ISCOR
flat steel

ISCOR VANDERBIJLPARK STEEL

ENVIRONMENTAL MASTER PLAN

SPECIALIST REPORT

SURFACE WATER:
Volume 1 of 3
Report

BY

VAN RENSSEN & FORTUIN
CONSULTING ENGINEERS

SERIES IV
DOCUMENT IVS/SR/027
DECEMBER 2002

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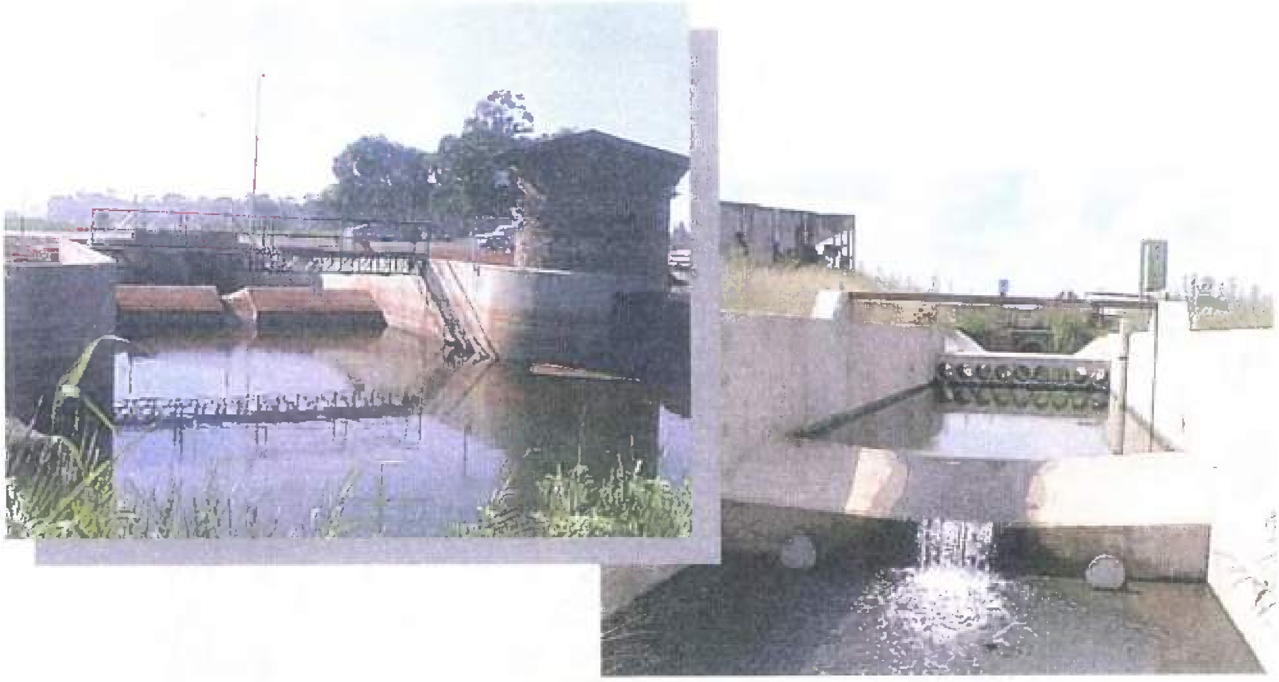

MASTER PLAN SPECIALIST REPORT: SURFACE WATER

DECEMBER 2002

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LIST OF ABBREVIATIONS

AH1, ..., 5	-	Analysis Houses 1, 2, 3, 4 and 5 within IVS
BF	-	Blast Furnace
BOF	-	Basic Oxygen Furnace
BS	-	British Standard
CCWR	-	Computing Centre for Water Research
CETP	-	Central Effluent Treatment Plant
CMA	-	Catchment Management Agency
CPA	-	Consolidated Plant Area
CRMF	-	Consolidated Residue Management Facility
DEAT	-	Department of Environmental Affairs and Tourism
DR	-	Direct Reduction
DWAF	-	Department of Water Affairs and Forestry
EAF	-	Electric Arc Furnace
EC	-	Electrical Conductivity
ECA	-	Environmental Conservation Act
ECC	-	Energy Control Centre
EIA	-	Environmental Impact Assessment
EPA	-	Environmental Protection Agency
FSL	-	Full Supply Level
GDACEL	-	Gauteng Department of Agriculture, Conservation, Environment and Land Affairs
IEM	-	Integrated Environmental Management
IFSP	-	Iscor Flat Steel Products
ILSP	-	Iscor Long Steel Products
IVS	-	Iscor Vanderbijlpark Steel
km^2	-	Square kilometres
LS1, ...6	-	Water quality sampling points in the Leeuspruit river system
MAE	-	Mean Annual Evaporation
m.amsl	-	Metres above mean sea level
MAP	-	Mean Annual Precipitation
MAR	-	Mean Annual Runoff
MAV	-	Maximum Acceptable Value
MGV	-	Maximum Guideline Value

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MTP	-	Main Treatment Plant
mm/a	-	Millimetres per annum
m/s	-	Metres per second
m^3/s	-	Cubic metres per second
NEMA	-	National Environmental Management Act
NW	-	North Works
NWRC	-	North Works Runoff Canal
OFT	-	Ockie Fourie Toxicologists (Pty) Ltd
ppb	-	Parts per billion
ppm	-	Parts per million
RDP	-	Reconstruction and Development Programme
RS1, ...10	-	Water quality sampling points in the Rietspruit, Rietkuilspruit and TETP Canal
RV2	-	Rand Water monitoring point in the Rietspruit River
SADWS	-	South African Drinking Water Standards
SABS	-	South African Bureau of Standards
TDS	-	Total Dissolved Salts (usually quoted in mg/l)
TETP	-	Terminal Effluent Treatment Plant
US EPA	-	United States Environmental Protection Agency
VRF	-	Van Renssen & Fortuin (Pty) Ltd
WHO	-	World Health Organisation
WMA	-	Water Management Area
WQO	-	Water Quality Objective
WRC	-	Water Research Commission
WUA	-	Water User Association
ZED	-	Zero Effluent Discharge
$10^6m^3/a$	-	Million cubic metres per annum

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LIST OF DEFINITIONS

Note: The following definitions are not necessary universal due to the varying interpretations and understandings of the specific technical words or terms. In this document the following specific words or terms are intended to have the meanings provided, and should not be confused with other interpretations or understandings of the meanings of the words.

Affected	-	Affected means that the water quality has been altered.
Attenuation	-	A flood attenuation facility is a dam with no long-term storage. Flow enters the dam, and is stored temporarily while continuously releasing flow. The purpose of a flood attenuation facility is to reduce the peak flow event.
Average	-	Arithmetic mean; A value arrived at by adding several quantities together and dividing by the number of these quantities.
Contaminated	-	Contaminated means the water quality has been altered, but the fitness for use may not necessarily have been compromised.
Dry weather flow	-	Flow occurring independent of a storm event (precipitation).
Effluent	-	Effluent is defined as a liquid of manmade origin, as a result of the following processes: (i) Take water in; (ii) Putting it through a process; (iii) Discharging it as an effluent. Effluent should be qualified as being contaminated or uncontaminated. The degree of contamination is of importance.
Filtrate	-	A filtrate is produced when water percolates through a matrix, and water insoluble components present in the water, are removed from the water into the matrix. This term essentially therefore implies a positive change in the quality (improvement) of the source water.
First Flush	-	This is a loose term for contaminated storm water during the first run-off period of a rain event. The term should rather not be used, as it is undefined in terms of quality, quantity or period of occurrence and because it could mean different things to different people. It is a function of many variables.

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Fitness for use	-	Fitness for use refers to the suitability of the water to be beneficially utilised for humans or the environment over the long term, as determined through toxicological investigations. The fitness for use is associated with a specific user of the water.
Ground water	-	This term refers to all water that occurs below the surface. The surface could either be the natural ground level, or a man made heap or dump.
Impacted	-	A water source is termed to be impacted when it has been influenced by an external influence. It may be impacted in terms of volume or quality.
Leachate	-	A leachate is produced when water percolates through a matrix and water soluble components present in the matrix, dissolve into the water. This term essentially therefore implies a negative change in the quality (deterioration) of the source water.
Median	-	The median of a specific data set is the 50-percentile value of that data set.
Peak Flow	-	The maximum flow during a specific storm event. The flow relating to the peak of the flow hydrograph for a specific storm event.
Percentile	-	The k-th percentile in a given data set is that data value that relates to the k/100 entry when the data set is ordered in ascending order. The value where k percent of the data points in a data set fall below the specified value.
Perched water table	-	A perched water table occurs at a higher elevation than the general (regional) ground water table in an area, and usually results from clay lenses, or other impermeable layers, occurring within the upper weathered or transported zones of the geological profile.
Polluted	-	The term polluted refers to the degree of contamination where the fitness for use of the water has been compromised. The water is no longer fit for beneficial use. Water can only be regarded as polluted if the limit value / criteria / standard specified for the water quality parameter is exceeded.
Process water	-	Effluent water
Return Period	-	The return period refers to the statistically determined recurrence interval of a specific storm event, i.e. a recurrence interval of one event every fifty years is termed to have a return period of 1:50.

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Seepage	-	Seepage refers to the flow mechanism of a water, in the sense that it describes the outflow / through-flow of water from / through a matrix (associated with a low flow rate). It can occur on surface, for instance in the form of leachate seeping from a dump or stockpile (surface seepage, toe seepage), or it can occur below surface (ground water seepage, base flow) for instance into a trench, canal, streambed, etc.
Storm water	-	Storm water is defined as surface water resulting directly from precipitation.
Surface water	-	Surface water refers to all water that occurs on the surface of the earth. Water in a dam / holding facility is therefore also classified as surface water.
Wet weather flow	-	Flow that occurs during or after a storm event, directly resulting from the storm event.
Zero Effluent Discharge (ZED)	-	The term ZED is defined by the proponent to indicate a state of the Works wherein no effluent is discharged from the site during dry weather conditions. Per definition therefore, the following statements can be made:

(i) The term ZED refers to effluent water only, i.e. it does not refer to storm water.

(ii) It refers to dry weather flows only, i.e. storm water discharges during rain events do not make you non-compliant to ZED.

(iii) Unpolluted storm water may still be discharged from site while the site is ZED compliant.

(iv) The definition of unpolluted is as above, and is linked to a set water quality objectives.

(v) ZED refers to water flowing over the site boundaries only, i.e. if water is pumped into a dam and stored on-site instead of exiting the site, this situation doesn't imply non-compliance in terms of ZED.

(vi) Storage of water on site is governed by separate conditions in the water permit.

(vii) ZED refers to surface water only, i.e. ground water movement off-site is not included under the ZED definition for Iscor Vanderbijlpark Steel, but managed through separate water permit conditions.

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EXECUTIVE SUMMARY

The surface water specialist study report was conducted for the IVS site and the surrounding receiving environment in order to obtain an understanding of the influence of surface water emanating from the works on the receiving environment.

The baseline description for surface water starts with an evaluation of the basic input parameters for surface water being rainfall and water intake to the plant, both of which can end up as surface water run-off or effluent discharge from the works. A comprehensive study was done on rainfall data obtained from weather bureau, statistical data, rainfall records kept by IVS as well as the data obtained from three continuous rainfall monitoring stations, installed on the site for the duration of the study period.

The rainfall analysis showed that rainfall during the year of analysis was exceptionally high and that the year could hardly be regarded as an average rainfall year over the longer term. Statistical analysis done on the rainfall data indicates that the highest runoff volumes are associated with the maximum rain events recorded over 24 hours, but that the peak flow events are typically related to peak storm events of 1 to 2 hour duration.

Correlation between the rainfall and evaporation data indicates that the IVS site has a negative water balance, meaning that on average more water will be evaporated from the site than the rainfall that will be discharged onto the site.

After an evaluation of the meteorological data, an assessment was made of the environment prior to the Works' construction. The IVS site is situated on high topography, and on a local watershed which divides the site into an eastern and western catchment. To the west surface water drains into the Rietkuilspruit which discharges into the Rietspruit, while the Rietspruit in turn discharges into the Vaal River at Loch Vaal upstream of the Vaal Barrage. The eastern catchment drains towards the Leeuspruit which drains directly into the Vaal River east of Vanderbijlpark. The Works obtains its water for process purposes from one of two sources, namely the Vaal Dam situated upstream in the catchment of the Vaal River, and the Vaal River itself to the south of Vanderbijlpark. Water qualities obtained from the Vaal Dam are relatively good, while water abstracted from the Vaal River varies in quality over time but is generally poor.

An assessment of the local environment (the Works and surrounding areas) indicates the division of the Works into an easterly catchment and a westerly catchment. Only two surface water outlet points exist on the site. Water from the site is predominantly discharged through the Rietspruit Canal to the Rietkuilspruit in the west. Dry-weather flows from the Leeuspruit side are captured and pumped back to process or towards the western discharge point. This means that treated effluent is only discharged towards the west. During wet weather conditions discharges to the eastern Leeuspruit catchment occur often. Most of the North Works surface water runoff is discharged towards the east, while the South Works stormwater channels drain predominantly towards the west.

An evaluation of water quantities and qualities discharged into the western catchment was performed. An assessment of the flow volumes discharge towards the west indicates that almost 76 % of water discharged originates from process while the other 24 % emanates from rainfall. The runoff rate from the western catchment amounts to 36 % of total rainfall falling onto the catchment.

Water quality analyses at the western discharge point were evaluated utilising three data sets. These include the bi-weekly grab sample monitoring data sampled in the Rietspruit discharge channel (point RS7), water samples collected by a continuous sampler installed at the western discharge point from the site, as well as data from the continuous analyser situated in the discharge channel feeding the Rietspruit canal. Indications from the analysis show that the plant is generally capable of complying with the requirements of the water license for most the parameters tested under control until the achievement of ZED in 2005. Elements that are difficult to control are typically fluorides, sulphates and iron. Storm event analyses were performed to determine whether water qualities improve during rain events after the initial first flush is captured. Indications are that water qualities discharged post ZED should be of relatively good quality however it is difficult to pre-empt the water qualities that would probably result from rainfall discharge after ZED when the process water component is eliminated.

Similar analyses for water quantity and quality were performed for the Leeuspruit discharge point at Frikkie Meyer weir. Results from this analysis indicate a run-off factor for the eastern catchment in the order of 32 %, while the volume discharged over the weir is estimated at about 9 % of the total rainfall that fell within the catchment. Water qualities measured for water discharged over the weir were evaluated. These results indicated that a number of elements exceed the water qualities as stated in the IVS water license. Some of the exceedances occur as a result of very strict standards being set in the water license. It was recommended that standards set for these parameters be re-evaluated and more realistic standards be obtained for discharge water to the Leeuspruit in accordance with what can normally be expected in surface discharge resulting from rain events.

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A number of elements though exceeded the realistic standards set in the water license. Specific reference is made to iron, sulphates, calcium and magnesium. A search for the source of these elements in the discharge waters was traced back to groundwater seepage emanating from the Steelserv slag handling area in the south-eastern corner of the plant. Management measures to eliminate this source have been proposed. It is recommended that the primary source of the contaminated, which is the slag area, is either removed and rehabilitated or upgraded to eliminate the further spread of pollution.

Internal surface water management has been described in the document and the specific relationship between process waters and surface waters addressed. To this extent proposals have been made to separate process from surface waters as much as possible and to dedicate infrastructure such as dams to either contain process effluence for treatment or re-use in the plant, or to keep specific dams for surface water purposes only. Contaminated surface water captured into such dams would become process water as soon as it is abstracted from such dams. Similarly groundwater abstracted from boreholes becomes process water the moment it is pumped out of the ground. Surface water monitoring infrastructure will have to be extended, and will play a major role in the management of surface waters on the site.

Analysis of waters within the receiving environment was performed for the Rietkuilspruit/Rietspruit Canal/Rietspruit System, which indicated surface water contamination within the Rietkuilspruit upstream from the confluence with the Rietspruit Canal. Evaluation of the results and integration with the source characterization and ground water specialist studies indicated a possible groundwater source entering the Rietkuilspruit whereby the water qualities in the spruit are compromised. A further dilution analysis between the Rietkuilspruit and the Rietspruit indicated that the quantity of water in the Rietspruit downstream of this rivers confluence with the Rietkuilspruit is approximately 4.3 times greater than the flow in the Rietspruit Canal. As far as water qualities are concerned, the flow from Rietspruit Canal increases the EC value in the Rietspruit by approximately 33.7 %. This situation will change significantly at ZED in 2005.

As far as the risk assessment is concerned, risk determinations were performed for human health and the environment for water discharged to the Leeuspruit as well as to the Rietspruit Canal. Risk assessments were also done for water qualities in the Vaal River as well as in the Rietspruit, both upstream and downstream of this rivers confluence with the Rietkuilspruit. The risk quantification for the Rietspruit Canal and Frikkie Meyer weir discharges indicate that there is a potential unacceptable risk to both human health and the environment. The risk

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assessments for the Rietspruit and Vaal River flows indicate that there is an acceptable risk to both human health and the environment in these flows.

Management objectives proposed include several site specific objectives. These focus on the need for a single water discharge standard for runoff water originating from rainfall over the site. Internal management objectives include the separation of process water and surface water throughout the CPA while surface water within the CRMF must be managed internally. Two to three discharge points are envisaged for the CRMF. Runoff water emanating from the CRMF will be separated as either contaminated and uncontaminated surface waters. The uncontaminated portion will be discharged directly to the receiving environment. Management measures proposed to obtain the objectives are mostly included in the Master Plan integration document and drawings and specifically include the cleanup and rehabilitation of many areas within the CRMF as well as the bunding and containment of process waters inside the CPA. Cost estimates for the proposed infrastructure are all included in the integration document as part of this Master Plan report.

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1. INTRODUCTION

Iscor Vanderbijlpark Steel was established during the 1940's when the development of the Vaal Triangle area as a heavy industrial area was started for development. The area of Vanderbijlpark was chosen as the ideal site due to its siting away, but draining towards the river system as well as due to the abundant availability of water in the nearby situated Vaal river, and the upstream constructed Vaal Dam. This dam was constructed during 1931.

Iscor Vanderbijlpark has produced steel ever since. Technological changes and expansion of the plant has taken place on a continual basis. Environmental issues were of limited concern during the early days of the plant operations. During the 1990's, Environmental Legislation and awareness was raised and more information became available on the effects or impacts of the activities on sites like Iscor on the environment.

Various studies had been commissioned by IVS to address certain aspects in certain areas of the works and attempts were made to limit the impact and better the situation from an environmental viewpoint.

During 1999, Iscor Vanderbijlpark Steel decided to commission a holistic environmental management investigation with the view of developing a Master Plan for environmental management of its works in years to come.

This report forms part of a series of baseline study reports compiled in terms of the holistic Master Plan concept and forms the basis of the measures proposed for improvement of the situation of Iscor Vanderbijlpark. This specific document is termed the Surface Water Specialist Report and deals with surface water aspects on and around the site. In terms of the holistic approach within which this study was conducted, the information supplied in this document needs to be read in conjunction with and in context with the other specialist study reports forming part of the Master Plan documentation.

This document addresses numerous issues relating to surface water specifically and one could easily loose track of the issues under discussion in the document. For this purpose a comprehensive index has been compiled and the reader is encouraged to use the index as a site map throughout this document.

Although much good information has been gathered and assessed during the study period, this document will not claim to give all the answers to every aspect of surface water issues on the

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site. However it is deemed that sufficient information has been acquired to get a proper understanding of the characterization and the operations on the site to make proper recommendations on how issues should be addressed in future. It must however be born in mind that surface water management is a highly variable aspect changing drastically over the short as well as long term of investigation. The information studied for this baseline study report was based on one years gathered information and cognisance should be taken thereof that weather patterns, flow volumes and qualities could drastically vary for different periods of similar investigation. This investigation or baseline study therefore gives a basis of understanding surface water aspects on the site, however continued monitoring and interpretation of such monitored results will need to take place if a long term managed environmental plan is to be effectively introduced, implemented and managed over the longer term.

1.1 Background

During 1999 Ockie Fourie Toxicologists (OFT) were appointed to perform the Environmental Master Plan Study for Iscor Vanderbijlpark Steel. Van Renssen & Fortuin Consulting Engineers (VRF) were subsequently appointed by OFT as sub-consultants to assist in the specialist fields of surface water, geo-technical investigations and land capability assessments. This report contains the findings of the surface water investigation.

A Pre-Master Plan study was performed during April 2000, wherein all available data, information, reports and maps appertaining to surface water were reviewed. The review was done to determine what information was available as obtained from earlier studies, which could be used in the Master Plan study that was to follow. In addition a gap analysis on the available information was then done to determine the areas where information was lacking which needed to be further investigated. The gap analysis was a determination of what additional investigations were needed in order to have a comprehensive understanding of surface waters within the Works' perimeter as well as in the receiving environment. This gap analysis formed the recommendations and scope of work for the Master Plan investigation.

This document constitutes the baseline study for the surface water component of the Master Plan process. Other specialist studies which form part of the Master Plan investigation are those compiled for:

- Geology
- Ground water
- Soils
- Source characterisation

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- Eco-terrestrial (plant and animal life)
- Aquatic ecosystem
- Air quality
- Archaeology
- Noise
- Aesthetics and sensitive landscapes
- Land use and Land capability
- Geotechnical conditions
- Socio-economic
- Social
- Process water
- Regulatory requirements
- Public consultation.

The objectives, measures and preliminary feasibility appertaining to the Master Plan are contained in an integration document (document number: IVS/MP/005) which is accompanied by a book of plans (document number: IVS/MP/002) and which forms the summary of the measures proposed, as determined for each discipline in an integrated manner.

This document, together with the other discipline baseline studies, as well as the above mentioned integration document are summarised into the Master Plan summary report (document number: IVS/MP/001), which forms the overarching summary of the study conducted.

1.2 Approach & Methodology

When a surface water study of this nature is undertaken, it is above all necessary to understand the sources of water contributing to the system under investigation. An in-depth understanding of all the sources and especially the rainfall source is a requirement due to its variability spatially and temporally. A whole section in this report is therefore dedicated to the understanding of rainfall patterns over the site before runoff and water flow on- and out of the site is considered.

The approach of water flow within the study area was done on an outside-in approach, whereby the receiving environment was taken as the outer boundary limit of the investigation. In terms of this approach, the following entities were identified as being possible receptors of impact due to the activities of the Works on the surface water environment:

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- *The rivers and streams downstream of the area under investigation.*
  Theoretically, surface water bodies impacted upon by activities that have taken place on a site would have an impact within their receiving water bodies all the way downstream to where the water enters the sea, and even in the sea. Due to dilution effects and chemical- and biological processes taking place within aquatic systems, the effects of the impacts are known to diminish over distance away from the source. In the case of this study, the limit of the investigation was taken to be in the Vaal river. All streams and rivers from the site up to the Vaal river were therefore evaluated in terms of their impacts within this study.

- *The land adjacent to and downstream of the site* area.
  Polluted surface water emanating from the site could flow over the adjacent land downstream of the site, whereby the site could get contaminated. The area to be investigated under this category however could only include areas in catchments *downstream* of the site boundaries and only up to where these waters would enter a stream or river. These areas were delineated and the possible impacts of surface water on them evaluated.

- *The land falling within the catchment upstream of the site.*
  Areas upstream of the site could not possibly be impacted upon by surface waters unless there is evidence that such areas were irrigated from within the Works. The upstream catchment does however influence the amount of uncontaminated water that could reach a downgradient stream while this water could get contaminated as it enters the site. Areas of such description therefore need to be taken into account in the surface water study.

- *Any areas contaminated on surface by activities historically performed by the Works*
  Where areas are known to have been irrigated with water emanating from the site, these areas could affect surface water qualities downstream even after such practices have seized to take place. Such areas would therefore also be regarded as the receiving environment and have been included in the study.

The approach to the study was further to monitor all the points on the perimeter of the site where water could possibly exit from the Works. This was done to be able to evaluate the water balance of the site as well as to determine the 'source' quality of the water that could have an effect on the receiving environment.

Once the water quantities and qualities at the perimeter were known, the approach was to determine the sources of the surface waters within the site perimeter. To this extent, a number

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of monitoring points within the site were identified and commissioned in order to obtain the required data.

Once data had been collected, interpretations were done of which the results are described in this report. Impact and risk assessments could thereafter be done. Finally the results lead to the setting of objectives for future management of surface waters on the site and measures to be implemented in order to obtain the objectives have been proposed.

The surface water measures and objectives were then combined with the other disciplines in an integration process where after the Master Plan emerged.

1.3 Legal Requirements

Various legal, guideline and policy documents were reviewed as part of the Master Plan process to ensure that the surface water baseline studies support the various regulatory processes and legal requirements. The following table presents the documents that were reviewed as part of the baseline studies for the surface water investigation, as well as a brief summary of the requirements specified within these documents (specifically referring to surface water requirements). The documents that are specifically applicable to IVS are contained in **Appendix 1**. These include the current Water Licence 10016047, the preliminary reserve determination and the expired Permit Exemption 1998B.

Vanderbijlpark Steel Water Licence: 10016047 in terms of the National Water Act, 1998.

- (App 1: 8) IVS must compile a Master Plan by 31 December 2002;
- (App 1: 10) IVS must submit quarterly progress reports to the Director : Water Quality Management;
- (App 1: 12.1) The Master Plan must result in a drastic reduction in water abstraction for use in industrial purpose;
- (App 2: 1.1) IVS must hold back and treat wastewater and polluted stormwater;
- (App 2: 1.2) IVS must develop plans to separate stormwater and process water and treat such where necessary;
- (App 4: 1.1.1) IVS may discharge 11 680 000 m^3 pa of industrial wastewater with a maximum of 32 000 m^3/day until December 2005;
- (App 4: 1.1.3) No wastewater or polluted stormwater may leave the site at the Leeuspruit;
- (App 4: 1.2.2) IVS may only discharge stormwater resulting from a storm event larger than 1:100 years and such discharge must meet quality requirements;

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- (App 4: 1.2.3) IVS must design a management system to comply with 4: 1.2.2 before end December 2002;
- (App 4: 2.1.2) Water quality specification for water discharge until December 2005;
- (App 4: 2.2.2) IVS must model water discharge at Leeuspruit as part of the Master Plan. Water quality parameters for discharge set in this paragraph;
- (App 4: 3.1) No contaminated stormwater may leave the site;
- (App 4: 3.4) Uncontaminated area runoff must be diverted away from the site;
- (App 4: 4.1.1) Flows leaving the site at Rietspruit canal must be measured;
- (App 4: 4.2.1) Daily composite sample of water discharged at Rietspruit canal must be analysed for specified parameters;
- (App 4: 4.2.2) Hourly grab samples must be taken during discharge at Leeuspruit and analysed for parameters specified;
- (App 4: 4.2.3) Grab samples must be taken weekly for specified points in Rietspruit and Leeuspruit and analysed for specified parameters;
- (App 4: 7) Grab sampling points in Rietspruit and Leeuspruit are listed;
- (App 4: 10.4.1) Master Plan must indicate how to terminate disposal of wastewater to Rietspruit and how to minimize intake water;
- (App 4: 10.4.2) Master Plan must indicate minimization of leachate from unlined dams;
- (App 4: 10.4.3) Master Plan must indicate plan to phase out evaporation dams;
- (App 4: 10.4.9) Master Plan must indicate timeframe for implementation of actions and plans;
- (App 5: 3.1.2) Dams on site must have freeboard of 0.8m minimum;
- (App 5: 3.2) Dams must be provided with furrows or trenches around to prevent stormwater ingress into dams;
- (App 5: 5) Sumps must be operated such that they will never overflow;

Application for Disposal Site Permit under Section 20 of the Environment Conservation Act, 1989.

