30.8	0
Jul-01	2.2	-20395.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	19.4	0
Aug-01	1.4	-20484	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	8	0
Sep-01	3	-20571	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-3.4	0
Oct-01	93.8	-20567.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-14.8	0
Nov-01	128.6	-20528.6	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-26.2	0
Dec-01	140.4	-20478.2	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-37.6	0
Jan-02	82	-20486.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-49	0
Feb-02	111.4	-20464.8	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-60.4	0
Mar-02	32.6	-20522.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-71.8	0
Apr-02	22	-20590.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-83.2	0
May-02	28.4	-20651.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-94.6	0
Jun-02	9.8	-20732	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-106	0
Jul-02	0.2	-20821.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-117.4	0
Aug-02	39.2	-20872.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-128.8	0
Sep-02	1.8	-20960.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-140.2	0
Oct-02	35	-21015.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-151.6	0
Nov-02	9.6	-21096.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-163	0
Dec-02	35.8	-21150.4	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-174.4	0
Jan-03	6.6	-21233.8	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-185.8	0
Feb-03	106.4	-21217.4	0	FALSE	TRUE	FALSE	FALSE	0	FALSE	-197.2	0
Mar-03	33.2	-21274.2	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-208.6	0
Apr-03	47.6	-21316.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-220	0
May-03	0	-21406.6	0	FALSE	FALSE	FALSE	FALSE	0	FALSE	-231.4	0
TOTALS	**38353.4**	**-7352160.8**	**5498.8**								**6962**

Summary

A new stable isotope-based technique, the Modified Amount Effect (MAE) Method, was developed during this investigation. This technique provides insight into episodic recharge processes by estimating the proportion of preferential pathway-to-matrix-derived flow entering an aquifer, and the amount of rainfall required to initiate recharge via the respective flow paths. Significantly, the proportion of bypass flow can be determined without undertaking expensive and time consuming unsaturated zone studies, both factors often of primary concern when undertaking recharge investigations in developing countries.

Four recharge thresholds can be identified using the MAE Method; the low and high recharge thresholds that must be exceeded before recharge occurs via preferential pathways or the matrix, respectively. These represent threshold limits, the low value only of importance following successive months of wet weather, the high value representing the rainfall that must be received to restore an aquifer system to equilibrium after prolonged dry spells. Once these thresholds are known, the recharge history of a site can be modelled using available rainfall data by adapting the Cumulative Rainfall Departure (CRD) Method. An important finding of modelling undertaken during this investigation is that in those semi-arid to arid areas where most recharge water enters the aquifer via the matrix, the period of time that elapses between successive rainfall events that exceed the matrix recharge threshold often extends to scores of years. This has significant resource management implications for much of the region as it indicates that the current approach of basing allocations on average recharge estimates is only justified if sufficient groundwater is available for use over the entire period between recharge events.

In terms of recharge estimation, the Stable Isotope (SI) Method was found to return comparable results to the Chloride Mass Balance (CMB) Method in both wetter and drier inland areas of South Africa. However, both the SI and MAE Methods were found to be sensitive to the recharge history of the site, the returned recharge estimate significantly higher when calculated immediately after recharge via the matrix had occurred. This is not to say that these estimates were wrong (indeed they were representative of site recharge processes at the time of sampling), but that rainfall in the months prior to sampling should be considered. In general though, sampling should be undertaken near the end of the dry season, which in the summer-dominant rainfall areas of Southern Africa is between September and November (allowing for a 30 to 60 day lag time between rainfall and subsequent recharge).

While the geological and geomorphological limitations of the CMB Method must be clearly understood before applying the technique, it does have application within many fractured rock terrains. On a regional scale, fractured rock aquifers are commonly regarded as equivalent porous mediums for modelling purposes, a necessity given the significant variations in porosity, hydraulic conductivity, and storage that occur between adjacent areas. Thus, even where long-term water level data is available, the hydraulic conditions that contribute to the observed water table response at a given site following recharge represent an average for the area surrounding a given borehole. The CMB Method negates the need for measuring or estimating these hydraulic parameters, as it already represents a long-term average of recharge. This is not to say that water levels should not be taken, but rather that recharge calculated using water balance methods be checked using the CMB Method in those areas completely overlain by a porous unsaturated zone of significant thickness. Indeed, the comparison of results obtained using multiple estimation techniques is recommended during all recharge-based investigations, whether conducted in fractured rock or porous environments.

Opsomming

‘n Nuwe stabiele isotoop-gebaseerde tegniek, die “Modified Amount Effect” (MAE) metode, is tydens hierdie ondersoek ontwikkel. Hierdie tegniek gee insig in episodiese aanvullingsprosesse deur ‘n skatting te verkry van die relatiewe volumes vloei wat ‘n akwifeer bereik langs voorkeurvloeibane en deur die matriks, asook die hoeveelheid reënval wat benodig word om die aanvullingsprosesse aan die gang te sit. Van belang is dat die verhouding van die voorkeurvloei tot die matriksvloei bepaal kan word sonder om duur en tydrowende ondersoeke van die onversadigde sone te onderneem. Tyd en finansiële faktore is van groot belang wanneer aanvullingsondersoeke in ontwikkelende lande onderneem word.