- (A.2.c) A number of alternative sites must be considered when selecting a new waste site;
- (B.9.a) A waste site may not be within a 3000m radius from the end of an airport / landing strip;
- (B.9.b) A waste site must be situated outside the 1:50 year flood line;
- (B.9.d) A waste site may not be situated within 5 km of a water source;
- (B.9.h) A waste site may not be situated within 100m of a source of surface water;
- (B.9.i) A waste site may not be situated within 1 km of a wetland;

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- (B.10.b) Indicate the wettest 6 months of the year (Nov – Apr or May – Oct);
- (B.10.c) Wettest wet season for 10 years; Total A-Pan evaporation for 6 months;
- (B.12.a) Detailed location of waste site (including special features);
- (B.13.a) Expected lifetime of the waste site;
- (B13.b) Type of waste and estimated daily quantities;
- (B15.b) Dimensions of the disposal site in SI units;
- (B15.c) Indicate the total volume available for the disposal of waste on the site;
- (B.15.d) Indicate the total volume already used for waste disposal;
- (C.19.a-h) Topocadastral map (1:50 000) indicating a 5 km radius, the disposal site, existing residential and industrial areas, possible future development, routes in transport of waste, other disposal sites, zoning and land use of surrounding areas, 1:50 year flood lines;
- (C.20.a-e) Plan (1:50 000 and 1:10 000) indicating 1km radius, boundaries of disposal site, springs, dams, excavations and water courses, use of surface water, 1:50 year flood lines;

Aide Memoire for Industrial Use and Disposal. Department of Water Affairs and Forestry.

- (2.4) Name of nearest surface water watercourse; water quality (pH, EC, etc); surface water use; water authority; presence of wetlands;
- (10.1) Hazardous or undesirable constituents within effluent;
- (10.2) Size of property; size of open factory area; 24 hour storm event (1:50 year); storm intensity analysis; volume of runoff from property; volume of runoff from factory roofs; description of type of containment; method of management;
- (12.1.1) Effluent quality in the dams and ponds (pH, EC, SS, COD, NH_3, P, E.coli, Heavy metals);
- (12.1.2) Effluent quantity entering dams (daily and monthly);
- (12.1.5) Slope of the site;
- (12.1.6) Monthly evaporation from each of the dams / ponds;
- (12.1.7) Positive / negative monthly evaporation rates;
- (12.1.8) Size of ponds required (including storage during months of negative evaporation);
- (12.1.9) Situation of the dams / ponds with regards to rivers and residential areas;
- (12.1.10) Protection from the ingress of stormwater;
- (12.1.12) Presence of plastic liners or bentonite for the sealing of dams;
- (12.1.13) Seepage collection drains and return pumps;
- (12.1.14) Leakage detection and monitoring system;

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- (12.4.1) Quantity of surface water effluent;
- (12.4.2) Annual discharge pattern;
- (12.4.3) Name and description of minor catchment;
- (12.4.4) Effluent quality analysis (pH, EC, SS, COD, NH_3, NO_3, P, E.coli, Heavy metals);
- (12.4.5) Established use of river;
- (12.4.6) Applicable water quality criteria;
- (12.4.7) Critical water quality components;
- (12.4.8) Name and description of major river catchment;
- (12.4.9) Quality of minor catchment before discharge into major catchment;
- (12.4.10) Quality of major catchment upstream of minor catchment;
- (12.4.11) Quality of major catchment river downstream of confluence with minor river;
- (12.4.12) Mean monthly runoff of major catchment upstream of minor river;
- (12.4.13) Description of the Regional Water Quality Objectives (RWQO) for the total catchment;
- (12.4.14) Calculated waste load allocations (WLA's) and the effect which the discharge will have on the REQO (Receiving Environmental Quality Objectives);

Minimum Requirements for Waste Disposal by Landfill. Department of Water Affairs and Forestry, Second Edition, 1998.

- (2.3.1) Due consideration of alternative landfill sites;
- (2.3.2) Provide a physical separation between the waste and the surface water regime, together with an effective surface water diversion drainage system;
- (3.3.1) Calculate the initial and maximum rates of deposition (IRD & MRD);
- (3.4) A leachate management system is required for all hazardous waste landfills;
- (3.4.2) Rainfall and Evaporation data for the calculation of the Climatic Water Balance (based on the wettest year calculation – see Appendix 3);
- (4.4) 3000m from an airport / runway; Areas below 1:50 year flood line; Catchment areas for important water resources; Areas characterised by steep gradients;
- (4.5.1) Economy of scale; Access; distance to surface water; importance of surface water; depth, quality and availability of soil on site; high visibility;
- (4.7.2) Soils must be described and classified in terms of type, permeability, depth and volume available for cover material;
- (4.7.5) Include 1:50 000 topographical map and 1:10 000 orthophoto map showing position of site, 1km radius, 1:50 year flood line, position of dams, springs and water courses, important roads and transportation corridors, and surrounding land uses;

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- (6.2.1) Appropriate topocadastral data; drainage patterns (annual and perennial); distance to nearest important water courses, wetlands and rivers; background surface water quality (if possible); comparison of surface water quality upstream and downstream of site; uses of water in the sub-catchment; earthworks which affect the natural drainage system; sewage works; climatic data;
- (6.3.1) Soil profile (quality) and cover (quantity);
- (7.3) Assessment of the environmental consequences of failure of environmental defense measures by the surface water contaminant pathway (NB. see figure 11);
- (7.5) Environmental impact control report – environmental impact identification matrix for surface water; response action plan; ultimate size of site; zone of influence; environmental management and design principles; environmental protection measures; monitoring strategy;
- (8.2.3) Surface drainage; storm water diversion drains; separation of unpolluted from polluted surface water; containment of polluted water on site in impoundments; separate leachate containment; surface water sampling points;
- (8.4.1) Drains must contain 1:50 year storm; separate unpolluted and polluted water; 0.5m freeboard;
- (8.5) Outer slopes of dump to have uninterrupted length < 20m; stormwater canals must be paved or armoured;
- (10.2.2) Waste acceptance and access control;
- (11.2) Determine method of waste site monitoring or auditing;
- (11.4) Monthly audits are applicable for hazardous waste sites; compile auditing checklist;
- (11.5.1) Daily and cumulative records of waste entering the site must be kept; a data base must be established and maintained; recording of position of all hazardous waste (plan and elevation);
- (11.5.2) The entire site must be surveyed prior to commencement of waste disposal and annually thereafter;
- (11.5.7) Maintenance programme for rehabilitated areas;
- (13.1) Post closure water quality monitoring continue for up to 30 years after the closure of a landfill;
- (13.2.1) Surface water quality must be monitored upstream and downstream of any landfill site in any associated drainage feature;
- (13.3.1) Routine detection monitoring is carried out every six months, and must include at least total alkalinity, NH_3, COD, Cl, EC, NO_3, pH, K, TDS; Additional parameters that must be analysed for on an annual basis are Ca, F, Mg, Na, SO_4.

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Regulations on use of water for mining and related activities aimed at the protection of water resources. Department of Water Affairs and Forestry, 1999.

- (4.a) 1:100 year flood line; 100m buffer zone around any watercourse;
- (4.b) 1:50 year flood line;
- (6.a&b) Confine any unpolluted water to a clean water system that can accommodate the 1:50 year storm event, away from any dirty area;
- (6.c&d) Collect all dirty water in a dedicated system that can accommodate the 1:50 year storm event;
- (6.e) The minimum freeboard of any dam associated with the dirty water system shall have a freeboard of 0.8m above the full supply level of the facility;
- (8.a) Dams with hazardous contents must be fenced off and warning notice boards must be erected;
- (8.b) Ensure access control into waste disposal areas;
- (9.1) Appropriate maintenance programme for pollution control measures;

Minimum Requirements for Water Monitoring at Waste Management Facilities. Department of Water Affairs and Forestry, Second Edition, 1998.

- (6.2) Rainfall for the past 24 hours must be recorded at 08:00 every morning;
- (6.2) The monitoring of evaporation potential from free-standing water is a requirement for hazardous disposal sites (A-pan or Penman). Note: Penman = f(wind speed, humidity, vegetation, surface type, season, time of day, relative humidity, saturated vapour pressure, temperature);
- (6.2) The quality and quantity of runoff water flowing off a disposal site must be recorded continuously (when stipulated in the permit);
- (6.3) Water sources around a waste management facility, within a radius as suggested by the risk assessment, must be sampled and preserved for chemical analyses;
- (6.3) Flow from fountains and in streams must be estimated. If the potential for pollution within the region due to the waste site exists, then continuous recording of flow and water quality should be done;
- (App C) Sample frequency and preservation should range from several times daily to weekly;
- (App C) Continuous monitoring of the discharged flow volume and quality (by the EC method), is required in instances where polluted water is disposed of into a public stream;

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Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste. Department of Water Affairs and Forestry, Second Edition, 1998.

- Refer to Source Characterization report by Ockie Fourie Toxicologists as part of the Master Plan study.

EIA Regulations Guideline Document for the implementation of Sections 21, 22 and 26 of the Environment Conservation Act.

- (3.2.3.1) Scoping report – project description; description of environmental issues and impacts; description of alternatives;
- (3.2.4.1) Plan of study for EIA – description of environmental issues and feasible alternatives; additional information; method of identifying and assessing impacts; project phases (pre-construction, construction, operational, decommissioning);
- (3.2.5.1) Environmental impact report – description of feasible alternatives; assessment of impacts (nature, extent, duration, intensity, probability); significance of impacts; mitigation;
- Appendix 1: Declaration of Interest by Consultant;

A National Strategy for Integrated Environmental Management in South Africa. Discussion Document. Department of Environmental Affairs and Tourism.

- (3.2) Assess and integrate all available spatial environmental information to identify environmentally sensitive zones;
- (4.3 & Fig 3) IEM procedure for new activities (proposal, authority review, scoping, review, EIA, conditions agreement, EMP, EMP review, EMP approval);
- (4.4 & Fig 4) IEM procedure for new activities (trigger, description of activity, authority review, scoping, environmental optimisation assessment, conditions agreement, EMP, EMP review, EMP approval);

Integrated Environmental Management provisions of the National Environmental Management Act (Act No. 107 of 1998)

- The procedures for the investigation, assessment and communication of the potential impact of certain activities must *inter alia* ensure the " … investigation and formulation of arrangements for the monitoring and management of impacts, and the assessment of the effectiveness of such arrangements after their implementation … ".

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Department of Water Affairs Permit 645 N (1987)

- (1) Volumes of water authorised for use for industrial purposes from the Lethabo weir (10 950 000 m^3/annum), Barrage (20 075 000 m^3/annum) and Municipality (6 205 000 m^3/annum) are specified (total = 37 230 000 m^3/annum);
- (2) The Permit Holder shall meter and record the quantities of water, separately in respect of each source, used monthly and submit a copy of the records to the Director-General, Water Pollution Control Directorate, DWAF at six monthly intervals.

National Water Act, Act No. 36 of 1998

- (Section 26) This section allows the Minister to make regulations inter alia requiring that the use of water from a water resource to be monitored, be measured and recorded, and requiring that the waste discharged or deposited into or allowed to enter a water resource be monitored and analysed, and prescribing methods for such monitoring and analysis.
- (Chapter 14) This chapter deals specifically with "Monitoring, Assessment and Information", with Part 1 dealing with the establishment of national monitoring systems of water resources. It is envisaged that the Minister will establish a National Monitoring System for water resources as soon as reasonably practicable, with the system providing for the collection of appropriate data and information necessary to assess, inter alia: quantity; quality; use; rehabilitation; compliance; health of aquatic ecosystems; and the influence of atmospheric conditions.

Dam Safety Regulations (GN R 1580 of 25 July 1986)

- A range of conditions regarding monitoring are imposed on the owner, or other person in control of a "dam with a safety risk", by this Regulation.

Requirements for the Purification of waste water and effluent (GN991 in GG 9225 of 18 May 1984, as amended)

- (4) All tests carried out in accordance with methods prescribed by and obtainable from the South African Bureau of Standards, or in accordance with a method approved by the Minister or an official of the Department of Water Affairs and Forestry.

Procedures to Assess Effluent Discharge Impacts, Department of Water Affairs and Forestry & Water Research Commission, South African Water Management Series, 1995

- (pg. i) These procedures must be followed to assess the impacts of effluent discharges on the quality, and therefore the fitness for use, of the receiving water bodies;
- (pg. ii) Public participation is a requirement for any application to discharge effluent;

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- (pg. xx) Roadmap of Effluent Discharge Investigation;
- (pg. 24) Effluent discharge investigations follow from the same fundamental philosophy as the Integrated Environmental Management (IEM) process;
- (pg. 58) Selection of the boundary of the study area;
- (pg. 63) Determine sources of impact on the water quality;
- (pg. 70) Determine water uses in the catchment;
- (pg. 77) Water Quality Requirements – see pg. 80, Most important set of information is SA Water Quality Guidelines (DWAF);
- (pg. 90) See SA Water Quality Guidelines (DWAF) to determine the constituents of concern;
- (pg. 91) Key water quality constituents are listed;
- (pg. 92) Determining water qualities during low flows is very important;
- (pg. 107) Hydrological characteristics determine receiving body assimilative capacity;
- (pg. 109) Classification of streams; stream flow characteristics; flow-duration information; streamflow models;
- (pg. 121) Analyse water quality upstream and downstream of potential discharge;
- (pg.124) Ascertain limitations and statistical characteristics associated with the data;
- (pg. 131) Estimate effects of non-point sources (e.g. groundwater intrusion);
- (pg. 136) *** Industry as a source of non-point source pollution;
- (pg. 138) Atmospheric deposition;
- (pg. 144) Modeling of non-point source impacts;
- (pg. 153) Rainfall erosivity and intenstity;
- (pg. 156-160) Effects of geology, soils and vegetation on surface water quality;
- (pg. 165-182) System modeling process – water quality and hydrological models;
- (pg. 212) See Proposed Table of Contents for Effluent Discharge Investigation Reports;
- (pg. 220) The uncertainty in the results should be assessed relative to the amount of data collected;
- (pg. 220) Produce document describing sampling and analysis procedures, as well as data storage, retrieval, analysis and reporting procedures;
- (pg. 221) Compliance Monitoring Manual (DWAF, 1991);
- (pg. 221) Compliance statistic which forms upper confidence limit is 95 percentile (a minimum of 20 observations are required to estimate the 95 percentile);
- (pg. 221) Computer program, COMPLY;
- (pg. 245) The median, maximum, minimum and 95 percentile values, as well as the water quality standard should be indicated in the tabular report;
- (pg. 270 - 320) Summary list of available water quality and hydrological models.

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Resource Directed Measures for Protection of Water Resources, Department of Water Affairs and Forestry, 1999

Not applicable – the responsibility of determining the environmental reserve for a specific catchment is the responsibility of the Department of Water Affairs and Forestry, not the water user.

2. BASELINE DESCRIPTION

2.1 Meteorological Data

When dealing with environmental components such as surface water or air quality, it is important to have a proper understanding of the functioning of natural phenomena such as water or wind in order to understand the interaction between the environmental components and the study area under investigation. For this purpose, a detailed meteorological data search, compilation and interpretation has been performed for this Master Plan investigation.

Since this specialist study deals specifically with surface water, only the meteorological aspects dealing with water have been listed. For meteorological data appertaining to air, the reader is referred to the air quality specialist report, which forms part of the baseline documentation for the Master Plan investigation.

2.1.1 Climate

The whole of South Africa lies within the semi-permanent subtropical high-pressure belt of the middle latitudes of the Southern Hemisphere (SANCOLD, 1994). Although IVS is situated near the tropic of Capricorn on latitude 26° 42' south, longitude 17° 50' east, it enjoys a moderate continental climate. This is predominately due to its altitude, which reached over 1500 metres above mean sea level. The climate at IVS is typical of the South African highveld, which is generally sunny and pleasant with mild winters (Anon, 1997).

2.1.2 Rainfall

The IVS Works is situated within the summer rainfall region (SANCOLD, 1994). This means that most of its precipitation occurs between the months of November to March, when an average of nine to fifteen days of rainfall occur per month. The mid-winter months, of May to September, have an average of less than four rain days per month.

The seasonal distribution of rainfall is caused by changes in the high-pressure systems and the height of the inversion layer. The heat of summer lifts the inversion layer above the level of the escarpment, allowing low-pressure troughs to develop periodically over the interior of the country. These troughs are oriented roughly to the north-west and south-east of the country. They draw moist air from the north and north-west which rises, cools and produces precipitation. These convergent systems are the source of most of the rain in the interior of South Africa, although their influence diminishes towards the west. In winter, the inversion layer drops to a

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level which is below the eastern highlands of the escarpment, thus inhibiting moist air from the Indian Ocean from initiating rain in the interior (SANCOLD, 1994).

Rainfall occurs predominantly as thunderstorms in the Vanderbijlpark region, and there is seldom mist or hail. Rainfall data is contained in **Appendix 3**. The IVS Works rainfall data has been obtained from various sources, and analysed. These data sources include:

- Five daily rainfall stations within IVS;
- Three continuous rainfall stations within IVS;
- Five daily weather stations within the Vanderbijlpark region that are, or have been, administered by the South African Weather Bureau;

Mean Annual Precipitation

The mean annual precipitation (MAP) as recorded by the Weather Bureau (station number: 0438550 A2) between 1961 and 1990 is 668 mm. Fluctuations in the annual rainfall during this period lie between 831 mm (1987) and 427 mm (1965). Other Weather Bureau stations in the Vanderbijlpark area are listed together with this station in the following table, with their MAP values.

Table 1: Summary of SA Weather Bureau Mean Annual Precipitation Values

SA Weather Bureau Station	Mean Annual Precipitation (mm)	Number of Rain Days (>1 mm)	Start of Record	End of Record
0438551 X – Vanderbijlpark	664.8	65.2	1977	1999
0438550 W – Vanderbijlpark – Yskor	663.7	78.8	1942	1985
0438550 AW – Vanderbijlpark – Yskor	670.2	81	1985	2000
0438553 W – Vanderbijlpark – Pur	709.3	92.9	1949	1977
0438550 A2 – Vanderbijlpark – Iscor	668	67	1961	1990

From the MAP values for the various stations it is apparent that there is a spatial variance in rainfall. This is to be expected, and the variance is not significant - the highest MAP is less than 7% greater than the lowest MAP. The average MAP, calculated from the five Weather Bureau stations listed, is 675.2 mm.

Daily Rainfall

As listed in the previous section, there are five SA Weather Bureau stations situated within the Vanderbijlpark area. The positions of these stations, together with their altitude and data record length, are listed in the following table:

Table 2: Position of SA Weather Bureau Weather Stations

SA Weather Bureau Station	Latitude	Longitude	Altitude (m.amsl)	Length of Data Record (years)
0438551 X – Vanderbijlpark	26° 41'	27° 49'	1496 m	22
0438550 W – Vanderbijlpark – Yskor	26° 40'	27° 49'	1496 m	43
0438550 AW – Vanderbijlpark – Yskor	26° 40'	27° 49'	1613 m	15
0438553 W – Vanderbijlpark – Pur	26° 43'	27° 49'	1496 m	28
0438550 A2 – Vanderbijlpark – Iscor	26° 40'	27° 49'	1613 m	29

The first station listed (0438551 X) is still operational, while the latter four were closed in 1985, 2000, 1977 and 1990 respectively. While a daily data record of the Weather Bureau data is not made available in this report, summary tables of the data are available in **Appendix 3**. The maximum number of days that it rained more than 0.1 mm in one year was 104. The least number of days that it rained more than 0.1 mm in one year was 65. Table 3 shows the average monthly rainfall values for the weather bureau stations listed:

Table 3: Monthly Average Precipitation (mm)

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Rain depth	72.4	97.4	115.3	118.9	80.0	78.3	50.8	17.8	6.7	4.6	9.2	25.6

Daily rainfall is also recorded by the IVS Works. The data is captured at five different stations within the Works. The rain gauges are of the SA Standard non-recording type (black; 127 mm orifice; 1.22 m height). They are read, recorded and emptied each day at 08h00 by a representative of the IVS Water/Environmental Management Department. The positions of the rainfall stations within the IVS Works are:

Table 4: Position of IVS Daily Rainfall Stations

	Local Grid		L.O. 29 Grid	
Rain Station	**X**	**Y**	**X**	**Y**
Dam 10	-1694.978	1607.278	-80,688.31	2,948,742.69
Du Preez Dam	-3493.302	1653.24	-80,642.44	2,946,944.64
Main Admin Building	-969.982	-948.403	-83,243.56	2,949,467.69
Leeuspruit Sump	-76.486	670.944	-81,624.43	2,950,360.97
Vaal Dam Reservoir	48.605	-1100.749	-83,395.84	2,950,486.12

The length of the data records at each of the daily rainfall stations within IVS are tabulated in the following table:

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Table 5: Length of Record of IVS Daily Rainfall Stations

Rain Station	Start of Record	End of Record
Dam 10	15 Dec 1998	Still Operational
Du Preez Dam	24 Jan 1998	Still Operational
Main Admin Building	25 Oct 2000	Still Operational
Leeuspruit Sump	20 Nov 2000	Still Operational
Vaal Dam Reservoir	19 Feb 2001	Still Operational

Tables of the daily rainfall results at each of these rainfall stations are provided in **Appendix 3**. The following table provides the total annual rainfall values for each of the stations with complete records for the specific years listed.

Table 6: Total Annual Rainfall at IVS Daily Rainfall Stations

Rain Station	1999	2000	2001
Dam 10	483.2	919.0	743.5
Du Preez Dam	777.6	1017.5	1023.0
Main Admin Building	-	-	1143.1
Leeuspruit Sump	-	-	1105.0
Vaal Dam Reservoir	-	-	1011.0

From the data sets it can be deduced that there is spatial variance in rainfall depths within the site. A short review of the reliability of the daily rainfall recorded at IVS, and a comparison of these records with the Weather Bureau and continuous monitoring data will be provided at the end of **Section 2.1.2**.

Continuous Rainfall

At the beginning of the Master Plan study, three continuous rain gauges were installed on the site, at positions that would represent the entire site. They were installed in the south-eastern corner of the site, at North Works and on the western boundary of the site at the TETP. These rain gauges are calibrated to provide a reading, together with the corresponding time, for every 0.25 mm of rainfall that falls at that position. The continuous rainfall stations are listed in the **Table 7**, together with their corresponding positions.

Data from the continuous rainfall stations is useful for analysing storm events in conjunction with continuous flow and water quality data. Such data enables the determination of rainfall-runoff delays, peak flows, incremental rainfall volumes and the first flush together with its related qualities and volumes. A monthly summary and analysis of the data obtained from the

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continuous rainfall stations is contained in a table at the end of **Section 2.1.2**. Monthly graphs of incremental rainfall are provided in **Appendix 3**.

Table 7: Position of IVS Continuous Rainfall Stations

	Local Grid		L.O. 29 Grid	
	X	Y	X	Y
Steelserv Sump	654.8	-785.5	-83,080.61	2,951,092.21
North Works	-1895.3	-866.5	-83,161.71	2,948,542.51
TETP	-195.9	2329.7	-79,965.94	2,950,241.50

Stochastic Rainfall

A 200 year statistically generated rainfall record was obtained from the Computing Centre for Water Research (CCWR). The record is a statistical compilation of daily records of combined rainfall stations monitored by the weather bureau in the Vanderbijlpark area and could be expanded to any record length required. This data was utilised for dam modelling purposes, and to obtain the extreme rainfall events for the IVS Works. The extreme rainfall events are tabulated in the following table:

Table 8: Extreme Rainfall Events at IVS (24-Hour Rainfall)

Return Period (1:x years)	Rainfall Depth (mm)
1:200	166.8
1:100	150.2
1:50	115.5
1:20	101.4
1:10	85.5
1:5	75.1
1:2	60.4

The maximum rainfall event to have fallen in 24 hours at any of the Weather Bureau stations was station 0438550 X. The rainfall depth during this storm event was 112 mm, and it occurred during April 1996. This rainfall event therefore relates to a storm event with a return period of approximately 42.4 years (this value is equal to the longest data record available from any of the rainfall stations).

Rainfall Summary

Table 9 provides a summary of the monthly rainfall occurring at each of the stations for the year of analysis for the Master Plan (March 2001 to February 2002). These values are all in the same order of magnitude, although the daily stations record monthly values approximately 13 %

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higher than the continuous monitors (on average). It is known that blockages within the orifice of the continuous monitors have occurred on occasions during the investigation period. These blockages were due to dust and debris collection within the funnel of the gauge, and were cleared during the bi-weekly routine maintenance inspections of the gauges. Due to evaporation of water in the funnel, an underestimation of a few percent of the total rainfall for the year could therefore be allowed in relation to the daily rainfall gauges. The continuous rain gauge at Steelserv sump did block up on a regular basis, due to the high dust fallout at the sump. The results from this station were therefore disregarded for purposes of this study.

The daily rainfall stations have an average rainfall of 885.5 mm, with the highest value being approximately 12 % higher than the lowest total value. The continuous rainfall analysis results have only been utilised for the incremental analyses for short periods, e.g. one day, or a portion thereof. For analyses of any periods greater than one week the daily rainfall values have been utilised.

Table 9: Summary of Monthly Rainfall Totals at IVS

	2001										2002		Total
Continuous Rain	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	
North Works	59.3	29.3	31.3	10.8	0.0	3.8	35.5	101.5	100.5	126.8	173.8	102.8	775.4
TETP	56.3	29.5	33.3	13.5	0.5	19.3	43.3	111.8	111.8	126.8	173.8	74.3	794.2
IFSP Daily Rainfall													
Dam 10	60.0	15.5	43.0	11.5	0.0	18.0	49.0	91.5	141.5	152.5	170.0	91.0	843.5
Du Preez Dam	62.0	15.5	43.5	14.0	0.0	20.0	42.0	91.0	144.5	146.5	153.5	93.3	825.8
Main Building	57.0	20.5	53.5	17.0	0.0	28.5	57.5	80.5	158.5	151.0	205.5	95.0	924.5
Leeuspruit Dam	57.5	21.5	47.5	12.5	0.0	21.0	45.0	91.5	158.5	165.5	217.0	79.5	917.0
Vaal Dam Reservoir	61.5	17.5	45.5	13.0	0.0	24.0	50.0	72.0	164.0	153.0	213.0	94.0	907.5
Weather Bureau													
Station [0438551 X]	66.5	27.5	28.5	12.5	0.0	16.0	37.0	137.5	125.0	151.0	240.7	52.6	894.8
Station [0438550 W]	Station Closed 1985/02												
Station [0438550 AW]	Station Closed 2000/06												
Station [0438553 W]	Station Closed 1977/05												
Average per Month	60.0	22.1	40.8	13.1	0.1	18.8	44.9	97.2	138.0	146.6	193.4	85.3	860.3

A graphical presentation of the rainfall record comparison is shown in **Appendix 3**.

Annual average rainfall has been calculated as 860.3 mm. Although the data was not collected for a hydrological year *per se*, the data still represents a consecutive 12 months data record and can therefore be compared to other years where hydrological data is available. If the average annual precipitation of 675.2 mm obtained from the weather bureau stations is considered, the year under investigation does represent an above average annual rainfall year.

A comparison of the year under consideration with the statistical data was also done. Calculations on precipitation of the statistical record yielded an average rainfall of 698 mm/a and the median at 693.2 mm/a (which correspond well with the weather bureau stations average). Again however, the measured average for the year under investigation is significantly higher than the calculated average for the statistical data record. Furthermore, the observed average value of 860.3 mm corresponds to an occurrence interval of once every 177 years when related to the statistical record. This figure might be on the high side due to the fact that the statistical record is merely an expansion of the observed record. However this is quite in line with the average annual rainfall figures of between 663 and 709 mm/a as measured by the weather bureau stations between 1942 and 2001. The measured records are however neither long enough, nor are the stations close enough to the Works area to be able to state that such return period is in fact reliable, and caution should therefore be applied when relating to this figure. Total rainfall figures for 2001 as measured by IVS indicate an even higher total for the year than the year under investigation. If year 1999 to 2001 IVS data is compared to the same years of weather bureau data, IVS rainfall in each case presented a higher value than weather bureau data. The differences encountered were up to 30% higher than weather bureau values. There is insufficient data available to draw any conclusion about a trend in this regard. Further monitoring and interpretations thereof in future might give an answer to this issue.

It can however be stated with confidence that the year under investigation was an above average wet year in terms of observed data available for the area. Therefore, analysis of runoff data further used in this document should not be regarded as "typical" over the longer term. Continued monitoring and analysis should be done over a longer term to either confirm or amend the interpretation of results discussed hereinafter.

2.1.3 Temperature

The temperature of the region is termed "moderate continental". Temperature data has been recorded by the Weather Bureau (station number: 0438550 A2) between 1961 and 1990.

Summer months extend from November to March, with the average daily maximum temperature during mid-summer being above 27 °C. The days are warm, with an average temperature during January of 22 °C. Summer nights are also warm, with the minimum temperature during January being 16.1 °C. The difference between day and night temperatures is therefore

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relatively small, i.e. less than 6 °C. The winter months extend from June to August. The average daily maximum temperature decreases from 27 °C during the summer months to below 18 °C. The average daily minimum temperature during mid-summer is above 15 °C, while this value decreases to below 3 °C during the winter months. The winters are cold, with an average July temperature of 10.3 °C.

Extreme temperatures throughout the year have ranged from above 36 °C to below -5 °C. A summary of this record is contained in **Appendix 3**. Temperature is not recorded by IVS staff. Due to the mild temperatures experienced on site, freezing and thawing of water is not regarded as an issue within this study.

2.1.4 Wind

Wind speed and direction data has been recorded by the Weather Bureau (station number: 0438550 A2) between 1985 and 1991. Average wind speeds range predominantly between 0 and 6 m/s, although wind speeds do occasionally exceed 10 m/s. For more information appertaining to wind in the Vanderbijlpark region, the reader is referred to the Master Plan specialist study report appertaining to air quality.

2.1.5 Evaporation

IVS do not record evaporation within the Works. An estimation of the annual, monthly and daily evaporation within the Vanderbijlpark area has been calculated from the WRC publication Surface Water Resources of South Africa 1990 (Midgley, Pitman, and Middleton, 1994). In accordance with this publication, IVS is situated:

- within evaporation zone 11A;
- on the boundary between quaternary sub-catchments C22J and C22K.

The monthly evaporation values as a percentage of the MAE for this evaporation zone are:

Table 10: Monthly Evaporation as a % of MAE

Evap Zone	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
11A	10.97	11.39	12.37	12.23	9.86	8.96	6.55	4.94	3.78	4.22	6.12	8.61

The MAE for quaternary sub-catchments C22J and C22K are 1650 and 1625 mm respectively. Since IVS is situated on the boundary of these two sub-catchments, the MAE for the site has been taken to be 1637.5 mm (average between two values). When multiplying this value by the values reported in table 9, the following monthly evaporation values (in mm) are obtained:

Table 11: Monthly Evaporation (mm)

Evap Zone	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
11A	179.6	186.5	202.6	200.3	161.5	146.7	107.3	80.9	61.9	69.1	100.2	141.0

The average estimated daily evaporation values (in mm) for IVS are therefore calculated as follows:

Table 12: Average Estimated Daily Evaporation (mm)

Evap Zone	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
11A	5.8	6.2	6.5	6.5	5.7	4.7	3.6	2.6	2.1	2.2	3.2	4.7

When comparing the evaporation figures with the rainfall figures for the site, nett evaporation potential for the site can be calculated. The combination of the monthly average rainfall figures as measured by the weather bureau stations with the evaporation data presented above, results in the following nett evaporation figures:

Table 13: Estimated Nett Average Monthly Evaporation (mm)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
107.2	89.1	87.3	81.4	81.5	68.4	56.5	63.1	55.2	64.5	91.0	116.0	**961.2**

It is important to note that in accordance with the DWAF document, Minimum Requirements for Water Monitoring at Waste Management Facilities (Second Edition, 1998), Section 6.2, the monitoring of evaporation potential from free-standing water is a requirement for hazardous disposal sites (A-pan or Penman). A proposal to include this parameter within the Environmental Monitoring Protocol for IVS is therefore suggested.

In terms of the Minimum Requirements for Waste Disposal by Landfill, a climatic water balance needs to be done for every waste site. This has been performed in **Table 14**. The five wettest years on record, utilising the average results of the weather bureau stations, are:

Table 14: Calculation of Climatic Weather Balance

Rank of Wettest Year	Year	Total Rainfall (mm)	Climatic Water Balance	B- / B+
1st	1996	950.7	-10.5	B-
2nd	1955	920.4	-40.8	B-
3rd	1967	904.3	-56.9	B-
4th	1974	825.7	-135.5	B-
5th	1987	818.3	-142.9	B-

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In this table the annual evaporation for each year has been taken to be the estimated nett average annual evaporation, since no other data is available. It is clear from the results that the water balance calculation for this site is negative i.e. B-. This value indicates that no significant leachate will be generated at this site as a result of the climate

2.1.6 *Extreme Weather Conditions*

Extreme weather conditions predominantly take the form of thunderstorms. On average approximately 59% (51 out of 86 days) of rainfall each year occurs as thunderstorms. An average of four days of hail and four days of fog occur each year in the Vanderbijlpark area. Snowfall has occurred in the area but it occurs, on average, less than one day per annum.

2.2 Regional Environment

The undulating topography of the Vanderbijlpark region results in a countryside that is relatively flat with few mountains, hills or valleys. The average altitude above sea level in the Vanderbijlpark area is approximately 1514 mamsl. The landscape is relatively flat with occasional ridges rising some 100 - 200 metres above the undulating plains. Important hills and ridges in this area are the Suikerbosrand, Gatsrand and Kliprivierberg, approximately 50 - 180 metres higher than the surrounding flatter regions. The countryside consists of grassy plains with a few scattered shrubs as acacia and protea. Willows and poplars line the Vaal River (Anon, 1997).

IVS is situated approximately 8.5 km north of, and drains towards the Vaal River. The Vaal is the major river draining the southern Gauteng region. IVS is situated on the boundary between quaternary sub-catchments C22J and C22K, in drainage region C (Midgley, Pitman, and Middleton, 1994).

The IVS Works is situated on the catchment divide between the Leeuspruit and the Rietspruit, both of which drain towards the Vaal river. Runoff from the area is therefore towards the East (Leeuspruit) and towards the West (Rietkuilspruit).

2.2.1 *Vaal River Catchment*

In terms of the regional perspective, Vanderbijlpark Steel is situated within the Vaal River catchment. This major river drains part of Mpumalanga, Free State, Gauteng, North West and the Northern Cape. The basin is mainly covered by highveld savannah vegetation, and drains from undulating hills in the east to flat landscape in the west, where it joins the Orange River.

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The water subsequently discharges into the Atlantic Ocean. The most important tributaries of the Vaal are the Wilge, Klip and Rietspruit (the spruit into which the Rietkuilspruit discharges).

The Vaal River is the most developed and regulated river in the country, with the Vaal River system supporting approximately half of the economic activity in South Africa. The largest use of water in the Vaal basin is irrigation, followed by the mining and industry, with the remaining water being utilised by the urban and domestic sectors. About 60 % of the water abstracted by Rand Water is returned as treated effluent to the Vaal and Crocodile Rivers (Basson, 1997).

Of the total naturalised runoff of 3 929 x $10^6m^3/a$ in the Vaal River, about 1 789 x $10^6m^3/a$ (46%) can be harnessed as usable yield. This has already been achieved with the construction of a number of dams (Vaal, Vaal Barrage, Grootdraai, Bloemhof, Sterkfontein) which virtually fully regulate the river. Discharge from IVS enters the Vaal river between the Vaal dam and the Vaal Barrage. Considering the water requirements of the Vaal basin of 2 029 x $10^6m^3/a$, the need for augmentation of the Vaal system from other sources is evident. This is achieved by means of water transfer schemes, which include the transferring of water from the Orange, Thugela, Buffalo, Assegaai, and Usutu systems towards the Vaal river, upstream of the Vaal dam. The catchment area of the Vaal River at the Vaal Dam is approximately 38 638 km^2. This upper portion of the catchment is characterised by a MAP of 673 mm/a, MAE of 1 451 mm/a and a MAR of 1 885 x $10^6m^3/a$ (Basson, 1997).

The Vaal River is one of South Africa's major rivers. The river forms the provincial boundary between North West and Free State, and Gauteng and the Free State. It is the dominant river flowing into the Orange River. The Vaal rises in Mpumalanga near Klipstapel and Breyten. It flows in a south-westerly direction for 1355 kilometres, joining the Orange River 13 kilometres west of Douglas. The Vaal Barrage was built in 1923 to provide water to the Witwatersrand area. The Vaal Dam was built in 1936 to increase this water supply. The Bloemhof and Grootdraai dams supply water to farmers. Major industrial areas, such as Vanderbijlpark, Vereeniging, and the Witwatersrand, depend on the Vaal for their water supply (Discovery Channel School, 2001).

IVS receives water for industrial purposes from both the Vaal River and the Vaal Dam. The volumes and qualities of this supply are recorded in **Appendix 4**. It is important to note that the water qualities from the Vaal Dam are of considerably better quality than the waters obtained from the Vaal River.

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2.2.2 Rietspruit Catchment

The Rietspruit catchment includes the towns of Ennerdale, Evaton, Orange Farm, Sebokeng, the north-western portion of Vanderbijlpark, and extends to just south of Westonaria and Lenasia. The catchment includes much land utilised for agricultural purposes. The Rietspruit exits into the Vaal River at Loch Vaal, upstream of the Vaal Barage.

The Rietspruit has a catchment area of approximately 1398 km^2, and is a tributary of the Vaal River (see **Figure 1**). The MAR of the Rietspruit catchment is about 262 million m^3/a. The longest channel in the Rietspruit is 59.5 km in length. A preliminary reserve and class determination of this catchment was performed in December 2001 (see **Appendix 1**).

The flow volumes and water qualities in the Rietspruit are monitored by Rand Water at a position (RV2) in the river approximately 1.3 km north of Loch Vaal (approximately 200m below the confluence of the Rietspruit and the Klein Rietspruit). This point is shown in **Figure 1**. The flow quantities and qualities recorded at this monitoring station are recorded in **Appendix 5** (water qualities) and **Appendix 7** (flow). This station is situated downstream of the confluence of the Rietspruit and the Klein Rietspruit, which is after the confluence of the Rietkuilspruit and Rietspruit. The catchment area of the Rietspruit and Klein Rietspruit are approximately 1398 km^2 and 199 km^2 respectively. Any analyses of flows and water qualities recorded at RV2 must take into consideration the volume of water emanating from the Klein Rietspruit tributary in order for a dilution analysis to be performed at the confluence of the Rietspruit and the Rietkuilspruit.

In addition to the Rand Water monitoring point, Iscor monitors water qualities at three positions in the Rietspruit (points RS6, RS9, RS10 in **Figure 1**). A summary of the analyses at these monitoring points is included in **Appendix 5**.

The average dry weather flow in the Rietspruit was calculated as approximately 4.2 times larger than the flow in the TETP Canal. The flow in the Vaal River is approximately 13.7 times larger than the flow in the Rietspruit. For an evaluation of water quantity and quality results existing in the Rietspruit, refer to **Section 2.4.2**.

2.2.3 Rietkuilspruit Catchment

The Rietkuilspruit catchment drains the western portion of the Works, as well as the agricultural holdings to the west of Iscor (Rietkuil, Lamont Park, Steelvalley, Louisrus, Rosashof, Cyferpan). The size of the Rietkuilspruit catchment is approximately 20.2 km^2. The catchment is indicated

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in **Figure 1**. The Rietkuilspruit enters into the Rietspruit approximately 15.4 km north of Loch Vaal. The MAR of the Rietkuilspruit catchment is approximately 4.2 million m^3/a.

The Rietkuilspruit has its origin in the northern part of Vanderbijlpark town and runs past the IVS south-western boundary up to the culvert under the Golden Highway, from where it runs in a westerly direction. Although the natural runoff discharge of the IVS site is towards the Rietkuilspruit, no runoff water is in fact discharged into this spruit as a result of constructed canals and discharge systems on site. The Rietkuilspruit does cross the discharge canal of IVS by means of a bridge structure situated just upstream discharge point of IVS into the Rietspruit canal. This canal enters the Rietkuilspruit some 4 km downstream, but before its confluence with the Rietspruit.

The land use in the Rietkuilspruit catchment upstream of the IVS Works consists of residential and small industrial use to the North of Vanderbijlpark. Land use downstream of the IVS site consists mainly of agriculture, with both game and cattle farming taking place. Iscor has bought out most of the land downstream of the IVS site during the previous interdict action. Ferroland on behalf of Iscor manages this land. For more information regarding the land use, stock ratios and zoning of this area, refer to the Master Plan specialist report appertaining to Land Capability.

A preliminary reserve and class determination of the Rietspruit catchment has been performed, of which the Rietkuilspruit forms an integral part. Water quality objectives for the catchment have been taken to be those contained in the Water Licence of IVS (see **Appendix 1**). The Rietkuilspruit catchment forms part of the Rietspruit catchment, and therefore falls under the WUA formed for the Rietspruit catchment, being the Rietspruit Forum.

Water qualities in the receiving environment of the Rietkuilspruit are monitored by means of grab samples by Iscor at seven positions in the Rietkuilspruit (see points RS0, ...RS5 and RS8 in **Figure 1**). Results of the analyses at these points are contained in **Appendix ~~7~~**. 5

The Rietkuilspruit flows approximately 5 km from where it passes under the Golden Highway to where the Rietspruit canal discharges into it. After this point the Rietkuilspruit flows approximately 1.3 km further before it discharges into the Rietspruit.

For an evaluation of water quantity and quality results existing in the Rietkuilspruit, refer to **Section 2.4.1**.

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2.2.4 Leeuspruit Catchment

The Leeuspruit catchment lies on the eastern side of Vanderbijlpark Steel, and flows initially in an easterly direction, and then in a southerly direction. The area of the Leeuspruit catchment is approximately 50.8 km^2, and the mean annual runoff from the catchment is approximately 10.79 million m^3/a. The total channel length of the river is approximately 10 km. Land use in the Leeuspruit catchment includes formal residential areas, informal settlements, agricultural holdings, industrial areas, a sewage treatment works, recreational areas and a wetland. Although not yet decided, the Leeuspruit catchment would probably fall under the governance of the above mentioned Rietspruit Forum (WUA).

The Leeuspruit flows through the community of Boipatong, then to the north of Tshepiso and Sharpville, and then to the west of Powerville, and finally enters the Vaal River to the east of Bedworth Park. There is a small dam located in the Leeuspruit River, just downstream of Boipatong. Outflow from the Leeukuil Dam (adjacent to Sharpeville) also enters the Leeuspruit River via a furrow. The Leeuspruit has for a large part been diverted away from its natural stream course due to the build-up of roads infrastructure (and Powerville) within the stream flow.

Water qualities are monitored by means of grab samples by Iscor at six positions in the Leeuspruit. Results of these analyses are included in **Appendix 10**.

During the Master Plan Study a number of short term measures were undertaken (see Section 9). These projects included the construction of a weir at the point where the Leeuspruit passes under the Frikkie Meyer Boulevard, in accordance with the requirements of the Permit Exemption 1998B, Section 7 Clause 7.1.2.1 (this Permit Exemption expired on 31 December 2001). The flow passing over the weir is measured in terms of quantity (flow) and quality (EC and pH) on a continuous basis and by means of grab samples when water flows over the weir. The construction of this weir, a compound Crump weir structure, was completed in December 2000.

A preliminary reserve and class determination of this catchment has been performed. Water quality objectives for the catchment have been taken to be those contained in Water Licence of IVS (see **Appendix 1**). For an evaluation of water quantity and quality existing in the Leeuspruit, refer to **Section 2.3.5**.

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2.3 Local Environment

The local environment at IVS is defined within this study as the area within the perimeter of the site, including the Kiewiet area. The local environment is the area to which the IVS has direct control and which can be manage internally.

The local environment describes the area where steel making activities have, and are taking place. It is therefore important to note that the area described herein is an impacted area, also called a brown fields site. The area is zoned as Industrial Type II, which allows industrial activities together with the disposal of waste. As reviewed in **Section 1.3**, which will be expanded upon herein after, the surface water within the local environment is managed subject to a Water Licence. This licence sets the objectives for management and discharge practises within the area under consideration.

An understanding of water flow mechanisms and quality aspects within the local environment forms the foundation of the baseline study for surface water. The activities, impacts and risks observed within the receiving environment, all occur as a result of what happens in the local environment. Any improvements that can take place for betterment of the conditions in the receiving environment are directly reliant on the change in activities within the local environment. An in depth understanding of the mechanisms acting within the local environment is therefore required to be able to make proper decisions on how to better manage waters within the site.

2.3.1 Site Water Balance

The site water balance forms an integral part of the process water requirements of the IVS site. For a detailed description of the requirements for process water at the site, the reader is referred to the process water specialist report as produced by RPA as part of the Master Plan study for Iscor Vanderbijlpark Steel.

Surface water management on older industrial sites such as Iscor Vanderbijlpark Steel is intimately linked to industrial water management and neither can be studied in isolation from the other. This is due to the fact that stormwater runoff emanating from rainfall can easily be mixed with any process water on surface, especially in the South Works area on this specific site. Industrial water and stormwater discharge lines have not been separated and single conduits are used to transport both stormwater and process effluent towards the outlet points of the site. It is needless to say that once mixed, process waters and surface runoff from rainfall cannot be

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distinguished or separated and therefore becomes a combined water body that needs to be managed within the site.

For purposes of this surface water study, the water balance requirements are focussed on the overall mass balance of water for the site only. Water management within the site therefore is discussed in the process water baseline study report as well as later in this report.

The overall site water balance can best be described at the hand of **Figure 6**. Water entering the site emanates from the following sources:

I1: Raw water intake from the Vaal dam as supplied by Rand Water from the Letaba weir and pumped to the site via a pump station at the Vereeniging purification works. This water is treated in the Vaal water purification works (VSA) on site where-after it is pumped to a 30 Ml reservoir from which the North Works and parts of the South Works is supplied.

I2: Raw water intake from the Vaal river is pumped from a pump station on the banks of the Vaal, situated to the south of Vanderbijlpark. Two parallel pipelines transport the water from the Iscor pump station to the main purification plant (HSA) at the works. Water is purified at (HSA) from where it is pumped into the industrial water supply system to the South Works and into the balancing reservoirs situated to the South of the Works.

I3: Water used for air conditioners, toilets, drinking water and some minor industrial uses are purchased from the Vanderbijlpark Municipality and supplied from the municipal reservoirs situated to the South of the works.

I4: Rainwater precipitation onto the site.

I5: Rainwater runoff from part of the Kiewiet site onto the Works.

Water discharged from the site consists of the following:

O1: Water discharged through the Rietspruit canal towards the Rietspruit in the south-west of the site.

O2: Water discharged to the Leeuspruit over the Frikkie Meyer weir.

O3: Water evaporated in industrial processes and from dams.

O4: Water evaporated from dams and wetted surfaces within the site.

O5: Water seeping into the ground and leaving the site as groundwater across the boundaries.

Discharge O3 is dealt with in the Master Plan specialist report for process water, while the others are discussed in more detail later in this report.

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2.3.2 *Intake Water Quantity*

While surface water intake onto the site (I4 & I5) has in detail being described in 2.3.3 hereafter, the industrial intakes (I1, I2 and I3) can best be discussed on the hand of **Table 15**.

Table 15: Total Monthly Flows into IVS (m^3) - Intake Waters Only

Month & Year	Vaal Dam (I1)	Vaal River (I2)	Domestic Supply (I3)	Monthly Totals
Mar 2001	962,500	1,110,418	142,343	2,215,261
Apr 2001	927,500	906,682	144,292	1,978,474
May 2001	801,900	760,452	109,937	1,672,289
Jun 2001	1,047,500	1,064,342	137,842	2,249,684
Jul 2001	967,930	1,025,498	127,277	2,120,705
Aug 2001	968,600	1,099,486	132,472	2,200,558
Sep 2001	959,800	1,327,054	123,287	2,410,141
Oct 2001	969,700	1,180,303	120,948	2,270,951
Nov 2001	989,700	1,234,860	125,744	2,350,304
Dec 2001	1,020,600	1,033,473	125,616	2,179,689
Jan 2002	1,030,000	952,903	135,710	2,118,613
Feb 2002	1,110,500	866,912	130,069	2,107,481
Total for Year	**11,756,230**	**12,562,383**	**1,555,537**	**25,874,150**
Percentage of total	45.4%	48.6%	6.0%	

Total volumes of water taken in from I1, I2 & I3, are summarized for the year under investigation on a monthly basis, as can be seen from the table. Water intakes from the various sources are fairly constant with variations of up to 20% from the average encountered. It can be seen that similar volumes of water are being abstracted from the Vaal dam system as from the Vaal river system. Domestic supply amounts to only 6,0% of the total water supply to the site.

Water intake volumes are not restricted by the current water use license (no. 10016047), however the license does state that the daily volumes of water abstracted from all the sources must be reported to the regional director on a monthly basis. (Appendix 1, paragraph 14) The license furthermore states that this Master Plan must result in the drastic reduction of the quantity of water that has been abstracted and used for industrial purposes (Appendix 1 - paragraph 12.1). This aspect of reduction of intake water is discussed in detail in the process water specialist report as part of the Master Plan.

2.3.3 *Water Intake Quality*

Surface water intake water qualities (I4 & I5) are difficult to quantify. Even though the previous permit exemption (1998B) requested that a study needs to be done in order to quantify the qualities of rainwater and surface water runoff from the site, a motivational report was compiled

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by VRF stating why such a study could have highly varied results and why a definitive statement on the resultant water qualities would require an in depth study for this site alone (the document referred to is the "Water Run-off Experiment within Veld Area"). Surface water input qualities are therefore not available for discussion in this document.

Water qualities for intake water I1, I2 and I3, are monitored on a continual basis and can best be described on the hand of **Figure 6**. The results of water quality testing are as follows:

The graph shows only the electrical conductivity (EC) parameter for the three supply sources. A range of other parameters are tested for by IVS of which the results are graphed in **Appendix 4**. Similar results to that encountered with EC can be seen when considering the other parameters. It can be seen from the graph that the electrical conductivity of both the Vaal dam and the domestic supply lines (I1 & I3) are fairly constant at a level between 20 and 30 mS/m. This relates to a good quality water in terms of the management target for the Vaal Barrage being set at 30 mS/m. When considering water qualities within the Vaal River system (abstraction from I2), a highly varied electrical conductivity profile is encountered with values ranging between 20 and 100 mS/m.

It is known that water qualities within the Vaal river system in the area of the Vaal Triangle are affected due to the highly industrialised nature of the area. It is also worth noting that during most of the periods water qualities exceed the interim target for the Vaal Barrage (70 mS/m). The current discharge water quality for the Iscor Works, as stated in the Water Licence is set at 170 mS/m for the Rietspruit Canal and 70 mS/m for the Leeuspruit. It is also worth noting that the water qualities in the Vaal river improve drastically during the wet weather season (December 1999 – May 2000, October 2000 – January 2001 as well as November 2001 – February 2002).

2.3.4 Overview of Water Quality Assessment

In an attempt to summarize the water quality guidelines and objectives available from national and international sources, a water quality comparative summary table has been compiled. Please refer to the table in **Appendix 2**.

All available water quality variables are listed in column 1, where they have been categorized according to their nature. Water quality categories include the physical properties of the water, the organic content thereof, microbiological aspects, macro variable elements as well as micro-variable elements. The difference between macro and micro variables has been drawn

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according to the normal units in which such variable is reported, being milligrams/l for macro variables or micrograms/l for micro variables. Columns from left to right summarize the different water quality standards that could be obtained and according to which water is classified in accordance with its fitness for use. The elements highlighted in green are those that are required to be measured according to the water license of IVS at its discharge points to the Leeuspruit and Rietspruit Canal.

The last three columns of the table have been added to aid in further discussions when future water license requirements are determined. The third last column represents an average good water quality in terms of all the water quality guidelines listed in the table. The last two columns represent what would probably be achievable water qualities before and after ZED in 2005.