Vier aanvullingsdrumpelwaardes kan geïdentifiseer word wanneer die MAE metode gebruik word, naamlik een lae- en een hoë-aanvullingsdrumpelwaardes wat oorskry moet word voordat aanvulling plaas kan vind òf langs voorkeurvloeibane òf deur die matriks. Hierdie waardes verteenwoordig die drumpellimiete met die lae waarde slegs van belang na opeenvolgende maande van nat weer, terwyl die hoë waarde die reënval verteenwoordig wat benodig word om die akwifeersisteem weer in ewewig te bring na ‘n lang droë tydperk. Wanneer hierdie drumpelwaardes bekend is, kan ‘n model van die aanvullingsgeskiedenis van ‘n omgewing bepaal word deur die beskikbare reënvaldata te gebruik en dit met die “Cumulative Rainfall Departure”(CRD)-metode aan te pas. ’n Belangrike bevinding van modellering gedoen tydens hierdie ondersoek is dat in semi-droë tot droë omgewings waar die aanvullingswater die akwifeer via die matriks binnegaan, die tydsperiode wat verbygaan tussen opeenvolgende reënvalgebeurtenisse waartydens die aanvullingsdrumpelwaarde van die matriks oorskry word, dikwels oor etlike jare strek. Hierdie aspek het aansienlike implikasies wanneer dit kom by hulpbronbestuur in die gebied en dui daarop dat die huidige benadering gebasseer op die berekening van gemiddelde aanvullings slegs geregverdig kan word indien voldoende grondwater beskikbaar is vir gebruik tydens die hele tydsperiode tussen aanvullingsgebeurtenisse.

In terme van die berekening van die benaderde aanvullingswaarde, is gevind dat die Stabile Isotoop (SI) metode waardes gee wat vergelykbaar is met die Chloried Massa Balans (CMB) metode in beide natter en droër binnelandse omgewings van Suid-Afrika. Daar is egter bevind dat beide die SI- en MAE-metodes baie sensitief is ten opsigte van die aanvullingsgeskiedenis van die omgewing. Die aanvullingswaardes wat verkry is, was aansienlik hoër wanneer die benaderde waardes bereken is direk na aanvulling plaasgevind het via die matriks. Dit beteken

egter nie dat hierdie berekeninge verkeerd is nie (dit was inderdaad verteenwoordigend van die terrein se aanvulling tydens monsterneming), maar dat die reënval tydens die maande voor die monsterneming plaasgevind het in ag geneem word. In die algemeen moet monsterneming aan die einde van die droë seisoen plaasvind. In die somer-dominante reënvalgebiede van Suid-Afrika is dit tussen die maande September en November (dit laat toe vir ‘n 30 tot 60 dae wagtydperk tussen die reenval en die daaropvolgende aanvullingsgebeurtenis).

Hoewel die geologiese en geomorfologiese beperkinge van die CMB-metode eers duidelik begryp moet word voordat die tegniek gebruik kan word, het die tegniek toepassing in verskeie fraktuurgesteente-omgewings. Op ‘n regionale skaal word fraktuur-akwifere oor die algemeen gesien as poreuse mediums vir die doeleindes van grondwatervloeimodellerings. Die redes hiervoor is die aansienlike verskille in poreusheid, hidrouliese konduktiwiteit asook die bergingskoeffisiënt tussen aangrensende gebiede. Selfs waar langtermyn watertafeldata beskikbaar is, is die hidroliese eienskappe wat bydra tot die watertafelreaksie na ‘n aanvullingsgebeurtenis slegs verteenwoordigend van die gemiddelde vir die area rondom die boorgat. Die CMB-metode benodig nie die meet of berekening van die hidroliese eienskappe nie, aangesien dit alreeds die langtermyn gemiddelde van die aanvulling verteenwoordig. Dit beteken nie dat die watervlakmetings in fraktuurgesteente-omgewings nie hoef plaas te vind nie, maar eerder dat die aanvullingsberekeninge wat deur middel van die waterbalansmetodes verkry word gekontroleer moet word deur die CMB-metode toe te pas, veral in gebiede wat oorlê word met ‘n poreuse, onversadigde sone van aansienlike dikte. Die vergelyking van resultate wat verkry is deur die gebruik van verskeie benaderingstegnieke word inderdaad aanbeveel tydens alle aanvullings-gebaseerde ondersoeke, hetsy die ondersoeke in fraktuur-getsteentes of poreuse omgewings uitgevoer word.