The second last column represents water qualities that can probably be achieved before 2005. These water qualities represent process effluent discharge before ZED, and can therefore to some extent be controlled through the process as much as the process equipment currently allows. The last column, which represents post ZED water quality is difficult to determine due to the fact that effluent discharge through the cannel will by that time, be eliminated. The water qualities of water discharged after ZED should therefore represent realistic stormwater runoff qualities after first flush discharge has been captured for recovery through process. It is therefore suggested that limited emphasis should currently be placed on water qualities post ZED and that a better understanding of the natural run-off water qualities as represented by the discharges over the Leeuspruit weir should be analyzed in order to determine an achievable water quality objective for run-off discharge from the site.

As far as post ZED water quality objectives for the Leeuspruit and the Rietkuilspruit are concerned it is recommended that only one water discharge quality objective be set for both these discharge points. Reason for this is that both discharges will emanate from surface water run-off only after capture of the contaminated portion of the first flush and due to the fact that water reporting at either discharge points originate on the same works area though it be within two catchments within the site. It is recommended that further discussions take place between IVS and the Authorities on this matter as well as within the WUA of the Rietspruit Forum.

2.3.5 Surface Water System

Before the measured water flow and qualities are discussed in more detail, it is necessary to provide a background description of the site properties from a water management perspective.

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The surface water system within the Works area at IVS has been systematically modified from its natural state prior to 1943, such that flow patterns within the area have been significantly altered to the current situation. These alterations have had a significant effect on where water discharges from the site, as well as the amount of discharge that occurs from the site. Both these alterations will now be evaluated.

Natural State

In 1922 Dr. van der Bijl declared that "The future of the industrial development of the Transvaal (Gauteng) must, of necessity, lie along the banks of the Vaal River". This was why he welcomed government proposals to build the Vaal Dam in 1933, knowing that water supply problems were one of the great barriers to industrial development at that time. During 1941 an area of approximately 95 km^2 was purchased by Iscor for the creation of a new industrial town west of Vereeniging (Anon, 1997). This town developed to be the present day Vanderbijlpark.

The location of the site made it ideal for development. There was sufficient slope for drainage towards the river and the area was downstream of Rand Water Board's pumping station intake.

Before Iscor developed its Iron and Steel Works on the present site, the site consisted of natural veld area draining in two directions. The western portion of the site, draining approximately 68.7 % of the Works area, fed into the Rietkuilspruit towards the West while the eastern portion of the Works area, consisting of the remaining 31.3 % of the Works area, drained towards the Leeuspruit to the East. **Figure 1** shows the approximate position of the natural catchment divide through the site.

Modified State due to Works

The western catchment of the site was modified to such an extent that runoff water which would previously have run-off overland towards the South-west, now all reports to a single discharge point at the Western boundary of the site. This single discharge point was further modified to drain via a canal, rather than into the natural drainage path of the Rietkuilspruit. This canal is called the Rietspruit canal. This canal re-enters the natural drainage channel approximately 4.75 km downstream from the site boundary. The western portion of the site now drains about 74.1 % of the Works area, while the eastern catchment drains about 25.9 % of the Works area.

The Rietkuilspruit catchment has therefore been reduced significantly since the canal was built and currently only drains water from a stormwater system emanating from the Northern side of the town of Vanderbijlpark and from the remaining catchment to the West of the Works. The

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stormwater system from Vanderbijlpark crosses the Rietspruit canal at the boundary fence of IVS and enters the Rietkuilspruit approximately 400 m north of the Rietspruit canal. The Rietkuilspruit then flows in a westerly direction.

The surface canals situated on the site boundary and drained towards the Du Preez dam have subsequently captured water previously flowing overland towards the Rietspruit to the North West of the site. From there, this water is pumped back to the process, thereby reducing run-off towards the Rietspruit.

Apart from altering the drainage pathways on the site, the runoff volumes from different areas within the site have also been altered due to the development of infrastructure within the site. Residue storage or disposal areas increase infiltration, thereby reducing runoff. Dams, such as the large evaporation or effluent storage facilities store water and therefore significantly reduce natural runoff due to their storage potential. Areas made impermeable by roofing or paving (such as significantly large areas within the North and South Works), with their associated stormwater canal systems, have an opposite effect on runoff volumes. Infiltration is reduced significantly, and runoff volumes, peaks and velocities are increased.

Similar as to the western catchment, the runoff from the eastern catchment has been altered by the various developments on site. Again, natural overland flow towards the Leeuspruit has been altered significantly such that water is currently channelled to one point on the site from where it is discharged into the Leeuspruit.

The construction of several water management systems has further changed historical natural flow patterns. The eastern catchment has been modified in a way that a portion of this catchment that historically drained to the Leeuspruit, now drains to the western catchment of the site. This was achieved by the construction of a network of stormwater canals in the South Works (which is situated on the watershed) that drain to the western side of the works. In addition to this gravity system, most of the dry-weather flows (natural or effluent) are pumped from the eastern catchment to the western catchment. Shallow ground water seepage from the Works has further created a marshy area at the low-lying area to the East of the Works.

Western Discharge

In this section, the water quantity and quality monitoring results obtained from the Western catchment discharge point is being discussed.

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The effective surface area of the western catchment within the Works perimeter is approximately 11.92 km^2. The area drains into the Rietkuilspruit catchment, which in turn drains into the Rietspruit catchment. These catchments are described in **Sections 2.2.2 and 2.2.3** respectively.

Sources of Water Runoff

The Rietspruit canal receives effluent water from the North and South Works, and storm water from the South Works and CRMF. Certain specific effluent streams are treated at the CETP from where treated water is discharged towards TETP and the western discharge point.

Water Quantity

The water released from the western discharge point consists of process effluent, stormwater and shallow groundwater that seeps into the stormwater drainage system. Seepage of ground water into the canals is difficult to monitor and is therefore regarded as process water for purposes of this study. This leaves essentially two sources of water reporting to the Western discharge point. The infrastructure utilised for managing and monitoring the water discharged at the outlet point will be reviewed later in this section, as well as the data obtained from that equipment.

Consider the contribution of rainfall to the volume of water discharged from the Western catchment.

Rainfall Volumes

The total rainfall that fell on the western catchment during the year of analysis was approximately 860.3 mm. This is the average depth of rainfall calculated from the continuous and daily stations data. The western catchment is approximately 11.92 km^2 in area. This means that approximately 10.25 million m^3 of rainfall fell within the western catchment during the period March 2001 to February 2002.

Runoff Volumes

The following table presents the calculation for the area weighted runoff factor "C" for the western catchment of the IVS Works. The following factors were utilised in determining the "C" factor:

- C_s: Average catchment slope;

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- C_p: Permeability of the surfaces; and
- C_v: Vegetation.

The "C" factor for each sub-area was then multiplied by that area's surface area, and divided by the total area to provide the area weighed average runoff factor for the Western catchment.

Table 16: Weighed Average Runoff Factor for Western Catchment

Area Description	Surface Area (ha)	C_s	C_p	C_v	C	C'
South Works	610	0.03	0.21	0.26	0.50	0.256
TETP	82	0.03	0.08	0.08	0.19	0.013
Existing Dump	179	0.03	0.04	0.04	0.11	0.017
Sinter Mixing Bed	3	0.03	0.04	0.04	0.11	0.000
Coal Stacking Area	13	0.03	0.04	0.04	0.11	0.001
By Products Area	34	0.03	0.04	0.04	0.11	0.003
Intermediate Site	19	0.03	0.04	0.04	0.11	0.002
Dams	N/A (243)	-	-	-	0.00	0.000
Other	252	0.03	0.12	0.15	0.30	0.063
Total Area :	**1192**				**Area Weighted "C" :**	**0.36**

Utilising this runoff factor an estimation can be made of the runoff volume that is discharged from this catchment during the year of analysis. When multiplying the total rainfall that fell in the western catchment during the year of analysis with this runoff factor, the volume of runoff as a result of rainfall in the western catchment is approximately 3 691 000 m^3.

Peak Flow Events

Peak flow events have been determined for the western catchment of IVS, and are contained in **Table 17**. Three methods were utilised for determining the peak flow from the western catchment of the site, namely:

- the rational method;
- the empirical deterministic method; and
- the unit hydrograph method.

These methods were subsequently compared and found to give answers of the same order of magnitude. An average between the various values for their respective return periods was then determined and further used in calculations below. The detailed calculations reported in the table are contained in **Appendix 19**.

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Table 17: Peak Flow Event for Various Return Periods for Western Catchment (m^3/s)

Return period	Rational Method	Empirical Deterministic	Unit Hydrograph	Average
1:100	61.0	66.2	64.7	64.0
1:50	52.0	52.4	51.4	51.9
1:20	40.9	37.5	34.5	37.6
1:10	30.2	32.6	20.6	27.8
1:5	27.2	-	18.0	22.6
1:2	16.1	-	7.9	12.0

Stormflow Volumes

While the peak flow is useful for the design of water management infrastructure (especially canals and spillways), another key surface water parameter is the volume associated with each of these storm events. The volumes for the western catchment have been determined utilising the unit hydrograph method, and the results are summarised in **Table 18**. The calculations for these storm volumes are also contained in **Appendix 16**. The highlighted values indicate the critical storm duration for each of the return periods, i.e. the storm duration that is associated with each peak flow event. As indicated in the table, the peak flow events are not associated with the 24-hour storm (although this has the largest volume discharge), but rather with the one or two hour duration storm events.

Table 18: Storm Volumes determined utilising Unit Hydrograph Method (m^3)

Return Period	0.5 hr storm	1 hr storm	2 hr storm	4 hr storm	24 hr storm
1:100	331,541	**585,143**	717,245	837,485	1,239,586
1:50	260,555	430,457	**592,406**	721,353	928,131
1:20	194,747	291,497	**397,542**	478,855	704,011
1:10	141,604	**184,575**	237,456	306,242	546,665
1:5	103,431	**162,795**	202,452	258,970	358,689
1:2	45,364	**71,065**	87,118	100,649	152,850

The volumes listed in this table can be utilised to determine the storage capacity of a facility that would capture a specific storm, e.g. to capture a 24-hour, 1:100 year flood event discharge at the Western discharge point, a dam with capacity of 1 239 586m^3 would be required.

Water Licence Requirements

The Water Licence: 10016047 authorises the disposal of a maximum quantity of 11 680 000 m^3 per annum. This allowable discharge volume includes industrial wastewater (effluent) as well as groundwater to surface water seepage but excludes any stormwater. This volume is based on a peak dry-weather flow of 32 000m^3 per day.

The water licence requires surface water discharge flow to be monitored "at the bridge on the Golden Highway where it crosses the concrete lined channel to the Rietkuilspruit". The current flow monitoring point linked to AH4 is situated at this point in the channel. The water licence specifies that the quantity of water must "be metered continuously at the monitoring point described ... and the daily flows must be recorded".

The comparison of measured data at this point with the licence requirements is discussed hereinafter. However, in order to understand what is measured at this point the reader should have an understanding of the operational water management system at the TETP area as follows:

Infrastructure in TETP Area

Water flows from the Works towards the TETP area via thirteen stormwater drains within the South Works (refer to **Figure 2** and **Figure 4**). Water transported in this way includes both process effluent as well as stormwater run-off during rainfall events. These stormwater drains discharge the water into the north and south buffer dams. These dams have capacities of 42 500 m^3 and 10 200 m^3 respectively.

The dams are balancing dams for the TETP process plant, and also act as silt settlement facilities. The buffer dams capture all dry-weather flows (process effluent) and part of the stormwater run-offs (the first flush discharge). The TETP is a filtering plant which has an operational capacity of approximately 88 000 m^3/day and consists of:

- Grit removal;
- Oil and grease removal;
- Coagulant and flocculant dosing and gravity separation;
- Sand filtration; and
- Chemical biocide dosing.

The buffer dam bypass canal leads from the south buffer dam to the north buffer dam. During high flow conditions both the buffer dams fill up to capacity where-after a spillway at the end of the buffer dam bypass canal is overtopped. This overflow then enters a second concrete bypass canal, which flows towards the Rietspruit canal outlet point.

At the point where the bypass canal flows into the Rietspruit canal, a structure within the Rietspruit canal limits the discharge flow rate to 6 m^3/s. This is done to prevent the canal further downstream from overtopping its banks. Should the flow at this point exceed the maximum discharge rate, the water spills over a wall into a flood attenuation dam. This dam has a holding capacity of approximately 153 000 m^3. When the storm runoff has subsided, the water flows out of this flood attenuation dam through a series of non-return valves into the Rietspruit canal.

The Rietspruit canal inside the Works consists of a U-shaped concrete channel with a bottom width of 2.4 m and vertical side walls of 1.5 m high. Flow measurement is done in the channel section of the canal downstream of the flow limiting structure. This is obtained by means of water flow depth measurement over a British Standard (BS) hump. The water level (and therefore the flow) in the canal is measured continuously by means of a calibrated Milltronics Multiranger ultrasonic instrument installed over the BS hump. The ultrasonic instrument converts the measured water depth into a 4-20 mA signal and sends the signal to AH4. From there, the signal is transmitted through a radio communication system to the Energy Control Centre (ECC) where the data is captured and stored. For the purposes of this report, flow data was extracted from the ECC system as averaged half-hourly readings. The data is available for the entire year of analysis, from March 2001 to February 2002.

Calibration of Rietspruit Canal

As soon as analysis of the flow data was done, it became apparent that the BS hump theory does not support non-modular flow conditions. These conditions occur during higher flows conditions. Due to the flat slope (1:800) of the canal, modular flow cannot be assumed since the downstream canal is acting as a control point and creates a backwater effect over the hump. The hump, as it is operating under the conditions, is said to be "drowned".

In order to correctly calibrate the Rietspruit canal, a flow velocity analysis was performed in the canal in association with the DWAF: Hydrometry Department during February 2002. Variable test depths were obtained by controlling the number of operational pumps at the TETP. Four flow depths were evaluated (relating to 2, 4, 6 and 9 operational pumps at the TETP). Velocities were established at two depths in the flow profile (0.2 H and 0.8 H), and for 25 positions across the channel for each profile and depth. The flows analysed provided only the low flows in the canal, since the TETP pumps do not have sufficient capacity to facilitate the calibration of the entire canal. High flow conditions only occur during large storm events.

Appendix 18 contains a graph which provides several calibration curves. The graph only indicates the low flow conditions in the canal (flows < 1 m^3/s). The flow rate in the canal can

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increase, but is also limited to 6 m^3/s. Calibration of the canal was done using the following theory relating to the lines shown on the graph:

- Chezy theory;
- Manning theory;
- The existing BS Hump calibration curve; and
- The four flow volumes relating to the flow analysis performed in association with DWAF.

The proposed calibration curve is based on these four sets of theory and the empirical data obtained. The majority of the empirical data values obtained from the flow analysis study performed in conjunction with DWAF are within 1.5% of the theoretical flow values calculated for a specific depth. The maximum deviation between the proposed calibration curve and the measured flow rates on site is no greater than 5%.

The calibration of the BS hump has been utilised for flows between 0 and 0.5 m^3/s. The calibration of the canal utilising the Chezy equation was utilised for the higher flows. The calibration of the canal with the Chezy equation was further verified utilising the Manning equation. In the Chezy equation, a factor of "k" is used. This factor represents the size of the eddy current formed at the base of the channel, and is dependent on particle diameter or dune formation flow length. For the AH4 canal a value of k = 3mm has been assumed (pre-cast concrete: mortar not wiped on inside of joint - Road Drainage Manual, Fig 3.8). For the Manning equation a roughness coefficient "n" is used also to describe the roughness of the canal surface. A value of n = 0.014 has been used in this calculation (n=0.010 is ideal for smooth concrete surfaces, but DWAF utilise 0.014 as a standard value for canals due to the presence of sand, joints and pebbles in canals).

The calibration curve for the canal was therefore modified from utilising only the BS hump theory, to a combination of the BS hump (0 - 0.5 m^3/s) and Chezy's equation (0.5 – 6.0 m^3/s) where the low flows for this calibration were verified utilising a physical calibration of the canal. The measuring instrumentation was subsequently re-calibrated to adopt the revised flow-depth graph for the discharge canal. Here then follows an analysis of the flow data obtained at the western discharge point over the review period.

Monthly Flow Quantity Data

The graph in **Appendix 7** shows the monthly maximum, 95-percentile, median and 10-percentile flows discharged to the Rietspruit canal. The 95-percentile and median flows are

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lower during the winter months than the months of spring and summer. This is because the Works falls within the summer rainfall region of South Africa.

The canal has a limiting flow capacity of 6 m^3/s. This amounts to a maximum discharge rate of 21 600 m^3/h. The maximum flow recorded was only 3600 m^3/h (1 m^3/s). The reason for this discrepancy is that the ultrasonic instrument was at that stage still calibrated to record only flows during dry weather conditions, i.e. below 1 m^3/s. This is problematic, especially during the months of September to November where the median flow values were above 3600 m^3/h. After calibration of the canal was done, the settings on the ultrasonic instrument have been changed. However, caution must now be applied with the analysis of the available data. For this reason, subsequent data obtained during the year 2002 was incorporated in the data set in order to circumvent this data problem.

Annual Flow Quantity Data

Table 19 presents the total daily flow volumes passing down the Rietspruit canal. This table shows that the maximum 24-hour discharge from the site during the period was 131 310 m^3 (18 November 2001), while the lowest 24-hour discharge was 13 164 m^3 (23 June 2001). The maximum volume discharged during one month was approximately 2 685 000 m^3 (November 2001), while the minimum volume discharged during the period was about 1 129 000 m^3 (June 2001). The total volume of water discharged during the year of analysis was almost 18 125 000 m^3. This volume includes approximately 1 862 000 m^3 transferred from the Leeuspruit Sump in the eastern catchment. This means that approximately 16 262 000 m^3 of surface water generated in the western catchment was discharged from the western discharge during the year of analysis. This volume of water includes the discharge of effluent as well as stormwater from the site.

The estimated volume of stormwater discharged from the western catchment has been calculated as 3 792 000 m^3 (see **Table 20**). From the industrial water balance on the site (refer to Master Plan Process Water Specialist Report: Table 5.1.5.1 and text following that table) it can be taken that approximately half of the industrial water that comes into the site is evaporated within the Works as steam, off gas cleaning and various quenches. This would mean that the volume of effluent discharged from the western catchment would be 12 159 000 m^3. Adding the estimated stormwater and effluent volumes together, the total volume of water discharged from the western catchment of the Works would be 15 951 000 m^3. This value is in the same order of magnitude as the volume of 16 262 000 m^3 calculated above.

Table 19: AH4: Daily Total Flow Volumes in the Rietspruit Canal (m^3)

	Mar 01	Apr 01	May 01	Jun 01	Jul 01	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 02
1	36214	41384	45198	39954	39702	36874	57806	44160	112750	44160	35267	15356
2	37044	42238	18394	49416	33495	32566	64938	27600	102406	27600	38660	41826
3	37310	39294	76640	42646	33495	32420	59090	37200	87708	37200	38208	40230
4	34020	40658	43290	43198	42024	40564	49740	50400	82488	50400	43482	42366
5	42774	38074	43198	41816	41060	42248	42578	37200	73838	37200	34874	32786
6	38032	39074	42698	42096	42184	43438	42936	21200	50048	21200	41348	37705
7	38232	37292	42248	45362	42676	43122	48730	37200	62504	37200	42184	37705
8	35970	42792	50796	36420	39292	44208	33470	49200	60738	49200	42672	55186
9	37434	37004	33074	42228	31412	44780	41934	50400	79260	50400	42136	55186
10	47390	34908	46722	42446	37204	41168	47752	40800	108820	40800	44086	55186
11	39936	41192	23730	32778	35256	42868	40960	39600	118550	39600	41556	42054
12	42236	38148	39534	19006	37692	58118	43756	51516	121676	51516	41702	41710
13	42002	39836	40888	36272	40536	47246	69786	61692	85512	61692	42430	42025
14	33438	41246	40256	39072	40008	61758	127848	56366	56646	56366	40368	42025
15	42096	42722	37368	35634	34592	42594	76848	52208	75238	52208	40574	45360
16	37092	40142	35628	25018	38886	42204	87284	70664	74920	70664	36590	46922
17	42616	25472	40922	52410	40080	40195	83542	70592	99930	70592	40852	42068
18	40716	30295	39262	31450	45368	40195	70932	81706	131310	81706	41816	35265
19	41584	30295	30524	31504	37954	61364	66630	81706	130260	81706	42248	35265
20	42066	30574	35598	38844	35036	30902	78172	52386	115612	52386	56072	44388
21	39928	38728	39422	18060	46182	39214	62272	45362	86452	45362	28768	39616
22	35156	39008	43056	60132	46182	51434	71480	53042	83120	53042	48114	39398
23	57356	48495	41068	13164	46182	38506	46724	70306	84716	70306	34612	39398
24	69542	48495	42548	72630	46182	43460	24244	70306	86720	70306	42510	41552
25	60468	43708	37642	43854	25772	43224	21000	90518	87452	90518	58474	41848
26	43992	43708	36648	29409	38834	42072	21000	70540	85608	70540	74428	42740
27	44644	43226	47658	33762	40388	42072	31200	95720	85708	95720	97216	33454
28	40716	42600	42856	30343	41998	45436	38400	97682	85572	97682	47460	41932
29	40716	40232	44566	27342	34262	42532	48000	85552	85629	85552	79622	-
30	40716	47340	40986	33731	37128	48594	43200	70514	85636	70514	86842	-
31	40716	-	46112	-	43470	57806	-	79284	-	79284	71068	-
Subtotal	1302152	1188178	1268530	1128997	1214532	1363182	1642252	1842622	2684827	1842622	1496237	1150552
Total												18124683
Max	69542	48495	76640	72630	46182	61758	127848	97682	131310	97682	97216	55186
95-Per	59,534	47,975	49,227	56,657	46,182	59,741	85,600	93,119	126,397	93,119	83,232	55,186
Median	40,716	40,187	40,986	37,632	39,702	42,594	48,365	53,042	85,633	53,042	42,184	41,837
Min	33,438	25,472	18,394	13,164	25,772	30,902	21,000	21,200	50,048	21,200	28,768	15,356

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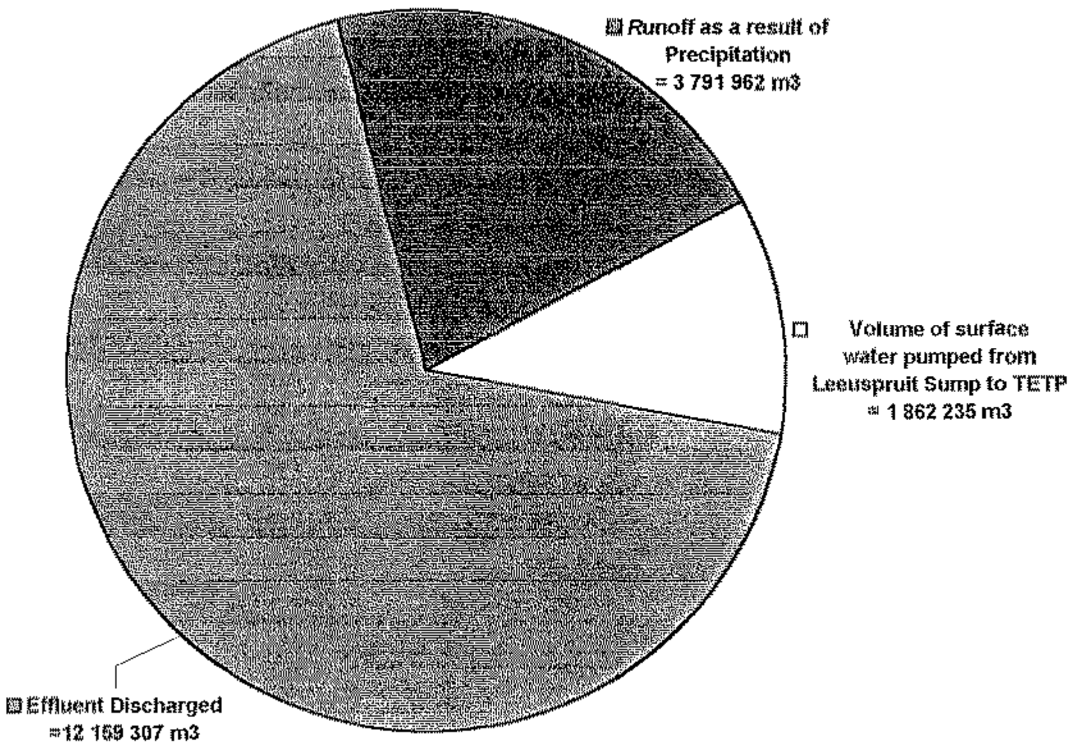
The following table provides a summary of the macro surface water balance for the western catchment of the IVS Works.

Table 20: Macro Surface Water Balance for Western Catchment

	Description of Water	Calculation	Volume (m^3)
A	Intake volume (Vaal River + Vaal Dam)	A	24,318,613
B	Volume evaporated within IVS process	B	12,159,307
C	Intake volume - Volume evaporated = Effluent	A-B	12,159,307
D	Runoff as a result of precipitation (Annual rainfall * Area * Runoff factor)	D	3,791,962
E	Total surface water = Effluent + Runoff as a result of precipitation	C+D	**15,951,268**
F	Volume of surface water pumped from Leeuspruit Sump	F	1,862,235
G	Flow volume in Rietspruit canal as monitored at AH4	G	18,124,683
H	Flow volume in Rietspruit canal from western catchment	G-F	**16,262,448**
I	Discrepancy	100(H-E)/H	1.9 %

The water balance is graphically shown in the following pie chart:

Graphical Presentation of Surface Water Quantity Discharged from Western Catchment



In terms of the IVS water licence, it can be said that, where the volume of effluent discharged from the site is estimated to be approximately 12 159 000 m^3 and the water licence authorises the disposal of a maximum quantity of 11 680 000 m^3 per annum, that IVS discharged about 6.7 % more water than permitted within their water licence over the period under investigation.

Daily Storm Events

Evaluation of the run-off volumes emanating from rainfall events needs some further consideration. To enable this, specific individual storm events have been analysed at the hand of the available continuous rainfall record data. Through this analysis, an understanding should be obtained of the run-off characteristics of the site, the lag times, run-off response times as well as water quality evaluations during storm flow events.

During the year of analysis several errors were encountered in the data set. These errors are mainly due to radio signal breakdown and lightning interference during the storm events. These malfunctions have been rectified since. Four storm events subsequent to the year of analysis have therefore been selected for analysis. These four storm events occurred between May 2002 and August 2002.

For each of these storm events two graphs have been prepared. The first presents the continuous flow (m^3/h), EC (μS/cm) and incremental rainfall (mm), while the second provides the continuous flow (m^3/h) and EC (mS/m) only. The reason for providing two sets of graphs is due to the scale difference used for the graphs. On the first graph each incremental rainfall dot represents 0.25 mm. The following storm events were analysed:

	Date of Storm Event	Rainfall Depth (mm)	Stormflow Volume (m^3)
1	22 May 2002	9.5	46621
2	31 May 2002	37.5	205197
3	13 June 2002	21.0	34231
4	27 August 2002	14.75	16378

All of the above storm events represent typical rainfall storm events with annual recurrence intervals that can be expected. The individual storms will now be analysed. Graphical representations of these storms are contained in **Appendix 9**.

Storm Event 1

Rainfall started on 22 May 2002 at 17:56.

Total amount of precipitation of the event was 9.5 mm.

Period during which rain fell approximately 6 hours.

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Therefore, the total volume of rainfall onto the western catchment amounts to 113 240 m^3. Using a runoff factor of 0.36 amounts to a runoff volume of 40 766 m^3.

The following table presents a summary of the times, flows, volumes and EC values associated with this storm runoff:

Table 21: Summary of Storm Event 1

Description	Date	Time	Rain (mm)	Flow in Canal (m^3/h)	Stormflow Volume (m^3)	EC (mS/m)
Rainfall started	22/05/02	17:56	0			
Runoff started	22/05/02	18:17		897	0	115
Peak of First Hydrograph	22/05/02	19:49		3145	1629	115
End of First Hydrograph	22/05/02	21:20		1401	1708	116
Peak of Second Hydrograph	22/05/02	22:29		7680	5081	117
Rainfall ended	22/05/02	23:53	9.5			
End of Second Hydrograph	23/05/02	01:32		1346	4688	122
Peak of Third Hydrograph	23/05/02	06:29		2397	4018	107
End of Third Hydrograph	23/05/02	09:33		1162	2982	109
Peak of Forth Hydrograph	23/05/02	13:44		2912	5789	116
End of Forth Hydrograph	23/05/02	18:19		1335	6096	123
Peak of Fifth Hydrograph	24/05/02	00:02		3484	7657	118
End of Fifth Hydrograph	24/05/02	05:00		1230	6973	117
Total Flow Volume during Storm Event					46621	

The flow in the Rietspruit canal was about 897 m^3/h before run-off discharge started. A value of 1000 m^3/h has however been taken to be the effluent discharge value during each of the four storm events. This value has been chosen as it represents an average effluent flow rate during the four storm events. Selecting the same value for all storm events allows for an effective comparison of the four events. This value was deducted from the flow hydrograph and whatever was above this value was deemed to be stormwater run-off flow.

The runoff from the western catchment as a result of this precipitation started coming down the canal approximately 21 minutes after the first rainfall at 18:17. The lag time between start of rainfall to start of runoff for this storm is therefore 21 minutes.

The first flow hydrograph to pass through the Rietspruit canal had a peak of 3 145 m^3/h (0.87 m^3/s). This peak occurred at 19:49, about 92 minutes (1,5 hours) after the stormflow entered the Rietspruit canal. The EC in the canal at that time was 115 mS/m. The water licence specifies a WQO for EC of 170 mS/m in the Rietspruit canal, and this runoff is therefore

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within the prescribed limits for EC. The volume associated with this first hydrograph was 3 690 m^3.

The second hydrograph had a peak of 7 680 m^3/h (2.13 m^3/s). The volume associated with this run-off event was approximately 9 770 m^3. The third, forth and fifth peaks associated with the runoff from this storm event were 2397 m^3, 2912 m^3 and 3484 m^3 respectively. The reason for the runoff from the western catchment having several hydrographs constituting the runoff is that there are thirteen stormwater drains flowing from the Works in an easterly direction. These drains have differing sub-catchments that they serve, with differing flow lengths and therefore with different lag times.

The electrical conductivity (EC) in the Rietspruit canal does reduce during the storm event. This is as a result of the relatively clean rainfall runoff mixing with the effluent runoff, thereby lowering the water quality parameter concentrations in the system. The maximum and minimum water EC values during the storm event are 123 mS/m and 107 mS/m respectively. Both of these values are below the water licence WQO of 170 mS/m. The value of 107 mS/m is associated with the peak of the third hydrograph, which occurred more than 12 hours after the runoff started. It took another 12 hours for the runoff EC value to climb back to 123 mS/m.

This runoff scenario will change post 2005. With the ZED infrastructure in place there will be no dry-weather (effluent) flows in the canal i.e. the canal should be dry when there is no rainfall. There should therefore be no flow before, or after, any storm event. The rainfall will begin, there will a lag time and then there will be a runoff hydrograph in the canal after which rainfall discharge will stop and the canal should remain dry again.

Although the rainfall event took place over some 6 hours, the total duration of the runoff from the storm event was approximately 35 hours. The total runoff volume associated with this storm event, assuming that the effluent component of the runoff was 1000 m^3/h throughout the time, was 46 621 m^3. This volume is about 14 % higher than the 40 766 m^3 determined utilising the total rainfall in the western catchment and the area weighted runoff factor. Many factors could explain this difference like:

- the effluent component of the runoff actually varying during the storm event,
- the antecedent moisture conditions,
- the rainfall locality, intensity and duration,
- assumptions made in determining the runoff factor.

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The order of magnitude comparison however gives confidence in the method adopted and of the results obtained.

From a water quality point of view, a greater reduction in EC was expected during the rain event. It must however be remembered that water discharged during the event included an effluent component as well. By 2005, this component should not be included any longer. The expected EC values could therefore be lower than the values currently experienced. A value of EC = 80 to 90 mS/m is therefore not impossible.

Storm Event 2

Rainfall started on 31 May 2002 at 00:24.
Total amount of precipitation of the event was 37.5 mm.
Period during which rain fell approximately 23.5 hours.
Therefore, the total volume of rainfall onto the western catchment amounts to 425 544 m^3.
Using a runoff factor of 0.36, this amounts to an estimated runoff volume of 153 196 m^3.

The following table presents a summary of the times, flows, volumes and EC values associated with this storm runoff:

Table 22: Summary of Storm Event 2

Description	Date	Time	Rain (mm)	Flow in Canal (m^3/h)	Stormflow Volume (m^3)	EC (mS/m)
Rainfall started	31/05/02	00:24	0			
Runoff started	31/05/02	04:09		888	0	126
Peak of First Hydrograph	31/05/02	09:30		3323	5351	110
End of First Hydrograph	31/05/02	11:24		2197	3061	105
Peak of Second Hydrograph	31/05/02	13:19		13047	11326	88
End of Second Hydrograph	31/05/02	15:36		6109	18631	89
Peak of Third Hydrograph	31/05/02	16:45		10906	9728	89
End of Third Hydrograph	31/05/02	20:11		5014	21223	89
Peak of Forth Hydrograph	31/05/02	22:51		16125	24700	89
Rainfall ended	31/05/02	23:58	37.5			
End of Forth Hydrograph	01/06/02	00:22		9285	16762	89
Peak of Fifth Hydrograph	01/06/02	01:08		10497	6983	88
End of Fifth Hydrograph	02/06/02	02:08		1701	87431	120
Total Flow Volume during Storm Event					205197	

The graph of this hydrograph in **Appendix 9** shows the runoff hydrographs from the various sub-catchments within the western catchment very clearly. Again the discharge hydrograph is composed of a number of hydrograph peaks, looking similar in shape to Storm Event 1. The lag time for this storm event amounted to approximately 3 hours and 35 minutes. The peak flow associated with the first hydrograph was 3323 m^3/h (0.92 m^3/s).

The EC value reduced from 126 mS/m at the start of the storm to about 88 mS/m during the second hydrograph. The EC then remained at this value for the duration of the runoff, and only increased to 120 mS/m at the end of the fifth hydrograph. The length of time for which the EC remained between 88 and 89 mS/m was almost 12 hours.

The total storm volume discharged from this rainfall event was approximately 205 197 m^3. This measured volume is approximately 34 % higher than the 153 196 m^3 determined utilising the total rainfall in the catchment and the area weighted runoff factor for the western catchment. The difference can be explained for the same reasons than listed above. It must be remembered that this rainfall event consisted of a higher rain depth and occurred over a longer period than Storm Event 1. When back calculation is done, the run-off factor must have been approximately 0.48 in comparison to the average of 0.36 used. Even this factor is well within the range of the accuracy of the method applied (i.e. averages for all rain events any time of the year).

<u>*Storm Event 3*</u>

Rainfall started on 13 June 2002 at 18:29
Total amount of precipitation of the event was 21 mm.
Period during which rain fell approximately 5 hours.
Therefore, the total volume of rainfall onto the western catchment amounts to 250 320 m^3.
Using a runoff factor of 0.36 amounts to a runoff volume of 90 115 m^3.

The following table presents a summary of the times, flows, volumes and EC values associated with this storm runoff:

The lag time between the start of the rainfall and the runoff response was approximately 71 minutes. While the rainfall event lasted approximately 7 hours, the runoff lasted about 26 hours. The runoff volume for the event was about 34 231 m^3. This value is about a third of the estimated 90 115 m^3. This relationship is different to the previous two storm events, where the volume obtained from the monitoring system was greater than that estimated utilising the total rainfall in catchment and the area weighted runoff factor. It is quite possible that the rainfall for

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this event was localised for only a part of the site, therefore resulting in an over estimation when calculating the run-off from an averaged discharge factor.

Table 23: Summary of Storm Event 3

Description	Date	Time	Rain (mm)	Flow in Canal (m^3/h)	Stormflow Volume (m^3)	EC (mS/m)
Rainfall started	13/06/02	18:29	0			
Runoff started	13/06/02	19:40		1062	0	136
Peak of First Hydrograph	13/06/02	21:34		6260	4279	111
End of First Hydrograph	13/06/02	21:57		5934	1882	105
Peak of Second Hydrograph	13/06/02	20:43		8566	4995	104
Rainfall ended	14/06/02	01:33	21.0			
End of Second Hydrograph	14/06/02	02:09		1851	8526	101
Peak of Third Hydrograph	14/06/02	05:35		2814	3444	100
End of Third Hydrograph	14/06/02	10:55		882	4318	97
Peak of Forth Hydrograph	14/06/02	12:04		2279	556	96
End of Forth Hydrograph	14/06/02	17:01		1264	3228	113
Peak of Fifth Hydrograph	14/06/02	19:19		2360	1603	113
End of Fifth Hydrograph	14/06/02	20:50		1605	1401	114
Total Flow Volume during Storm Event					34231	

The hydrographs for this storm event are not all evident, as with the previous two storm events. The first hydrograph has a peak of 8 566 m^3/h, while the second largest hydrograph peak after this one is just more than half of this value. This set of hydrographs, together with the monitored volume being significantly lower than the estimated runoff volume suggest that rainfall did not fall over the entire site, but that the rainfall fell predominantly within the one sub-catchment associated with the highest peak runoff and storm volume.

The EC value during this storm event decreased by almost 30 % from 136 mS/m to 96 mS/m. This phenomenon illustrates how the water quality improves during a storm event. The water licence WQO for EC at the western discharge is 170 mS/m.

Storm Event 4

Rainfall started on 27 August 2002 at 14:31

Total amount of precipitation of the event was 14.75 mm.

Period during which rain fell approximately 12.5 hours.

Therefore, the total volume of rainfall onto the western catchment amounts to 175 820 m^3.

Using a runoff factor of 0.36 amounts to a runoff volume of 63 295 m^3.

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The following table presents a summary of the times, flows, volumes and EC values associated with this storm runoff:

Table 24: Summary of Storm Event 4

Description	Date	Time	Rain (mm)	Flow in Canal (m^3/h)	Stormflow Volume (m^3)	EC (mS/m)
Rainfall started	27/08/02	14:31	0			
Runoff started	27/08/02	16:58		1306	0	130
Peak of First Hydrograph	27/08/02	19:16		1826	1350	128
End of First Hydrograph	27/08/02	20:19		1159	1254	130
Peak of Second Hydrograph	28/08/02	00:59		6009	6078	120
Rainfall ended	28/08/02	03:00	14.75			
End of Second Hydrograph	28/08/02	04:02		1331	3397	122
Peak of Third Hydrograph	28/08/02	05:33		1719	885	123
End of Third Hydrograph	28/08/02	05:56		1543	207	122
Peak of Forth Hydrograph	28/08/02	06:19		1825	314	121
End of Forth Hydrograph	28/08/02	08:37		1194	731	91
Peak of Fifth Hydrograph	28/08/02	10:08		1744	816	91
End of Fifth Hydrograph	28/08/02	12:48		1362	1345	107
Total Flow Volume during Storm Event					16378	

This storm event has similar characteristics to the previous one (Storm Event 3). The second hydrograph was significantly larger than any of the other hydrographs, indicating again that the rainfall fell predominantly within one of the sub-catchments of the IVS Works. The runoff volume for the event was about 16 378 m^3. This value amounts to only 18 % of the estimated 90 115 m^3. The highest peak flow of just more than 6000 m^3/h was associated with the second hydrograph. This peak occurred about 10.5 hours after the rainfall started, although the rainfall did stop between 14:44 and 22:00 on 27 August 2002.

The reduction in EC values for this event is not as evident as for the other three events analysed. Reason for this could likely be that the percentage stormwater runoff discharged to the amount of effluent discharged was low. Disregarding the first few millimetres of rainfall, the storm predominantly fell over a period of about 4 hours with discharge predominantly taking place over some 6 hour period. This amounts to an average discharge rate of 2 700 m^3/h of which about 40% could have been effluent discharge (at 1000 m^3/h on average). If for this scenario the EC of the effluent is taken as 150 mS/m (as before the storm event), this means that to arrive at a mixed EC of 120 mS/m, the stormwater runoff EC value must have been 108 mS/m. It is unexplained why the EC value dropped to 90 for a while after the runoff event and then to 30 for a low peak.

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Summary of the Storm Event Analysis:

In summary of the events analysed, the following comparative table has been compiled:

Table 25: Summary of the Four Storm Events

Event	Date	Rainfall Depth (mm)	Rainfall Duration (hr & min)	Lag Time (hr & min)	Peak Flow (m^3/h)	Estimated Runoff (m^3)
1	22 May 2002	9.5	5 hr 57 min	21 min	7680	46621
2	31 May 2002	37.5	19 hr 49 min	3 hr 35 min	16125	205197
3	13 Jun 2002	21.0	7 hr 4 min	1 hr 11 min	8566	34231
4	27 Aug 2002	14.75	12 hr 29 min	2 hr 27 min	6009	16378
Average			**11 hr 20 min**	**1 hr 53 min**		

From the data presented, it can be seen that every storm event is unique and that there are many parameters that could influence the shape of the discharge hydrograph. However, it can also be seen that the quality of water definitely improves during a storm run-off event. The discharge water quality is difficult to judge from the available data, however an EC value of 80 mS/m is not unreasonable. The actual values will however only be known after 2005, when the effluent component of the discharge water will be measurable.

A further water sample analysis from the continuous sampler was done for water quality corresponding to the discharge during a storm run-off event. The data relates to Storm Event 2.

Table 26: Water Quality Parameters during Storm Event 2

Date & Time	pH	EC	F	Cn	Cl	NH_4	Mn	Phenols	SO_4	NO_3	Na	COD
31-05-02 22:50	8.6	89	2.3	0.03	22.0	2.1	0.018	0	118.7	19.5	5.5	2.7

Consider the matter of uncontaminated surface water discharge from the site. When the principle is accepted that no unpolluted water should be held back by the Works, the impact of such principle objective is dependant to a large extent on the level at which contaminated runoff is being defined. Let's assume for the moment that only EC is considered as determining factor to decide on whether runoff water is contaminated or not. As can be seen from the above, it is difficult to judge what the EC water quality for runoff water would be post 2005. It was also stated that an EC value of 80 to 90 mS/m would not be unrealistic for storm water runoff from the site at that stage.

Let's take the criteria of EC = 100 mS/m as the definition split between contaminated and uncontaminated water. In the case Storm Event 2, analysed above, approximately 156 000 m^3

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of uncontaminated water could be released. If however the split is made at EC = 90 mS/m, about 139 600 m^3 could be discharged. If the criteria was 85 mS/m then no water could be discharged.

The conclusion reached from the data analysed therefore suggests that the Water Quality Objective set for discharge of uncontaminated water is extremely inelastic. This means that an objective set within the range of a few mS/m mean that either a significant amount, or nothing at all of the rainfall runoff can be discharged from the site.

The data presented herein and analysed for only one year of operation is admittedly insufficient to provide good guidance as to what the discharge standard objective should be post ZED. It is therefore recommended that monitoring of rainfall events and runoffs are continued with until ZED and thereafter. Only then can achievable long term objectives be determined.

In the mean time, a discharge standard of EC = 170 mS/m seems to be well into reach as a discharge standard for uncontaminated stormwater runoff.

Water Quality

Where the previous section focussed on getting an understanding of the quantity of water discharged from the Western catchment, this section is aimed to do the same for water quality aspects from the discharge.

The water quality data obtained from the three monitoring programs at the western discharge is within this section evaluated against the licence requirements.

Water Licence Requirements

The water licence of IVS requires a water quality monitoring point to be situated "at the bridge on the Golden Highway where it crosses the concrete lined channel to the Rietkuilspruit". The existing flow monitoring point linked to AH4 is situated at this point in the channel. The licence specifies that this water "must be monitored by taking 24-hour composite samples at the monitoring point described". The variables that are to be analysed in these 24-hour composite samples, in accordance with the water licence, are:

- pH;
- Electrical conductivity;
- Sulphates;
- Chlorides;

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- Sodium;
- Suspended solids;
- Ammonia;
- Nitrates and nitrites;
- Manganese;
- Total phenolic compounds;
- Iron
- Fluorides;
- Phosphates;
- Magnesium;
- Total chromium;
- Zinc;
- Tin; and
- Soaps, oil and grease.

The water quality monitoring results must be submitted monthly to the Regional Director within one month after the close of the period.

Water Quality Objectives

The WQOs for this discharge point are contained in **Table 27**. The WQOs contained in the current water licence are listed in the third column of this table. Also provided in this table are the water quality requirements stipulated in the Preliminary Reserve and Resource Class Determination, the WQOs of the expired water permit, as well as the SADWS MGV and MAV concentrations. These additional values are provided for reference and comparison purposes.

A more comprehensive table with additional South African and international water quality requirements for a wide range of water quality parameters is contained in **Appendix 2**. This more comprehensive table was reviewed in **Section 2.3.4**.

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Table 27: Summary of WQOs, Regulations and Guidelines for Western Catchment

Water Quality Parameter	Units	Water Licence: 10016047 (current)	Preliminary Reserve & Class: C22J	Permit Exemption: 1998B (expired)	SADWS: Maximum Guideline Value	SADWS: Maximum Acceptable Value
Chlorides	mg/l	300	200	350 (250)*2	250	600
Electrical Conductivity	mS/m	180 (170)*1	154 *3	190	70	300
Iron	mg/l	0.3		0.1	0.1	1.0
Manganese	mg/l	0.4		0.4	0.05	1.0
Nitrates & Nitrites	mg/l	5		5	11	19
Sodium	mg/l	110 (100)*1	166	130	100	400
Sulphates	mg/l	300	360	300	200	600
Total Ammonia	mg/l	10	< 0.1	10	1	2
Calcium	mg/l	160	80		150	200
Potassium	mg/l	46	46		200	400
Magnesium	mg/l	40	17		70	100
Phenolic compounds	mg/l	0.1			5	10
Suspended Solids	mg/l	25				
Oil	mg/l	2.5				
Total Chromium	mg/l	0.5			0.01	0.02
Zinc	mg/l	5			1	5
Soluble Orthophosphate	mg/l	1.0	< 0.1			
Tin	mg/l	1.0				
Fluoride	mg/l	2.5		2	1	1.5
Dissolved Oxygen	%		94		100	100
Nitrogen / Phosphorus	ratio		36			

KEY:

*1: denotes that the WQO was reduced to the value in brackets after 1 July 2002.

*2: denotes that the WQO was reduced to the value in brackets after 31 December 2001.

*3: this value was specified as a TDS 0f 1000 mg/l in the Preliminary Reserve and Resource Class Determination – Quaternary Catchment C22J.

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Before the water quality results are evaluated, an understanding of the monitoring infrastructure at the western discharge point is required.

Description of Monitoring Infrastructure

The required monitoring position in the Rietspruit canal, before it passes under the Golden Highway, is the primary compliance point for IVS in terms of surface water quality and quantity. At this point, three methods of monitoring that are utilised by IVS in this canal. These are:

- the continuous analyser (AH4);
- the continuous sampler; and
- the taking of grab samples in the Rietspruit canal at point RS7.

The data obtained from these three methods of monitoring will be reviewed individually and then integrally, in this section.

Analysis House 4

The continuous analysing house situated adjacent to the Rietspruit canal, where this canal passes under the Golden Highway, will be reviewed first. This monitoring facility is termed Analysis House 4 (AH4). The position of this analysing house is provided in the following table:

Table 28: Position of AH4

	Local Grid		L.O. 29 Grid	
	X	Y	X	Y
Analysis House 4	-120.497	2817.363	-79,478.35	2,950,316.86

The water quality data obtained from this analysing house is utilised primarily for water management purposes within the IVS site, since the data is not required or utilised for reporting purposes to the regulating authority (DWAF). The variables that are analysed in this canal, for which continuous data is available, are listed in the following table:

Table 29: Water Quality Parameters analysed at AH4 4

EC	pH	COD	Cl	SO_4	Cn	Na	F	NH_4	NO_3	Mn

Water is abstracted from the canal adjacent to the analysing house, and pumped to a settling tank on the roof of the analysing house. The water is abstracted from the water surface by means of a float mechanism to limit the entrance of sediment into the system. Filters are fitted at the pipe inlet in the canal, at the pump inlet, and at the inlet to the settling tank (three filters in

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series). From the roof top reservoir, water gravitates down into the analysing system from where water enters the various analysers. Water that is not utilised for the purposes of analysis enters a drain, which returns the water to the canal. A pump circulates the water on a continuous basis. **Table 30** describes the equipment that is utilised to analyse the different variables that are analysed at AH4.

Table 30: Variables Analysed and Analysing Equipment Utilised at AH4

Variables Analysed	Analysing Equipment
pH, EC	Foxboro Analyser
F, SO_4, NO_3, NH_3, Phenol, Cn, Cl, Na, Mn	Tytronics Sentinel meters

There are two types of Tytronics Sentinel meters, being probe analysers and colormetric analysers. Probe analysers utilise a reference probe and a measuring electrode to measure fluorides, chlorides, nitrates and sodium. Colormetric analysers are utilised to analyse phenol, manganese, ammonia, sulphates and cyanide. All meters are calibrated on a daily basis. The analysers are calibrated according to standard solutions with an accuracy of 95%. Buckman Laboratories prepare the standard solutions used for calibration purposes.

Outsourced personnel permanently on site (Anysico) maintain this analysing house. Personnel are available on a 24-hour callout for system emergencies. Their responsibility is to provide a 4-20 mA signal into the radio communication system for data transfer to the Energy Control Centre. The radio communication is the responsibility of the Instrumentation and Control Department of IVS. The continuous analyser provides half-hourly average water qualities to the ECC, the data which is also used for this report. There are therefore 48 water quality values recorded for each parameter measured for each day.

Continuous Sampler

In accordance with the requirements of the water licence, a continuous sampler is positioned in the Rietspruit canal. The composite sample obtained is analysed in the IVS laboratory and the results of the daily analysis are reported to DWAF on a monthly basis. Data is available for the following parameters:

Total Hard	NO_3	Total Alk.	PH	Cl	SO_4	EC	SS	F	Cn	NH_3	P
Ca Hard	NO_2	Phenol	Mn	Na	Fe	Zn	$KMnO_4$	Oil	Sn	Cr	K

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The equivalent statistical value (maximum, x-percentile, median or minimum) from the continuous sampler is generally different to the value obtained from the continuous analyser, due to the different method of sampling.

The sampling method used by the continuous sampler comprises of a daily composite sample, which is obtained by means of extracting a sample, that is representative of the entire day's flow. The sample therefore represents an average water quality for the day. The intake of water into the continuous sampler is done at set time intervals, and is therefore not linked proportionally to the discharge volume. The resultant sample is analysed in the laboratory on a daily basis.

Grab Sampling Point RS7

Water quality is monitored downstream of the continuous sampling position in the Rietspruit canal by means of a weekly grab sample. This sampling point forms part of the programme aimed at monitoring the receiving environment in the western catchment. Although this sampling point is situated outside of the Works, no other sources of water enter (or are extracted from) the canal between where it exits the site and this point. The water sampled at this point is therefore the same water that exited the site. This monitoring point is termed RS7 (see **Figure 1**), and is one of the eleven grab sampling points in the western catchment receiving environment.

The following parameters are analysed for in these grab samples;

pH	EC	Ca	Mg	Na	K	MAlk	Cl	SO_4	NO_3	F	Fe	Mn	NH_3	Cr	Cn	NO_2	PO_4	Zn

The difference in the results of this monitoring point and the continuous sampler is attributed to the difference in the sampling frequency and method. The continuous sampler results comprise of daily composite samples, i.e. an average water quality for the day. The RS7 grab sample is an instantaneous grab sample taken on a weekly basis and only represents the water quality at that specific point in time.

Data Obtained

The maximum, 95-percentile, median, 10-percentile and minimum concentrations for the various parameters have been determined where possible. The maximum and minimum values provide an indication of the total spread of the data set. The 95-percentile and median values are often utilised as statistical compliance criteria for water quality because these values provide a representative indication of the water quality data set over time. An average value can be distorted by outliers (high or low), and the maximum and minimum values on their own are not representative of water quality over time – especially when such a large amount of data is available.

The grab sample analysis results for RS7 have been plotted on the same set of axes as the SADWS MGV and MAV, together with the water licence WQO in **Appendix 5**. Also provided in this appendix are tables providing the grab sampling analysis results, as well as the annual maximum, 95-percentile, median and minimum values. No monthly maximum, 95-percentile, median and minimum values have been determined for the RS7 data since insufficient data exists to perform a statistical analysis on. A minimum of 20 values would be required to determine the 95-percentile, and a maximum of five values exists for any month, since weekly grab samples only are taken at this point.

The monthly tables containing the continuous sampler data are provided in **Appendix 6**. Also presented in this appendix are tables and graphs of the maximum, 95-percentile, median and minimum monthly concentrations of the various parameters analysed. On the same set of axes as the box and whisker graphs, the SADWS MGV and MAV, and the WQOs have been plotted. The WQO line indicates the concentration that, if exceeded, constitutes a non-compliance incident when reporting to DWAF.

Tables and graphs of the maximum, 95-percentile, median and 10-percentile monthly concentrations of the various parameters analysed at AH4 are contained in **Appendix 7**. The statistical summary values were determined from the AH4 continuous analyser data set, which comprises of average values for every half-hour for the year of analysis for each of the water quality parameters. Forty-eight values are therefore available for each parameter in the AH4 data set for each of the days in the year of analysis. The SADWS MGV and MAV, and the WQOs have been plotted on the same set of axes as the box and whisker plots.

Each of the parameters analysed for will now be discussed in more detail:

pH

The pH of water does not have a direct consequence on water quality except in extreme situations. The adverse effects of pH result from the solubilisation of toxic heavy metals and the pronation or depronation of other ions.

When reviewing the continuous sampler, AH4 and RS7 data it is evident that the water in the canal is generally slightly alkaline. The maximum, 95-percentile, median, 10-percentile and minimum pH values are relatively stable in the canal, with a few outliers in the AH4 data set (July, August, November 2001 and February 2002). These outliers seem to be attributable to data errors since this data is not consistent with the other parameter data. No WQO is specified in the water licence for pH. The SADWS maximum guideline upper and lower values for pH are 9 and 6 respectively, while the maximum acceptable values are 9.5 and 5.5 respectively.

In conclusion therefore, it seems that the works has no difficulty in keeping the pH value of water discharged within the limits set within the WQOs of the water licence.

Electrical Conductivity

The EC of water is widely used to indicate the total ionised constituents of water. It is directly related to the sum of the cations (or anions), as determined chemically, and is closely correlated in general with the total salt concentration. EC, measured in mS/m, is related to TDS, measured in mg/l. The conversion ratio between the two parameters typically ranges between 5.5 and 7.5. After examining various analyses within the Works, this value was taken to be 6.5 for the IVS site. EC is a rapid and reasonably accurate determination, and values are expressed at a standard temperature of 25 °C to enable the comparison of readings taken under varying climatic conditions. The dominant water quality parameters comprising the salts in the water are chlorides, sulphates, sodium, calcium, magnesium, nitrates and potassium.

For analysis of the RS7 data, refer to **Appendix 5**. When reviewing the data it is evident that the WQO of 190 mS/m was exceeded in four of the thirty-six samples. (The 190 mS/m refers to the WQO as specified in the Permit Exemption 1998B, which was valid to the end of 2001. Subsequently, this value was lowered to 180 mS/m until 30 June 2002 where after it became 170 mS/m as specified in the current Water Licence: 10016047). This means that 89% of the grab samples at RS7 fell inside of the WQOs for the Rietspruit canal outlet and 11% outside. The highest EC value in the grab sample data set is 218 mS/m, and the median is 155.9 mS/m.

For analysis of the continuous sampler data, refer **Appendix 6**. The figure shows a box and whisker plot of the minimum, median, 95 percentile and maximum average monthly data set available for the review period (each month's data therefore represents a summary of 30 or 31 laboratory analysed water sample results). SADWS limits (70 and 300 mS/m) and WQOs (190 going down to 180 mS/m) are also indicated for reference purposes.

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The continuous sampler data shows that the highest EC value during the year of analysis was 229 mS/m. This value corresponds well to the RS7 results. The 95-percentile value ranges from 150.9 mS/m to 221.6 mS/m, and this statistical value exceeds the WQO during three months of the year of analysis. Occurrences of exceedance all happened towards the beginning of the review period and a downward trend in the values towards the end of the year can be noted.

For analysis of the continuous analyser data, refer to figure **Appendix 7**. The figure shows a box and whisker plot of the minimum, median, 95 percentile and maximum average monthly data set available for the review period (each month's data represents a summary of all the half hourly results and therefore represents some 1440 readings each). SADWS limits (70 and 300 mS/m) and WQOs (190 going down to 180 mS/m) are also indicated for reference purposes.

The AH4 data provides higher maximum values, due largely to the significantly larger data set than that of the continuous sampler. The 95-percentile value exceeds the WQO during half of the months in the year of analysis, although it exceeded the quality limits only marginally during September and October 2001.

All three data sets indicate that during the months of January and February 2002 the EC is significantly lower than the previous ten months. Even the maximum EC values from the AH4 data set are well below the new water licence WQO value of 180 mS/m.

In conclusion therefore, it can be stated that with respect to EC values for water discharged, the water quality has been close to the limit of the WQO objectives set for the western discharge, but that an improvement of quality towards the end of the review period has been noticed. The datasets however indicates that it will be possible for the works to keep its discharge water quality (EC only in this case) below the WQO set for discharge until ZED in 2005.

Chemical Oxygen Demand

The Chemical Oxygen Demand (COD) test is used to estimate the amount of organic matter in the water. The COD is the amount of oxygen required to degrade the organic compounds of within the water. COD is only monitored by the continuous analyser at AH4. COD is not a required monitoring element specified by the Water Licence: 10016047, nor are there limits set for COD in terms of SADWS. The GN R991 Regulations specify a general standard of 75 mg/l.

The 95-percentile monthly COD concentration ranges considerably from zero to about 120 mg/l, but is below 85 mg/l for eleven of the twelve months under review. The highest monthly median value is 37.7 mg/l.

In conclusion therefore, it can be stated that with regard to COD, the works should be able to keep the values below the 75 mg/l limit for most of the time (95 percentile) until effluent discharge is eliminated with ZED in 2005.

Cyanide

The concentration of cyanide in the Rietspruit canal is not specified in the IVS water licence. The SADWS MGV for cyanide is 0.2 mg/l, and the MAL is 0.3 mg/l.

Cyanide was not analysed for at RS7 before August 2001. The highest cyanide concentration recorded at the RS7 grab sampling point after this date was 0.09 mg/l, which falls within the SAWDS MGV limit as stated above.

Cyanide concentrations as measured by the continuous sampler also indicate that all 95 percentile values are well within the SADWS MGV value and therefore poses no problem.

The AH4 continuous analyser 95-percentile values are also consistently below 0.1 mg/l, with the exception of June 2001 where the value reached 2.4 mg/l. A graph showing the data obtained from the continuous analyser for the month of June 2001 is attached in Appendix 6. The data shows that the values measured are inconsistent with the data recorded by the continuous sampler. Taking only the 2nd June 2001, the continuous analyser showed that the concentrations of Cyanide were above 1 mg/l for most of the day. However, analysis of the continuous sampler reported a value of 0.03 mg/l for the day.

The inconsistency of data reported is of major concern and efforts should be made to rectify the inconsistencies.

In conclusion therefore, it seems as if Cyanide concentrations can be kept well within the limits of SADWS by the works until seizure of effluent disposal to the canal in 2005. However, efforts should be made to ensure that the quality of water discharged to the canal is monitored accurate and that the confidence level of data is increased.

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Fluorides

The WQO specified in IVS's water permit that expired on 31 December 2001 is 2 mg/l. The current water licence, which is valid until June 2003, specifies a WQO of 2.5 mg/l. The dominant source of fluorides in the Rietspruit canal is the CETP.

The RS7 data indicates that fluoride levels were consistently higher than WQOs as specified in the water licence, even after the relaxation of the limit to 2.5 mg/l in January 2002. A maximum fluoride concentration in the water of 5.6 mg/l was measured during October 2001. Most of the data points however seem to fall between 2 and 3 mg/l with no exceedences after November 2001.

With reference to the continuous sampler, the data looks fairly constant with most of the months reporting 95-percentile values below 4 mg/l. The median values normally are below 3 mg/l. Higher Fluoride concentrations during the dry season are consistent with lower flows measured during the same months.

The continuous analyser data is shown in **Appendix 6**. The dataset shows similar results to those obtained by RS7 and the continuous sampler. Data typically ranges between 1.5 and 3 mg/l with the 95 percentile mostly below 4 mg/l.

In conclusion therefore, with reference to Fluorides, the works has difficulty to comply to a WQO of 2.5 mg/l and consistently exceeds this limit up to about 4 mg/l. Variability of the values however seems low. For more details on how IVS intends reducing the Fluoride levels until 2005, the reader is referred to the Process Water Specialist Report.

Chlorides

Chloride is a common constituent in water. It is highly soluble, and once in solution tends to accumulate. Chloride can only be removed from water by energy-intensive processes. At elevated concentrations chlorides impart a salty taste to water. The WQO for chlorides in the current licence is 300 mg/l, whereas in the previous water permit the value was 350 mg/l. The dominant sources of chlorides within the Works are the CETP, the demineralisation plant and the direct reduction plant.

With reference to Chloride levels reported from grab sample analysis at RS7, it seems that Chloride values typically vary between 200 and 350 mg/l with only three data points exceeding

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the set WQOs. It is important to note that since December 2001, Chloride levels did not exceed either the SADWS MAV or the WQO set at 300 mg/l.

Data obtained from the continuous sampler indicates values quite consistent with that found at RS7, with 95 percentile values typically below 400 mg/l for the first 6 months and below 300 mg/l for the second 6 months. Again, a decrease in Chloride values is evident towards the end of the year under investigation. Mean values were typically between 200 and 250 mg/l for the second 6 months of investigation.

Data obtained from the continuous analyser at AH4 shows Chloride values varying typically between 200 and 400 mg/l with the months September and December showing 95 percentile values up to 700 mg/l. This data show values inconsistent to the other months. For an analysis of the data, refer to the monthly summary data for the particular months under review.

The September graph shows that Chloride values exceeded the limit values significantly during the 1st and 2nd of the month. The detection limit for Chlorides is 700 mg/l, indicating that values might have been higher during the review period. The second exceedance occurred during the 16th and 17th of the month, however data for this period is limited. Not too much can therefore be said from this second occurrence. The exceedance during the 1st and 2nd is however inconsistent with the data obtained from the continuous sampler which reported values of 244 and 276 mg/l respectively. The data inconsistency poses a problem with the analysis and efforts should be made to rectify the inconsistency in data obtained.

When considering the month of December 2001, the data obtained from the continuous analyser shows many discrepancies and is of limited value. The period between the 11th and the 13th however is of concern and shows elevated Chloride levels above the 700 mg/l detection limit. The corresponding values obtained from the continuous sampler analysis are 211, 240 and 253 mg/l for the 11th, 12th and 13th respectively. This discrepancy again highlights the need to investigate the variation in values obtained from the different analysing methods.

In summary therefore, it seems that the works has the capability to keep the Chloride discharge concentrations in general within the specified WQOs until ZED in 2005, however, exceedances of the limit can be expected for short periods of time. An effort should be made to investigate the discrepancies between the continuous analyser and the continuous sampler data, which is of major concern.

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Nitrates, Nitrites and Ammonia

Nitrogen refers to all inorganic nitrogen forms present in water. Ammonia, ammonium, nitrates and nitrites are the most dominant forms of Nitrogen that exist in waters. In uncontaminated water the nitrate-nitrogen concentration is typically less than 2 mg/l as N. Nitrates and nitrites do not have any taste, colour or smell, and do not affect the colour of water. Nitrogen occurs predominantly as a nitrate in water, and the ammonium form is usually a result of a process effluent affecting the water. Nitrates, nitrites and ammonia emanate predominantly from Coke Ovens and Blast Furnaces. Both the expired water permit and the new water licence specify a WQO for nitrates and nitrites combined of 5 mg/l. Ammonia is restricted to a WQO of 10 mg/l. The SADWS MGV and MAV are 6 and 10 mg/l respectively.

A review of the Nitrate (NO_3) values measured at RS7 indicates that most of the values (86%) fall below the SADWS MGV. Nitrites (NO_2) indicate average values below 2 mg/l. Nitrites have only been analysed for since August 2002 and no combined value can be supplied before this date. The combined WQO for Nitrate and Nitrite is 5 mg/l and 71 % of the values comply with this limit.

As far as the continuous sampler is concerned, the combined values for Nitrate and Nitrites fall typically in the range of 5 mg/l (median values) and 9 mg/l (95 percentile). Values for N are therefore typically hovering at the WQO limit with 50% of the values typically above the WQO of 5 mg/l. This data is consistent with data obtained at RS7.

At the continuous analyser, only Nitrates are measured (not Nitrites). An evaluation of the data shows similar results to that obtained from the continuous sampler and the RS7 data. When evaluating the continuous analyser monthly data, it is evident that Nitrate levels are kept well below the 5 mg/l limit and typical values between 0 and 2 mg/l are encountered. However, occasional exceedance spikes in the values occur over short periods of time. Even if a typical Nitrite concentration of 1 mg/l (see RS7 data) is taken, the total N graph would still be within the 5 mg/l limit for most of the time.

In summary therefore with reference to Nitrogen it is evident that the works has difficulty in keeping N levels below the WQO. Periodic exceedances of the limit do occur as higher spikes over short periods of time. The WQO limit is however low when compared to the SADWS levels. For further information on how the works intends reducing the number of exceedances until ZED in 2005, the reader is referred to the process water specialist report.

As far as Ammonia is concerned, typical values vary between 0 and 7 mg/l for the RS7 measured point. This is below the water licence requirement of 10 mg/l. IVS only started monitoring Ammonia levels from August 2001 and therefore only 6 months of data is available.

With reference to the continuous sampler, Ammonia levels were typically below the WQO limit of 10 mg/l with exception of July 2001 where the 95 percentile went up to about 12 mg/l. Of significance is to note that the occurrence of WQO exceedance decreased significantly for the second half of the year. This can be ascribed to the construction of the Coke Ovens sump, which captures most of the Ammonia rich Coke Oven effluent during emergency situations.

Ammonia levels as measured by the continuous analyser shows similar results to that measured at RS7 and in the continuous sampler. Again, exceedances are linked to high spikes over short periods of time, and on average, the values reduced over the second half of the year.

In conclusion therefore, with respect to Ammonia levels, the works is able to keep within the ammonia level as stated by the WQOs since the construction of the Coke Oven sump and until ZED in 2005.

Manganese

Manganese originates predominantly from the CETP. Manganese is a metal micro-determinant, common in soils and often associated with water. This element is responsible for the dark tea-like colour of some water sources. The typical concentration of manganese in uncontaminated water is 0.001 to 0.2 mg/l. WQO set for effluent discharge to the Rietspruit canal is set at 0.4 mg/l, while the SADWS are 0.05 mg/l recommended and 1.0 mg/l maximum.

The RS7 data indicates that the manganese levels measured are typical between 0.05 and 0.4 mg/l with exceedances occurring in 14% of the cases.

Review of the continuous sampler indicates Manganese levels are typically below the 0.4 mg/l level but that during the months July, November and December this value was exceeded on various occasions.

When considering data obtained from the continuous analyser, 95 percentile values were typically within the 0.4 mg/l limit. This is inconsistent with the data obtained from the continuous sampler and RS7. Data obtained for January 2002 is particularly high and needs more evaluation.

Manganese levels reported were elevated during the period 10th to 12th January and again during 20th to 22nd. During the former period, Manganese levels up to 1 mg/l were encountered, while levels up to 5 mg/l were reported for the second period. Data from the continuous sampler recorded levels of 0.04 mg/l for the 10th, 0.29 mg/l for the 11th, 0.02 mg/l for the 20th and 0.01 mg/l for the 21st. This means that data reported for the first occurrence was probably correct while the second occurrence could have been an instrumentation problem at the continuous analyser.

In conclusion therefore with regards to Manganese, the works should be able to keep Manganese levels below the WQO limit of 0.4 mg/l until ZED in 2005.

Sulphates

Sulphate levels in unpolluted fresh water are typically less than 10 mg/l. Sulphates at elevated concentrations impart a distinctive bitter taste and rotten egg (H_2S) smell to the water. While the preliminary reserve and class determination for the quaternary catchment puts forward a water quality reserve for sulphates of 360 mg/l, the water licence WQO is 300 mg/l (the old permit exemption value was also 300 mg/l). Within the IVS Works the dominant source of sulphates is the CETP. Sulphates may also originate from Air Products, the Blast Furnace, Slag Granulation or the Vaal River intake water.

The RS7 data set indicates that Sulphate concentrations hover around the 300 mg/l level with typical values between 200 and 400 mg/l.

Data obtained from the continuous sampler indicates similar results with typically the median values below the WQO and the 95 percentile above.

Sulphate values obtained from the continuous analyser confirms the above results. Interesting to note is how the Sulphate values are managed within a range between 200 to 300 mg/l except from incidents where the values go up for a certain period, where after the values go down again to normal.

In conclusion therefore, with relation to Sulphates, the works seems to be able to keep levels below the WQQ level of 300 mg/l until ZED in 2005, except during process malfunction when Sulphate levels could increase up to 400 or 500 mg/l.

Sodium

Sodium is present in all food to varying degrees. Sodium is an essential dietary element needed to maintain the electrolyte balance in the body. The preliminary reserve determination water quality limit for sodium is 166 mg/l. The WQO for the Rietspruit canal was 130 mg/l during the permit exemption, reduced to 110 mg/l in the preliminary licence and reduced to 100 mg/l since July 2002 in the new water licence.

Data obtained from RS7 shows that Sodium is present in the effluent within a narrow range between 70 and 130 mg/l. All data samples analysed were within the WQOs limits.

The continuous sampler provides very similar results than point RS7, with the median at or below 100 mg/l and the 95 percentile within the WQOs limit.

The continuous analyser shows that the Sodium levels vary significantly during the day and values between 40 and 150 mg/l going up to 200 mg/l are generally encountered. The 2 day running average confirms the data obtained from the continuous sampler and RS7 analysis i.e. laying generally below the 100 mg/l mark. Due to the fact that the continuous sampler has an upper detection limit of 200 mg/l, it is difficult to estimate the maximum values to where the peaks go. If possible therefore, the upper detection limit for Sodium at the continuous analyser should be increased to about 400 mg/l, the SADWS – MAV for Sodium.

In conclusion therefore, with regard to Sodium, the works is able to keep the general trend of Sodium values below the WQO limit of 130 mg/l until ZED in 2005 when measured by the continuous sampler method. It must however be realised that values exceeding the limit will occur during the period of review.

Suspended Solids

The water licence WQO for suspended solids is 25 mg/l. This requirement was introduced into the water licence principally to limit the volume of sediments passing down the canal. The reason why this WQO was introduced is due to a concern that sediments emanating from the site may have adsorbed heavy metals, which may by these means be transported out of the site. Suspended solids in the water are largely removed at the TETP, although during wet weather flow conditions the water is diverted around the buffer dams and the water does not pass through the filters.

Suspended solids are not analysed for in the RS7 samples.

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Suspended solids analysed in the continuous sampler typically show values below 50 mg/l. with the exception of January and February 2002 where the values were higher. Suspended solids readings for January included three instances where the values were 274, 300 and 191 mg/l while all the other readings were below 50 mg/l. The dates on which the high values occurred coincide with high rainfall activity on the site, however other days where it rained show SS levels no higher than 11 mg/l. It is therefore inconclusive to state where the high levels detected originate from and further investigations during rain events should be performed.

The continuous analyser, due to its filtering system does not measure suspended solids.

In conclusion therefore, with regard to Suspended solids, it can be stated that the works can comply to a WQO of 25 mg/l under dry weather conditions (due to filtering at the TETP) but that this limit is likely to be exceeded during rain events. Infrastructure therefore needs to be put in place to be able to comply to the limit and the limit might need review in light of normal stormwater qualities that can be expected during rain events.

Phenol

Phenol is a colourless or white solid when it is pure. It is however usually sold and used as a liquid. It has a strong odour that is sickeningly sweet and irritating. It evaporates more slowly than water and dissolves fairly well in water. Phenol is usually found in the environment below 100 ppb, although much higher levels have been reported. The dominant source of phenols within the Works is the Coke Ovens. The WQO in the new water licence for phenolic compounds is 0.1 mg/l. No WQO was specified in the old permit exemption.

Phenol is not analysed for in the RS7 samples. Data from the continuous sampler indicates that phenol levels are commonly below 0.1 mg/l (95-percentile) except for the months of March and November 2001 when higher values were encountered. The month of November includes two occasions where Phenol levels were elevated for 4 and 3 days respectively. Phenol levels detected were up to 0.38 and 0.45 mg/l for the two incidents respectively. The continuous analyser does not monitor phenol levels.

In conclusion therefore, with respect to Phenols, it seems that the works is capable of keeping the phenol levels below the WQO of 0.1 mg/l, but that the necessary steps should be taken to ensure that incidents of high Phenol occurrence can be avoided.

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Phosphorus

The WQO for Phosphorus is set as 1 mg/l in the current water licence.

Phosphorus analysed from the RS7 samples indicate levels of Phosphorus typically at 0.05 mg/l, which is well below the WQO limit. Data obtained from the continuous sampler also shows values for Phosphorus of 0.1 mg/l, again well below the WQO limit. Phosphorus is not analysed for in the continuous analyser.

In conclusion therefore, with regard to Phosphorus, it seems that there is no problem with Phosphorus on the site and that levels are well below the WQO limit. It is recommended that Phosphorus be deleted from the list of variables to be tested as a requirement in the water licence.

Iron

The metallic element iron in its pure state is silvery-white, but iron usually appears brown or black in colour because of the oxidation of the surface of the metal. The reddish colour of soil is usually due to the presence of iron. The concentration of iron in uncontaminated fresh water ranges from 0.001 to 0.5 mg/l. Since most soils are iron-rich, its concentration in the soil solution is determined primarily by soil pH and soil aeration. The dominant sources of iron within the site are the CETP, Direct Reduction and Vaal River intake water. Being an iron and steel works, it goes without saying that iron concentrations throughout the works must certainly be high in dusts on surface. The WQO for iron in the current water licence limits its concentration in the canal to 0.3 mg/l. The old permit exemption specified a value that coincides with the SADWS MGV of 0.1 mg/l.

Water sample analysis from the RS7 samples indicate that Iron levels in waters typically range between 0 and 1 mg/l. More than half the samples lie above the WQO limit of 0.3 mg/l.

Data obtained from the continuous sampler indicate similar results to that of RS7 with values typically below 0.4 mg/l.

Even with the relaxation of the WQO in the new water licence, the works has difficulty in complying with the set WQO. The presence of iron in water is further discussed in the risk assessment section of this document and in the specialist reports for source characterisation and process water. No analysis of Iron is done in the continuous analyser.

In conclusion therefore, with regards to iron, the works has difficulty in complying with the current WQO of 0.3 mg/l until ZED in 2005.

Zinc

Zinc is an essential nutritional trace element for plants and animals. Zinc is also required for the proper functioning of the immune system. The concentration of zinc in uncontaminated fresh water is very low, typically approximately 0.015 mg/l. The SADWS MGV and MAV for zinc are 1 mg/l and 5 mg/l respectively. No WQO was specified for zinc in the old permit exemption, but the water licence specifies a WQO that coincides with the SADWS MGV of 5 mg/l.

Zinc values obtained from the RS7 samples indicate Zinc levels typically between 0 and 0.5 mg/l. The data analysed is fairly consistent and falls well under the WQO limit of 5 mg/l.

Samples analysed from the continuous sampler indicate similar Zinc levels typically below 0.5 mg/l except for March and April 2001 where the level was typically below 1.2 mg/l (95-percentile). The December analysis showed one level of 5.6 mg/l, which can not be explained. All the other data for December 2001 lies below 0.5 mg/l. Zinc is not analysed for at AH4.

In conclusion therefore, Zinc does not seem to be a problem at the works and the current WQO limit of 5.0 mg/l can easily be adhered to. It is recommended that Zinc be deleted from the list of water qualities to be tested in the water licence.

Oil

Oil is widely used in the works for lubrication purposes and in the mills process. Oily waters are treated at CETP before release to TETP. The WQO for Oil, specified in the water licence is 2.5 mg/l.

Oil is not analysed for in the RS7 samples. Results obtained from the continuous sampler for Oil indicates typical values below 2.5 mg/l (95 percentile) with mean values ranging between 0 and 1.1 mg/l. The continuous analyser does not analyse for oil.

In conclusion therefore, with regards to Oil, the works should be able to keep Oil levels below the WQO of 2.5 mg/l until ZED in 2005.

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Tin

The WQO for tin in the new water licence is 1 mg/l. Tin is used in producing Tin plate and the wastewater streams containing Tin are treated in CETP before they are sent to TETP for discharge.

Tin is not analysed for in the RS7 samples. Results from the continuous sampler show Tin levels typically below 0.6 mg/l (95 percentile), and within the WQO of 1 mg/l as specified in the water licence. The results for November 2001 however show Tin levels in excess of the WQO. On analysis of the daily data, one level of 2.3 mg/l and one of 1.2 mg/l were encountered. These values are unexplained. All the other data for the month was below 0.7 mg/l. Tin is not analysed for in the continuous analyser.

In conclusion therefore, with regards to Tin, the works should have no problems in keeping within the WQO limit of 1 mg/l until ZED in 2005.

Chromium

Chromium is mostly found in one of three valence forms. Chromium (III) occurs naturally in the environment, while Chromium (VI) and Chromium (0) are normally associated with industrial processes. The WQO specified in the new water licence for total Chromium is 0.5 mg/l. Chromium is used in the process to produce Chromadec sheeting and wastewater effluent from the process is treated in the CETP plant before it is sent to TETP for discharge to the canal.

Results obtained from analysis of the RS7 samples indicates a level of Chromium typically of 0 mg/l with some values reaching up to 0.2 mg/l. The levels are well below the WQO limit of 0.5 mg/l.

Chromium levels reported from samples obtained from the continuous sampler indicate typical Chromium values below 0.4 mg/l (95 percentile). These values report higher levels than the RS7 samples. The reason for this discrepancy might be that the RS7 sample is taken 2.5 km downstream from the outlet point of the canal and that Chromium has the tendency to adsorb to the soil particles whereby it would not reach the RS7 sampling point. All data values obtained from the continuous sampler except for one fell below the WQO limit of 0.5 mg/l. Very limited quantities of chromium was detected in samples analysed for during the months of December 2001, January of February 2002 (typically between 0 and 0.1 mg/l very occasionally).

Chromium is not analysed for in the continuous analyser.

In conclusion therefore, the works seems to be able to keep the Chromium concentrations under control and below the WQO limit of 0.5 mg/l until ZED in 2005.

Potassium

Potassium is an alkali metal, and is the main intracellular positive ion in living tissues. It is an essential dietary constituent. The concentration in uncontaminated fresh water is typically 2 to 5 mg/l. At elevated concentrations potassium imparts a bitter taste to water, but it does not affect either the smell or appearance of the water. The WQO for Potassium specified in the water licence is 46 mg/l. This limit is substantially lower than the SADWS MGV of 200 mg/l.

Potassium levels obtained from analysis of the RS7 samples indicate typical values between 0 and 50 mg/l. Potassium levels vary within a narrow band and were all below the WQO limit of 46 mg/l.

Potassium levels obtained from the continuous sampler provide similar results to that of the RS7 data with levels mostly below the WQO limit. Potassium is not analysed for in the continuous analyser.

In conclusion therefore, with regards to Potassium, the works seems to be able to control Potassium levels to below the WQO limit of 46 mg/l until ZED in 2005, even though this limit is very low compared to SADWS.

Total and Calcium Hardness

Total hardness is the sum of calcium and magnesium concentrations expressed in mg/l calcium carbonate ($CaCO_3$) and is calculated as follows:

Total Hardness = [2.497 x calcium (mg/l)] + [4.118 x magnesium (mg/l)]

The total hardness value indicates whether the water is soft or hard, and relates to the ease or difficulty of lathering of soap.

The water licence does not specify any limit for Total hardness, however Calcium and Magnesium levels are restricted to 160 and 40 mg/l respectively. The limit set for Magnesium is significantly stricter than the SADWS MGL of 70 mg/l.

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Calcium levels measured at the RS7 point indicate typical levels highly variable between 20 and 200 mg/l. Magnesium levels reported from RS7 vary in a narrow band between 20 and 50 mg/l and are usually kept below the WQO level of 40 mg/l. Data obtained during May and June 2001 indicate elevated levels of Magnesium of up to 200 mg/l. The cause of this however seems to have been resolved since.

The continuous sampler analysis is done for Total Hardness and Calcium Hardness only. Total Hardness values typically range between 350 and 550 mg/l (95-percentile). If the calculation for Total Hardness is done on the WQO limits for Calcium and Magnesium, a value of 564 mg/l should be the limit for Total Hardness. The works seems to be able to keep Total Hardness values within this limit. Total Hardness is not analysed for in the continuous analyser.

In conclusion therefore, with regards to Total Hardness, no WQO has been set. The calculated value of 564 mg/l however indicates that the works should be able to control Total Hardness below this limit. Regarding the components of Total Hardness individually, it seems that the works has difficulty in complying to the WQO of 160 mg/l for calcium while it can comply to a relatively strict WQO set for Magnesium at 40 mg/l.

It is recommended that in future either the Total Hardness be limited in the water licence and the analysis been done therefore, or that the WQO limits for Ca and Mg be reviewed and all analysis been done for the two components individually.

Total Alkalinity and Potassium Permanganate

Both these elements are being analysed for in the continuous sampler, however neither of them are required for water licence requirements and no standards have been set in terms of WQOs. The data obtained is however shown on the graphs in Appendix 6.

In conclusion therefore, with regards to Total Alkalinity and Potassium Permanganate, there are no WQOs to which the works should comply and therefore, unless there is good reason for analysis of these two elements, it is recommended that they are deleted from the list of parameters to be analysed for.

Eastern Discharge

The surface area of the eastern catchment of the IVS Works is approximately 4.19 km^2. This eastern portion of the Works area drains into the Leeuspruit catchment, which is described in **Section 2.2.4**. In evaluating the eastern catchment of the IVS Works, it is essential to initially

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identify the sources of surface water within this portion of the site that report to the Eastern Discharge point as the Frikkie Meyer weir.

Sources of Water Runoff

The areas from where stormwater runs off to eastern catchment include the North Works, the Steelserv area, Hecketts South and the Leeuspruit open veld area including the marshy area at upstream from the Frikkie Meyer weir. The volumes of surface water reporting to the eastern catchment will be evaluated first, where after a review of the water qualities associated with these waters will be done.

Water Quantity

The single discharge point from the eastern portion of the IVS Works area is the Frikkie Meyer weir. The water released from the works at this discharge point is limited to stormwater emanating from the eastern catchment.

Before the infrastructure and management of the eastern catchment discharge point is discussed, it is necessary to understand the rainfall hydrology for the area, which is herewith discussed.

Rainfall Volume

The total rainfall that fell on the eastern catchment during the year of analysis was approximately 860.3 mm (refer to **Section 2.1.2**). This is the average depth of rainfall as measured by the continuous and daily stations on the site. The eastern catchment is approximately 4.19 km^2 in area. This means that approximately 3.6 million m^3 of rainfall fell within the eastern catchment during the period March 2001 to February 2002.

Runoff Volume

Utilising the total rainfall that fell within the eastern catchment of the site, together with the runoff factor for this catchment, the runoff volume associated with this catchment can be estimated. The following table presents the calculation of the area weighted runoff factor "C" for the eastern catchment of the IVS Works. The following factors were utilised in determining the "C" factor:

- C_s: Average catchment slope;
- C_p: Permeability of the surfaces; and
- C_v: Vegetation.

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The "C" factor for each sub-area was then multiplied by that area's surface area, and divided by the total area to provide the area weighted "C' " for each sub-area.

Table 31: Area Weighted Runoff Factor "C"

Area Description	Surface Area (ha)	Cs	Cp	Cv	C	C'
North Works	2172994	0.03	0.21	0.23	0.47	0.24
Hecketts South	535314	0.03	0.04	0.04	0.11	0.01
Leeuspruit Sump	418766	0.03	0.06	0.06	0.15	0.01
Training Grounds	462947	0.03	0.15	0.15	0.33	0.04
Leeuspruit Vlei Area	603446	0.03	0.04	0.04	0.11	0.02
Total Area :	**4193467**				**Area Weighted "C" :**	**0.32**

Utilising this runoff factor an estimation was made of the runoff volume that was discharged to the eastern catchment discharge point during the year of analysis. The volume of runoff calculated for the eastern catchment for the year of analysis, as a result of precipitation was approximately 1 153 356 m^3. A comparison between this figure and the discharge volume measured is done hereinafter as well as a statistical comparison with the return period calculation.

Peak Flow Events

Peak flow events have been determined for the eastern catchment of IVS, and are contained in **Table 32**. Three methods were utilised for determining the peak flow from the eastern catchment of the site, namely the rational, empirical deterministic and unit hydrograph methods. These methods were subsequently compared and found to be in the same order of magnitude. An average between the various values for their respective return periods was then determined, and is also provided in the table.

Table 32: Peak Flow Event for Various Return Periods at Frikkie Meyer Weir (m^3/s)

Return period	Rational Method	Empirical Deterministic	Unit Hydrograph	Average
1:100	45.4	43.1	41.7	43.4
1:50	37.3	34.2	30.6	34.0
1:20	33.5	24.4	20.8	26.2
1:10	21.6	21.2	14.4	19.0
1:5	19.3	-	11.6	15.4
1:2	11.6	-	5.1	8.3

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Stormflow Volume

The peak flow calculation is usually utilised for the design of water management infrastructure. The volume of water discharged is however also of critical importance to this study. These volumes have been determined utilising the unit hydrograph method, and the results are summarised in **Table 33**. The bold underlined values indicate the critical storm duration for each of the return periods, i.e. the storm duration that is associated with each peak flow event. The peak flow is therefore not associated with the 24-hour storm, which has the largest stormflow volume, but with the half or one hour duration storms.

Table 33: Storm Volumes determined utilising Unit Hydrograph Method (m^3)

Return Period	0.5 hr storm	1 hr storm	2 hr storm	4 hr storm	24 hr storm
1:100	116,429	**202,827**	248,616	290,294	594,495
1:50	90,317	**149,209**	205,344	250,040	445,124
1:20	67,505	**101,041**	137,799	165,984	337,638
1:10	**49,127**	64,026	82,358	106,209	262,176
1:5	35,853	**56,429**	70,175	89,766	172,026
1:2	15,725	**24,633**	30,198	34,888	73,306

The storm volumes can be utilised to determine the storage capacity of a facility that would capture a specific storm, for example capturing the 24-hour 1:100 year flood would require a dam with holding capacity of 594 495m^3.

The requirements of IVS's water licence will now be reviewed in terms of the requirements appertaining to water quantity discharge, monitoring and management in the eastern catchment.

Water Licence Requirements

Clause 7.1.2.1 of the Exemption Permit 1998B requires that the flow volume be monitored in the Leeuspruit on the western side of the culverts that pass under Frikkie Meyer Boulevard. The Frikkie Meyer weir was constructed to meet this requirement. This water exemption permit has subsequently expired and a new water licence has been issued to IVS (see **Appendix 1**).

In terms of the volume of water that may pass over the Frikkie Meyer weir, the current water licence specifies that "no wastewater, polluted stormwater or seepage" may leave the Licensee's premises via the Frikkie Meyer weir into the Leeuspruit. This licence specifies that wastewater, polluted stormwater runoff and seepage from the eastern part of the Licensee's property must be discharged into the Rietkuilspruit via a canal after treatment and in compliance with the Rietspruit canal WQOs.

The licence does however authorise the discharge of uncontaminated stormwater into the Leeuspruit via the Frikkie Meyer weir. This licence however states that this discharge must include only water that exceeds the 1:100 year storm event. To this end the new water licence specifies that "collection and containment systems must be designed in such a way as to contain polluted stormwater that might result from a storm event of 1:100 years over a 24-hour period". This infrastructure is not currently in place.

A more detailed description of the infrastructure within the eastern catchment that is utilised for the management and/or monitoring of surface water will now be given.

Infrastructure in Leeuspruit Area

During year 2000, substantial changes to the surface water management infrastructure in the eastern catchment of the Works were done. The existing surface water management infrastructure was upgraded to form three "lines of defence" for the south-eastern corner of the Works, namely the Steelserv and Hecketts South areas. This infrastructure includes the:

- "First line of defence" - Steelserv drain and Steelserv Sump capturing seepage water from the Steelserv slag handling area and pumping this water back to process;
- "Second line of defence" - South-eastern boundary flow diversion wall towards Leeuspruit Sump. The infrastructure comprises a 1m high brick wall along the South-eastern boundary of the site which ensures that no surface runoff from within the works area can flow uncontrolled over the boundary of the site into the receiving environment. Water held back by this wall is routed into the Leeuspruit sump from where it is pumped towards the Western catchment outlet point at TETP.
- "Third line of defence" – Frikkie Meyer weir and return pump house. This infrastructure consists of a measuring weir with an associated pump station. The pumps are operated such that dry weather flows reporting to the weir are pumped to the Leeuspruit sump from where it is further pumped towards the Western discharge point at TETP;

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This infrastructure is presented in **Figure 5**. Monitoring systems have been commissioned in the area of the eastern discharge point to monitor the flows and water qualities at the following points:

- North Works Runoff Canal;
- Vaal Dam Canal;
- At Steelserv sump;
- At Leeuspruit sump;
- At Frikkie Meyer weir;

Each of these components of the surface water management infrastructure for the eastern catchment will now be reviewed individually. Photographs of several of these structures are contained in **Appendix 17**.

Steelserv Drain

The Steelserv area is an area containing slag processing plants, metal yards, hot metal and slag pits. A more detailed description of this area is provided in **Section 2.3.7**. Surface water runoff is low from this area due to a high infiltration rate into the slags. Infiltrated water however does flow underground towards the lowest point in the East, where it decants onto surface. This water is typically very high in sulphates, sodium, iron and calcium.

Managing the surface water runoff during wet weather conditions and seepage flows during dry weather conditions from this area is seen as being critical if the water quality objectives for the Leeuspruit are to be complied with. A surface water drain was therefore designed to accumulate the surface water flow from the area. A sand filter and fin-drain were placed alongside to the drain to facilitate the flow of seepage water into the drain by means of inlets into the drain spaced every two metres. The construction of this drain was completed in January 2001. The drain lies on the southern and eastern boundaries of the Steelserv area. It leads into a flood attenuation area in the south-east corner of the Steelserv area, from where it flows via a culvert to the Steelserv Sump.

Steelserv Sump

The Steelserv sump was commissioned during January 2001. Its primary purpose is to capture surface runoff and shallow seepage from the Steelserv area. It comprises a settling facility that facilitates periodic clearing of sediment and a pump station from where captured water can be pumped to process.

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The structure has two spillways. The first spillway is approximately 6 m in length. Water overtopping at this level flows into a pump sump. The available volume of the settlement facility up to the lower spillway level is approximately 108 m^3. Water is pumped from this sump by means of dry pumps (maximum delivery of 100 m^3/h) to either the Combination Line (South 9) storm water drain which flows to the TETP, or the Basic Oxygen Furnace (BOF) for reuse in the process. The Steelserv Sump is operated at approximately 40 % of FSL. This level is necessary to ensure that the pumps do not cavitate.

The second spillway of the sump, which is approximately 300 mm higher than the first, is also approximately 7 m in length. When the pumps can no longer accommodate the flow into the Steelserv Sump (typically during rain events) this second spillway is overtopped. The volume of water in the sump when it begins overtopping is about 158 m^3. The water flows naturally from the apron of the spillway, through energy dissipaters, along a channel to the south-eastern boundary flow diversion wall towards the Leeuspruit sump.

South-eastern Boundary Flow Diversion Wall

This flow diversion wall intercepts any surface water that would move out of the south-eastern boundary of the Works area, and conveys it inside the boundary of the IVS Works to Leeuspruit Sump. The flow diversion wall was commissioned during January 2001. The one metre height of the wall was selected for practical reasons (permanence and visibility) and to facilitate flood attenuation in specific locations.

The total length of the flow diversion wall is 1167 m. Along the length of the diversion wall are three flood attenuation facilities. These flood attenuation structures ensure that controlled flows are received at Leeuspruit Sump.

In addition to the south-eastern boundary flow diversion wall which diverts surface water towards the Leeuspruit Sump, two canals exist to the North of the eastern discharge area, which convey dry-weather flows from the North Works area to the Leeuspruit sump. The two canals collect water from the North Works area and from the Vaal treatment plant area respectively. The canals are commonly known on site as the NWAK and Vaal Dam canals.

North Works Runoff Canal (NWAK)

The NWAK is the dominant stormwater canal that collects surface water from the North Works stormwater system. This stormwater canal is a 1400 mm deep concrete trapezoidal canal with a bottom width of 2500 mm, and 45° side slopes. The canal flows in a southerly direction. Dry-weather flows are diverted from the NWAK to flow directly to the Leeuspruit Sump. During storm events this diversion weir is overtopped and the stormwater flows into the Leeuspruit marshy area upstream of the Frikkie Meyer weir, thereby bypassing the Leeuspruit Sump during high flow conditions. An ultrasonic instrument is installed in this canal, and the flow volume is calculated from the height readings utilising Chézy and Manning theory.

Vaal Dam Canal

The Vaal Dam canal flows from the southern portion of the North Works, in the vicinity of the Vaal Dam reservoir, bio-plant and desalinisation plant, towards the Leeuspruit Sump. This canal is unlined. A concrete V-Crump weir has been constructed in the canal for flow and quality measurement purposes. The height of the flow passing over the V-Crump weir is monitored on a continuous basis by means of an ultrasonic instrument.

The canal does not have a means for diverting storm events directly through to the Frikkie Meyer weir. Dry-weather as well as storm flows in the Vaal Dam canal flow directly to the Leeuspruit Sump.

Leeuspruit Sump

The Leeuspruit Sump is an important facility for the management of surface water in the eastern catchment. This HDPE lined dam was constructed in 1998 to attenuate dry-weather and storm flows on the eastern side of the Works. The capacity of the dam is approximately 12 500 m^3.

Two 35 kW KSB pumps (each delivering 300 m^3/h at 32 m head) operating with float control switches pump the water from the sump to the Combination Line (South 9). This stormwater drain flows to the western catchment, and this water exits into the Rietspruit canal after passing through the TETP.

Water collected in the Leeuspruit Sump emanates from the south-eastern boundary flow diversion wall, the NWAK (North 2), the Vaal Dam canal (North 1) and the Cold Mills Line (South 14). During storm conditions, when the Leeuspruit Sump spillway overtops, the water flows into a bypass channel adjacent to the sump towards the Frikkie Meyer weir.

The water level in the sump is monitored on a continuous basis by means of an ultrasonic instrument. This level is recorded as a percentage of the full supply level of the sump. The volume of water pumped to the western catchment is also recorded on a continuous basis. This data is transferred by means of radio communication to the ECC.

Frikkie Meyer Weir

The Frikkie Meyer weir was designed to facilitate the maximum flow that the two 1500 x 1800 box culverts under the Frikkie Meyer Boulevard can accommodate. This gives a design capacity of approximately 19 m^3/s. However, flow measurement over the weir can only be accurately measured up to 10.8 m^3/s since any flows greater than this would probably "drown" the weir structure. A flow of 10.8 m^3/s relates to a peak flow event of approximately 1:3 years. The weir was commissioned during December 2000. A calibration curve for the compound Crump weir is contained in **Appendix 21**. The height of the water passing over the compound Crump weir is monitored on a continuous basis by means of an ultrasonic instrument. This data is transferred by means of radio communication to the ECC.

A compound Crump weir structure was selected for this application in conjunction with DWAF: Directorate Hydrometry. The central Crump accommodates the lower flows, between 0 and 300 l/s, while the two side Crumps accommodate the larger flows. The ultrasonic instrument is installed three metres upstream of the weir crest. Curved guide walls were utilised to promote uniform flow patterns in front of the weir by inhibiting the formation of a *vena contracta*.

Adjacent to the weir, a pumphouse has been constructed. The pumps pump all low-flow volumes reporting at the weir towards the Leeuspruit Sump. The two centrifugal pumps in this pump house are capable of delivering a combined flow of 100 m^3/h. The volume of water pumped back to the Leeuspruit Sump is recorded on a continuous basis, and this data is also transferred by means of radio communication to the ECC.

The flow volume data obtained from the various monitoring stations will now be reviewed.

Data Obtained

Flow data is available for the following stations:

- Leeuspruit Sump;
- Frikkie Meyer Weir;
- North Works Runoff Canal; and
- Vaal Dam Canal.

Monthly Flow Quantity Data

Frikkie Meyer Weir:

A summary of the major flows within the eastern catchment is presented in **Table 34**. This data presents the monthly flows over the Frikkie Meyer weir, water volumes pumped from the weir to the Leeuspruit Sump as well as water pumped from the Leeuspruit Sump to the TETP.

Table 34: Summary of Major Flows in Eastern Catchment

	Flow over Frikkie Meyer Weir (m^3)	Flow pumped from Frikkie Meyer Weir to Leeuspruit Sump (m^3)	Flow pumped from Leeuspruit Sump to TETP (m^3)
March 2001	21512	10202	238993
April 2001	0	3972	84944
May 2001	259	16498	243869
June 2001	0	3060	154188
July 2001	0	2225	102510
August 2001	704	8212	116426
September 2001	8261	11720	105507
October 2001	14848	10008	106407
November 2001	21649	9345	148600
December 2001	0	6415	150075
January 2002	0	14815	178851
February 2002	127155	11024	231865
Total	**194388**	**107496**	**1862235**

The data obtained from the continuous monitor at the Frikkie Meyer weir shows that the highest volume of water, approximately 127 155 m^3, passed over the weir during the month of February 2002. During the dry months of April to August 2001 less than 1000 m^3 flowed over the weir.

The monthly totals provided in this table also indicate that during December 2001 and January 2002 no water flowed over the weir. The total rainfall during these two months was however higher than that in February 2002, which had the highest total monthly runoff.

Review of the data obtained for December 2001 and January 2002 indicated a lot of missing data, apparently largely due to radio interference and lightning activity in the area. Data was also found to be missing during other periods of the year. Analysis of the data is therefore restricted and results should be interpreted with care. The following table presents the percentage of data that is missing during the various months of analysis at the Frikkie Meyer weir:

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Table 35: Percentage of Data Missing at Frikkie Meyer weir

2001										2002		Ave
Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
1.4	23.9	18.9	3.5	18.1	0	3.3	0	3.3	23.6	23.6	29.2	12.4

This table shows that during half of the months analysed the amount of missing data exceeded 18 %, while during the other half of the months the amount of missing data was less than 4 %. The most critical gap in the data was during the months of December 2001 to February 2002, since these were the months associated with high rainfall.

The total flow volume recorded as passing over the weir is therefore an underestimation of the actual volume that passed over the weir during the year of analysis. The average monthly missing data amounts to approximately 12.4 % of the total data for the year of analysis.

The total volume of water pumped from the Frikkie Meyer weir to Leeuspruit Sump during the period of analysis was approximately 107 496 m^3. This data is subject to the same data deficiency as the flow over the weir, and is therefore an underestimation of the flow from the weir to the Leeuspruit Sump. This data provides a maximum monthly volume of water pumped to the Leeuspruit Sump of 16 498 m^3 during the month of May 2001. The maximum monthly volume pumped to the sump usually occurs during the high rainfall months of spring and summer, since this is the time of year when the most surface water runoff reports to the weir.

Leeuspruit Sump:

The volume of water pumped from the Leeuspruit Sump to the western catchment during the year of analysis is recorded as being 1 862 235 m^3. The highest monthly volume was pumped during the month of May 2001.

Table 36 presents the monthly maximum, 95-percentile and median levels in the Leeuspruit Sump as a percentage of the full supply level (FSL) of the sump. From this table it is evident that the Leeuspruit Sump overtopped during eight months of the year. During the months of May 2001, January 2002 and February 2002 water was flowing over the spillway of the sump for at least 5% of the time during the month.

The median level in the sump provides an indication of the operational level of the sump. The average monthly median level is approximately 17 %, which indicates that the sump is normally operated at a low level. This is required in order to keep storage capacity available for storm water runoff during rainfall events.

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Table 36: Monthly Level in Leeuspruit Sump

Month	Maximum (% of FSL)	95-Percentile (% of FSL)	Median (% of FSL)
March 2001	100	94.1	23.3
April 2001	98	70.1	21.1
May 2001	100	100	16.2
June 2001	56.1	30.5	15.9
July 2001	64.2	30.4	15
August 2001	47	20.4	17.9
September 2001	100	51.1	19.8
October 2001	100	72	20.8
November 2001	100	93.1	19.9
December 2001	100	87.6	17.6
January 2002	100	100	9.9
February 2002	100	100	8.1
Average		**70.8**	**17.1**

North Works Runoff Canal (NWAK):

The NW and Vaal Dam canals are the two stormwater canals that transfer water from the North Works to the Leeuspruit Sump. **Table 37** presents the flow volumes in the NWAK. No data is available for this station for the period of March 2001 to February 2002. The station was only commissioned during February 2002. Flow data in the NWAK is therefore presented for the months of March 2002 to September 2002. The maximum flow recorded in the NWAK was 2055.8 m^3/h (0.57 m^3/s). This was the highest average flow that occurred during one hour. The median and 10-percentile values indicate that there is a dry-weather flow emanating from the NWAK on a continual basis. This dry-weather flow is diverted to the Leeuspruit Sump, from where it is pumped to the TETP via the South Works stormwater system.

Table 37: Flow Volumes in the North Works Runoff Canal (m^3/h)*

	Mar 2002	Apr 2002	May 2002	Jun 2002	Jul 2002	Aug 2002	Sep 2002
Maximum	1930.7	727.6	1407.6	1052.9	276.8	2055.8	642.0
95-percentile	161.2	113.2	131.8	113.2	131.8	126.6	104.1
Median	90.9	73.9	61.7	78.1	73.9	73.9	69.8
10-percentile	31.0	20.3	9.9	16.1	9.9	23.8	23.8

* These are average hourly flows.

The annual flows in the eastern catchment have been reviewed. The data has been used to compile a macro surface water balance for the eastern catchment of the IVS Works.

Annual Flow Quantity Data

The total volume of water to pass over the weir during the year of analysis was recorded as 194 388 m^3. Although it has been shown that this value is an underestimation of the total volume of flow over the weir for the year, this value will be utilised in the analysis of the macro surface water balance for the eastern catchment in the absence of more accurate data.

The total volume of water pumped from the Leeuspruit Sump to the Combination Line (South 9) storm water drain during the year of analysis was approximately 1 862 235 m^3. This relates to an average monthly transfer of water from the Leeuspruit Sump to the TETP of approximately 155 186 m^3. Assuming that the volume of water that passed over the Frikkie Meyer weir during the year of analysis was 194 388 m^3, then the total volume of water that exited the eastern catchment of the site during the year of analysis is estimated to be 2 056 623 m^3.

The total estimated runoff from the eastern catchment of the IVS Works (utilising the average rainfall from all of the rainfall stations and the area weighted runoff factor) is 1 153 356 m^3.

Although NWAK data is not available for the year of analysis, the flow in this canal is relatively constant over time. The median flows provide a good estimate of the dry-weather flows emanating from this canal. For the purpose of this macro surface water balance for the eastern catchment it has been assumed that the average monthly median flow for the available months is the average flow for the year of analysis. Using this assumption the estimated volume of effluent to pass down the NWRC during the year of analysis is 653 496 m^3. The median hourly flow that passed over the Vaal Dam V-Crump weir was approximately 32 m^3/h. This value has been assumed to be the average flow in the Vaal Dam canal during the year of analysis, yielding an annual flow of effluent in this canal of 280 320 m^3. These dry-weather flows are routed to the Leeuspruit Sump, and do not flow directly to the Frikkie Meyer weir.

Table 38 provides a summary of the macro surface water balance for the eastern catchment of the IVS Works utilising the total annual flows.

This table indicates that the flows into and out of the Works during the year of analysis are in the same order of magnitude. The combined flows of rainfall runoff and effluent in the NWAK and Vaal Dam canals amount to a total annual flow into the eastern catchment of approximately 2 087 172 m^3. A total flow of about 2 056 623 m^3 exits the site via the overflow at the Frikkie

Meyer weir and pumping from the Leeuspruit Sump to the TETP. This analysis forms the macro surface water balance for the eastern catchment.

Table 38: Macro Surface Water Balance for Eastern Catchment

	Details		Volume (m^3)
	Total Annual Flow into Eastern Catchment		
A	Estimated stormwater runoff from eastern catchment	A	1 153 356
B	Dry-weather flow in NWAK	B	653 496
C	Dry-weather flow in Vaal Dam canal	C	280 320
D	Total surface water flow towards eastern catchment discharge	A+B+C	2 087 172
	Total Annual Flow exiting Eastern Catchment		
E	Flow over Frikkie Meyer weir	E	194 388
F	Volume pumped from Frikkie Meyer weir to Leeuspruit Sump	F	107 496
G	Volume pumped from Leeuspruit Sump to TETP	G	1 862 235
H	Total surface water exiting in eastern catchment	E+G	2 056 623
	Discrepancy in flows	100*(H-D)/D	1.5%

A better understanding of how surface water behaves in the eastern catchment can be obtained by evaluating specific storm event data obtained from the various monitoring stations within the eastern catchment. Some of the specific storm events that resulted in surface water passing over the Frikkie Meyer weir are now reviewed in more detail.

Daily Storm Events

Four storm events have been selected for a detailed analysis of the flow characteristics over the weir as a result of precipitation in the eastern catchment. The following table, **Table 39**, presents a summary of the four storm events selected for this analysis. Listed in this table are the dates on which the events occurred, the rainfall depth that fell within the eastern catchment and the volume of water that flowed over the Frikkie Meyer weir as a result of the storm event.

Table 39: Summary of Storm Events in Eastern Catchment

	Date	Rainfall Depth (mm)	Volume of Overflow (m^3)
1	23 Mar 2001	46.25	21 512
2	12 Sep 2001	30.00	8 261
3	31 Oct 2001	22.50	21 649
4	26 Feb 2001	24.25	127 036

The outlet point from the eastern catchment of the IVS Works is a zero effluent discharge point. This means that no surface water leaves the site at the eastern catchment discharge point during dry weather conditions. Dry-weather flows that reach the Frikkie Meyer weir are pumped

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to the Leeuspruit Sump before they can flow over the gauging facility. Therefore, flow volumes over the weir prior to a rain event is zero. When runoff from a storm event reaches the weir, the level behind the raises and the pumps at Frikkie Meyer weir will start pumping water to the Leeuspruit Sump. The first portion of any runoff event will therefore also be pumped back to the Leeuspruit sump. When the flow rate of water towards the weir exceeds the combined storage capacity behind the weir and the pumping capacity, the weir will start overtopping.

The four storm events will now be analysed individually.

Storm Event 1

Table 40 provides a summary of the key events that occurred during the first storm event being analysed. A graphical representation of this storm event is shown in **Appendix 11**.

Rainfall started at 07:08 on 23 March 2001 and continued for almost 24 hours. A total of about 39 mm fell during this rainfall period. The overflow at the Frikkie Meyer weir started approximately 2 hours and 22 minutes after the rainfall started, and this time period is taken to be the lag time of the storm. The peak of the first hydrograph occurred approximately three hours later. Water continued to flow over the weir during the night, and at 06:30 the following morning the second hydrograph had passed over the Frikkie Meyer weir.

Table 40: Summary of Storm Event 1

Description	Date	Time	Rain (mm)	Flow over Weir (m^3/h)	Stormflow Volume (m^3)
Rainfall started	23/03/01	07:08	0		
Runoff started	23/03/01	20:30		112	0
Peak of First Hydrograph	23/03/01	23:30		2123	4762
End of First Hydrograph	24/03/01	02:30		808	4036
Peak of Second Hydrograph	24/03/01	04:00		3594	3241
End of Second Hydrograph	24/03/01	06:30		796	4395
Start of Third Hydrograph	24/03/01	17:00		254	0
Peak of Third Hydrograph	24/03/01	18:30		1777	1764
Rainfall ended	24/03/01	18:51	46.25		
End of Third Hydrograph	24/03/01	23:00		108	3312
Total Flow Volume during Storm Event					**21512**

Rainfall resumed again at 16:23 on 24 March 2001. This second period of rainfall continued for approximately two and a half hours. In total, approximately 46.25 mm fell during the two days. The third hydrograph started flowing over the weir at 17:00, and continued to flow for about six hours. The total volume of water to pass over the weir was approximately 21 512 m³ (8 798 m³, 7 636 m³ and 5 076 m³ for the first, second and third hydrographs respectively).

The estimated runoff for the eastern catchment for this storm event is 62 012 m³. This value was determined by multiplying the total rainfall that fell within this catchment with the area weighted runoff factor for the catchment. The measured overflow was only about 34.7 % of this volume. This means that only about one third of the storm event runoff was eventually discharged over the Frikkie Meyer weir. The rest of the water was pumped either from the weir to the Leeuspruit sump, or directly from the Leeuspruit sump to the western discharge point at TETP. Pumping volumes obtained from the Leeuspruit sump indicate that a total volume of about 19 185 m³ was pumped from the sump towards TETP. This brings the total volume accounted for at 40 697 m³. Calculating back from this figure gives a real runoff factor of 21%. This figure is realistic if the soil conditions were dry at the beginning of the rainfall even.

Storm Event 2

Table 41 provides a summary of the key events that occurred during the second storm event being analysed for the eastern catchment. A graphical representation of this storm event is contained in **Appendix 11**. A total of 30 mm fell over a period of four days. Initially almost 20 mm fell during the first 24 hours, and then the subsequent 10 mm fell steadily during the next three days. The lag time, before discharge started from the eastern catchment over the Frikkie Meyer weir, was about three hours.

Table 41: Summary of Storm Event 2

Description	Date	Time	Rain (mm)	Peak Flow over Weir (m^3/h)	Stormflow Volume (m^3)
Rainfall started	12/09/01	14:24	0		
Runoff started	12/09/01	17:30		586	
First Hydrograph	12/09/01	18:00		676	735
Second Hydrograph	13/09/01	07:00		2934	4726
Third Hydrograph	13/09/01	10:30		2072	1036
Forth Hydrograph	13/09/01	11:30		3529	1765
Rainfall ended	16/09/01	14:28	30.0		
Total Flow Volume during Storm Event					**8261**

In total four hydrographs passed over the weir with storm volumes of 735 m³, 4726 m³, 1036 m³ and 1765 m³ respectively. The total volume to pass over the weir was therefore approximately 8 261 m³. The peak flow over the weir, approximately 3529 m³/h, was associated with the fourth hydrograph.

The total estimated runoff from the eastern catchment was 40 224 m^3. The actual runoff was approximately 20% of this value. It is interesting to note that during the period within which the last 10 mm fell, no discharge was reported over the weir. This indicates that the pumping arrangements are quite capable of dealing with rain events that occur with low intensity. In this case, flow over the weir occurred as a result of a rainfall intensity of 1 mm/h during the first 18 hours of the storm, while the second half of the storm, with an intensity of 0.2 mm/h produced no overflow events over the weir.

If therefore, we assume that overflow of the weir was due to the rainfall of the first 18 mm of the rain storm event, the total calculated runoff to that point would have been 24 134 m^3. Of this, 8 261 m^3 went over the weir, which amounts to 34.2%. This number now corresponds well with the number obtained for Storm Event 1.

Storm Event 3

A graph presenting the flow hydrograph and incremental rainfall during the third storm event is contained in **Appendix 11**. This graph shows two relatively large hydrographs passing over the Frikkie Meyer weir. The first 0.25 mm of rainfall fell at 07:13, but the storm event only started at 11:08. The runoff as a result of this precipitation started flowing over the weir approximately four hours later. The lag time associate with this storm event is therefore about four hours.

Table 42: Summary of Storm Event 3

Description	Date	Time	Rain (mm)	Flow over Weir (m^3/h)	Stormflow Volume (m^3)
Rainfall started	31/10/01	07:13	0		
Runoff started	31/10/01	15:00		4924	0
Peak of First Hydrograph	31/10/01	15:30		4998	4974
End of First Hydrograph	31/10/01	17:30		589	2887
Peak of Second Hydrograph	31/10/01	18:30		4103	2954
Rainfall ended	31/10/01	19:11	22.5		
End of Second Hydrograph	31/10/01	22:30		84	4034
Total Flow Volume during Storm Event					**14 848**

The storm duration was approximately 11 hours, and about 22.5 mm of rainfall fell during this period giving an average rainfall intensity of 2.0 mm/h. The estimated calculated runoff as a result of this rainfall is about 30 168 m^3. The actual runoff measured over the weir was approximately 49.2 % of this value. This Storm event confirms the suspicion that the volume discharged over the weir is more related to the rainfall intensity than to the amount of rainfall *per se*.

Storm Event 4

The flow hydrograph associated with the forth storm event analysed is graphically presented in **Appendix 11**. **Table 43** provides a summary of the times and volumes associated with this storm event. The rainfall started in the catchment at about 14:31 on 27 August 2002. About 1.5 mm of rainfall fell within the catchment initially, and then the rainfall resumed at about 21:58.

Table 43: Summary of Storm Event 4

Description	Date	Time	Rain (mm)	Flow over Weir (m^3/h)	Stormflow Volume (m^3)
Rainfall started	27/08/2002	14:31	0		
Runoff started	27/08/2002	21:49		16.9	0
Rainfall resumed	27/08/2002	21:58	1.5		
Peak of First Hydrograph	28/08/2002	01:15		32 104	21 184
Rainfall ended	28/08/2002	03:00	14.75		
End of First Hydrograph	28/08/2002	10:47		9.4	61 820
Total Flow Volume during Storm Event					**83 024**

The lag time associated with the rainfall was about five hours, but this length of time is deceptive due to the temporary cessation in rainfall. The hydrograph flowed over the weir for approximately 13 hours.

In the grab sample taken during this storm an incident was reported for sulphates, iron and phosphates. However, during this storm event the Leeuspruit Sump did not overtop, and the maximum level in the sump was 76 % of FSL. The pumps at the weir and the sump operated during the storm. The source of the contamination that caused the exceedances could therefore not have been the Leeuspruit Sump.

The estimated stormflow runoff as a result of the rainfall is approximately 19 441 m^3. The actual monitored flow over the weir is about four times higher. This indicates that this ultrasonic was recording incorrectly during the storm, and needs to be recalibrated.

Summary of Storm Events

Table 44 presents a summary of the four storm events. Analysis if the Storm events described indicate the following, recognising that the data is of limited quality to make firm conclusions:

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- That the infrastructure seems to be capable to restrict surface water discharge during dry weather flow conditions.
- That the lag time between start of rainfall to start of weir overflow is typically in the order of 2 to 4 hours.
- That the discharge volumes over the weir seem to be in the region of 35% of the total runoff from the site and about 11% of the total rainfall over the eastern catchment.
- That spillage over the weir is more a function of rainfall intensity than of total amount of rainfall on the catchment.
- That better data will have to be obtained to be able to calculate the above mentioned figures to greater confidence levels.

Table 44: Summary of the Four Storm Events

Event	Date	Rainfall Depth (mm)	Rainfall Duration (hr & min)	Lag Time (hr & min)	Peak Flow (m^3/h)	Overflow (m^3)	Estimated Runoff (m^3)
1	23 Mar 2001	46.25	35 hr 43 min	2 hr 22 min	3 594	21 511	62 012
2	12 Sep 2001	30.00	96 hr 04 min	3 hr 06 min	3 529	8 261	40 224
3	31 Oct 2001	22.50	11 hr 17 min	3 hr 52 min	4 998	21 649	30 168
4	27 Aug 2002	14.75	12 hr 29 min	7 hr 18 min	32 104	83 024	19 441
Average			**40 hr 3 min**	**5 hr 23 min**			

The water qualities associated with the surface water volumes in the eastern catchment will now be reviewed.

Water Quality

In this section initially the water licence requirements and WQOs associated with the eastern catchment will be reviewed. A description of the various monitoring points will then be provided, followed by a presentation of the data obtained from these monitoring stations.

Water Licence Requirements

The water licence of IVS requires a water quality monitoring point at the Frikkie Meyer weir on the western side of the Frikkie Meyer Boulevard. Grab samples are to be taken once hourly when water flows over the compound Crump weir. In accordance with the current water licence the following water quality parameters must be analysed for in the grab samples:

- pH;
- Electrical conductivity;
- Ammonia;

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- Sulphates;
- Chlorides;
- Manganese;
- Iron;
- Fluorides;
- Phosphates;
- Calcium;
- Potassium;
- Magnesium;
- Suspended solids;
- Total chromium;
- Zinc;
- Tin; and
- Soaps, oil and grease.

Water Quality Objectives

Table 45 presents a summary of the WQOs, regulations and guidelines applicable to the eastern catchment of IVS Works. The WQOs contained in the current water licence are listed in the third column of this table. Also provided in this table are the water quality requirements stipulated in the Preliminary Reserve and Resource Class Determination, the WQOs of the expired water permit, as well as the SADWS MGV and MAV concentrations. These additional values are provided for reference and comparison purposes.
A more comprehensive table with additional South African and international water quality requirements for a wide range of water quality parameters is contained in **Appendix 2**. This more comprehensive table was reviewed in **Section 2.3.4**.

There are various water quality monitoring points in the eastern catchment of the IVS Works. Only the grab sampling point LS1 is required by the water licence. Several additional monitoring points have however been constructed in this catchment to aid in the management and understanding of the behaviour and characteristics of surface water in this catchment.

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Table 45: Summary of WQOs, Regulations and Guidelines for Eastern Catchment

Water Quality Parameter	Units	Water Licence: 10016047 (current)	Preliminary Reserve: C22J	Permit Exemption: 1998B (expired)	SADWS: Maximum Guideline Value	SADWS: Maximum Acceptable Value
Chlorides	mg/l	80	200	80	250	600
Electrical Conductivity	mS/m	70	TDS : 1000	70	70	300
Iron	mg/l	0.1		0.1	0.1	1.0
Manganese	mg/l	0.05		0.05	0.05	1.0
Nitrates & Nitrites	mg/l	5		5	11	19
Sodium	mg/l	50	166	50	100	400
Sulphates	mg/l	100	360	100	200	600
Total Ammonia	mg/l	5	< 0.1	5	1	2
Calcium	mg/l	80	80		150	200
Potassium	mg/l	46	46		200	400
Magnesium	mg/l	17	17		70	100
Phenolic compounds	mg/l	0.1			5	10
Suspended Solids	mg/l	25				
Oil	mg/l	1				
Total Chromium	mg/l	0.5			0.01	0.02
Zinc	mg/l	0.3			1	5
Soluble Orthophosphate	mg/l	0.1	< 0.1			
Tin	mg/l	1.0				
Fluoride	mg/l	1.0			1	1.5
Dissolved Oxygen	%		94		100	100
Nitrogen / Phosphorus	ratio		36			

KEY:

*[1]: denotes that the WQO was reduced to the value in brackets after 1 July 2002.

*[2]: denotes that the WQO was reduced to the value in brackets after 31 December 2001.

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Description of Monitoring Points

The following water quality monitoring points exist, which will hereafter be described:

- North Works Runoff Canal;
- Vaal Dam Canal;
- Steelserv and Hecketts South shallow groundwater sampling points;
- Leeuspruit Sump;
- Frikkie Meyer Weir; and
- Grab sampling point LS1.

The infrastructure appertaining to these monitoring points has been described in the previous section appertaining to the water quantity in the eastern catchment. In this section additional details regarding the measurement of the water quality at these points will be described.

At the NWAK and Vaal Dam canals, EC and pH are monitored on a continuous basis, and average hourly values are recorded. The completion of the infrastructure in these locations was however only commissioned in February 2002. This means that data is not available prior to this date, particularly during the year of analysis. All dry-weather flows from these areas flow directly to the Leeuspruit Sump.

Water qualities are not monitored at the Steelserv Sump. Six test pits were however dug to the east of this area to determine the quality of the shallow water table. The constituents and concentrations of this water are indicative of the water quality parameters in the surface water runoff from this area, as most dry weather flow at Steelserv sump emanates from seepage water. The analyses appertaining to the water obtained from these test pits will hereafter be reviewed.

EC and pH are monitored on a continuous basis in the Leeuspruit Sump. In addition, grab samples of the water in this sump are regularly taken. This grab sampling data provides an indication of the constituents of the electrical conductivity. EC and pH are also monitored on a continual basis at the Frikkie Meyer weir. In accordance with the water licence requirement for surface water quality monitoring in the eastern catchment, grab samples are taken of water that passes over the compound Crump weir. Both the continuous and grab sampling data appertaining to the Frikkie Meyer weir will be presented.

The data obtained from these various monitoring stations will now be reviewed.

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Data Obtained

Initially the various sources of surface water that flow to the Leeuspruit Sump will be reviewed. The data obtained from this sump will then be reviewed. Finally the continuous and grab sampling data appertaining to the Frikkie Meyer weir, the discharge point for the eastern catchment of the IVS Works, will be presented.

North Works Runoff Canal and Vaal Dam Canal

The positions of these two stations are provided in **Table 46**.

Table 46: Position of NWAK and Vaal Dam Canal

Monitoring Station	Local Grid		L.O. 29 Grid	
	X	Y	X	Y
NWAK	-638	-1734.9	-84,029.92	2,949,799.65
Vaal Dam Canal	-638	-1699.1	-83,994.12	2,949,799.65

No continuous water quality data was available for these two stations during the year of analysis since these stations were only commissioned during February 2002. **Table 47** provides a summary of the EC values in the NWAK and the Vaal Dam Canal for the months of March 2002 and September 2002.

Table 47: Summary of EC values in NWAK and Vaal Dam Canal

Month	NWAK			Vaal Dam Canal		
	Maximum	95-percentile	Median	Maximum	95-percentile	Median
Mar 2002	97.1	48.6	37.4	160.3	82.5	52.3
Apr 2002	66.9	48.2	41.5	143.4	134	78.5
May 2002	86.5	46	37.4	126.3	116.3	74.9
Jun 2002	88.6	41.7	37.1	96.9	85.1	73.8
Jul 2002	53.4	41.5	41.5	104	96.2	81.5
Aug 2002	45.8	41.5	33.8	96.9	90.8	64.6
Sep 2002	-	59.2	32.3	63.1	61.5	52.6
Average	**73.1**	**46.7**	**37.3**	**113.0**	**95.2**	**68.3**

These EC values provide a good indication of the quality of the dry-weather flows emanating from the North Works. The average of the median EC values contained in this table are 37.3 mS/m and 68.3 mS/m for the NWAK and the Vaal Dam canal respectively. These values indicate that the median values for both canals are within the WQO for EC of 70 mS/m for the eastern catchment with the 95 percentile values slightly higher. The dry weather flows in these

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two canals are however routed directly to the Leeuspruit Sump and do not report to the Frikkie Meyer weir.

Grab sample analyses are available for water in the NWRC in **Appendix 10**. These results indicate the concentrations of the various parameters that make up the salts. These results indicate that the median sulphate and iron values for flows in the NWRC are 76 and 0.1 mg/l respectively. The median EC value is 42 mS/m, and the 95-percentile value is 56.2 mS/m.

Steelserv and Hecketts South

Two other sources of surface water that flow towards the Leeuspruit Sump are the Steelserv and Hecketts South areas. As mentioned previously in this document, water qualities are not monitored at the Steelserv Sump. Analyses have however been performed on the shallow groundwater within the Steelserv and Hecketts South area. **Table 48** provides a summary of the analyses of this water (the full analyses are contained in **Appendix 12**).

Table 48: Summary of Shallow Groundwater Quality in Steelserv Area

Parameter	Units	Test Pit Reference Number						Average
		1	2	3	4	5	6	
EC	mS/m	340	405	268	919	814	926	612
Alkalinity	mg/l	480	1086	240	1810	2284	2000	1317
Cl	mg/l	70	453	19	325	86	122	179
SO_4	mg/l	1269	1166	1340	2453	2174	2725	1855
Na	mg/l	533	775	358	2140	4800	4680	2214
Mn	mg/l	8.6	4.2	2.0	1.5	0.079	0.925	2.9
Fe	mg/l	7.1	87	35	25	1.13	33	31.4

The Steelserv area contains slag processing plants, metal yards, hot metal and slag pits. The area is a high-infiltration low-runoff area due to the flatness of the site, and the high permeability of the material stored on the surface of the Steelserv area. Rainwater falls on the surface of this area, dissolves constituents from the various pits, stockpiles or yards and percolates into the ground. From this table, it is evident that sulphates, sodium and iron are contained in this water in very high concentrations. The portion of the water that does flow from the Steelserv and Hecketts South areas as surface water runoff (if not contained at the Steelserv Sump and pumped directly to the BOF), flows to the Leeuspruit Sump.

Leeuspruit Sump

Table 49 presents the EC value in the Leeuspruit Sump during the year of analysis. The second, third, forth and fifth columns in this table present the maximum, 95-percentile, median and 10-percentile EC values in the Leeuspruit Sump during the various months. The sixth column presents the average EC of the water when the sump was at 100 % of the FSL, spilling towards the Frikkie Meyer weir.

Table 49: EC in Leeuspruit Sump (mS/m)

Month	Maximum	95-percentile	Median	10-percentile	Average when spilling
Mar 2001	76	74.7	72.3	70	64.1
Apr 2001	99.1	78.2	52.4	36.1	-
May 2001	78.5	74.9	53.6	43.2	63.4
Jun 2001	83	75.2	64.8	39.3	-
Jul 2001	90.5	85.6	74.9	54.5	-
Aug 2001	99.1	98.1	90.9	84.3	-
Sep 2001	98.7	97.4	89.7	82.8	88.3
Oct 2001	97.2	94.9	83.2	43.6	28.7
Nov 2001	86.1	82	70.7	30.3	33.8
Dec 2001	100	100	57.5	32.8	18.7
Jan 2002	100	100	52.1	31.2	73.6
Feb 2002	100	100	75.8	33.8	49.4
Average	**92.4**	**88.4**	**69.8**	**48.5**	**52.5**

The detection limit for EC at this monitoring point is 100 mS/m, and this value was reached during the last three months of analysis for at least 5% of the time. The average of the median EC values in the sump is 69.8 mS/m. This value is essentially equal to the WQO for the eastern catchment. This water is predominantly pumped to the TETP.

The sump spilled during eight of the twelve months of the year. Under storm conditions when the sump did overtop, the average EC during the year was 52.5 mS/m. This is the quality of the water that flowed from the Leeuspruit Sump spillway towards the Frikkie Meyer weir.

Grab samples are taken regularly in the Leeuspruit Sump to ascertain the exact constituents of the water in this facility. **Table 50** presents a summary of the water qualities in the Leeuspruit Sump. The statistical values were determined from data for the period July to November 2002, since no data was available for the year of analysis. The comparison of these two sets of data is deemed acceptable due to the fact that no major changes have occurred within the catchment between these periods, and because the EC values are in the same order of magnitude. The actual water quality analyses are contained in **Appendix 13**.

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Table 50: Summary of Water Qualities in Leeuspruit Sump

	Ca	Mg	pH	Cl	SO_4	EC	SS	F	Na	Fe	Mn	Zn	Oil
	Mg/l	mg/l	mg/l	mg/l	mg/l	mS/m	Mg/l	Mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Max.	62.0	683.0	8.7	120.0	196.0	99.9	36.0	0.7	94.0	1.1	0.4	1.8	6.0
95-per.	60.6	35.8	8.2	76.8	182.6	81.3	19.7	0.7	71.7	0.7	0.2	1.5	2.7
Median	48.0	21.5	7.2	55.0	130.5	70.0	5.5	0.5	48.5	0.4	0.1	0.3	0.2
10-per.	38.2	17.0	6.5	32.4	111.3	61.5	3.0	0.4	30.3	0.2	0.1	0.1	0.0
WQO	**80**	**17**	-	**80**	**100**	**70**	**25**	**1**	**50**	**0.1**	**0.05**	**0.3**	**1**

This table shows that the water in the Leeuspruit Sump does not for all elements comply with the WQOs for the eastern catchment. This is pumped to the western discharge of the Works to pass through the TETP before being released in that catchment.

Frikkie Meyer Weir

Table 51 presents the 95-percentile and median EC values of the water flowing over the Frikkie Meyer weir. This table also presents the median EC values of the water that is pumped from the Frikkie Meyer weir to the Leeuspruit Sump.

Table 51: Summary of EC Values at Frikkie Meyer Weir

Month	95-percentile EC of Flow over F.M. Weir (mS/m)	Median EC of Flow over F.M. Weir (mS/m)	Median EC of Flow from F.M. Weir to Leeuspruit Sump (mS/m)
Mar 2001	29.8	29.8	66
Apr 2001	-	-	58.6
May 2001	41.8	38.6	87.7
Jun 2001	-	-	100.2
Jul 2001	-	-	83.8
Aug 2001	31.1	30.9	36.3
Average	**34.2**	**33.1**	**72.1**

Results obtained from the continuous monitoring probe show data obtained after August 2001 to be unreliable and could therefore not be used in the analysis. Only the grab sample analysis for the Frikkie Meyer weir (point LS1) can therefore be used in the analysis and is reviewed hereafter.

The EC of the water during the four storm events described for the eastern catchment will now be evaluated.

The data from the continuous monitor at the Frikkie Meyer weir will be utilised for Storm event 1 only as this is the only event analysed before August 2001. The graph associated with this storm event is contained in **Appendix 11**. The graph shows the flow hydrographs for the storm events with the associated EC profile obtained from the continuous monitor at the Frikkie Meyer weir superimposed on the same graph.

Review of the EC profile during the storm event indicates that the EC value exceeded 150 mg/l before flow over the weir occurred. During the rainfall event, the EC value significantly reduces to 49 mS/m at the time where discharge starts occurring and the further reduces to below 30 mS/m during the main discharge over the weir. When the tail of the hydrograph passed over the weir the EC was still well below the WQO at 41 mS/m. Additional to the EC profile obtained during the overflow event, grab sampling data during the runoff events are available for further analysis.

Grab Sampling Point LS1

The grab sampling point immediately downstream of the Frikkie Meyer weir is termed "LS1". Graphs presenting the water quality analyses at this point are contained in **Appendix 10**. The following table presents a summary of the water quality results at LS1 for the year of analysis. This data is based on 27 grab samples taken between March 2001 to February 2002.

Table 52: LS1: Summary of Water Qualities

Parameter	Units	Maximum	95-percentile	Median	10-percentile	WQO
pH	-	8.8	8.6	7.4	6.9	-
EC	mS/m	96.3	94.3	45.7	18.6	70
Na	mg/l	54.7	54.6	36.5	17	50
K	mg/l	16.0	16	10.1	4	46
Cl	mg/l	140	74	32	9.84	80
SO_4	mg/l	750	747	153	62.2	100
NO_3	mg/l	3.4	2.87	1.2	0.16	5
NO_2	mg/l	0.77	0.42	0.07	0.02	
NH_3	mg/l	3.4	1.88	0.78	0.05	5
F	mg/l	2.1	1.91	0.52	0.32	1
Fe	mg/l	1.9	1.75	0.45	0	0.1
Mn	mg/l	0.65	0.29	0.1	0	0.05
Cr	mg/l	0.1	0.1	0	0	0.5
Cn	mg/l	0.09	0.06	0.03	0.01	-
PO_4	Mg/l	0.6	0.41	0.2	0.19	0.1
Zn	mg/l	0.7	0.7	0.3	0	0.3

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This data provides a more comprehensive understanding of the water qualities passing over the Frikkie Meyer weir than the continuous analyser, since the analyser only records pH and EC. Grab samples are only taken at this point when water flows over the weir.

Evaluation of Eastern Discharge Water Quality Results

The water qualities associated with the discharge from the eastern catchment will now be reviewed. These water qualities have been taken to be the grab sample results from LS1. The water quality parameters will be evaluated individually.

pH

IVS's water licence does not stipulate WQOs for pH. The SADWS provides MGVs of 6 and 9, and MAVs of 5.5 and 9.5.

The median pH value indicates that the water is generally slightly alkaline. All four statistical values are within the SADWS maximum guideline and maximum acceptable limits.

In conclusion, with regards to pH, it seems that pH values are typically within the SADWS MGV in the absence of WQOs to be compared with.

Electrical Conductivity

The WQO for the eastern discharge from the IVS Works area is 70 mS/m. The SADWS MGV and MAV are 70 mS/m and 300 mS/m respectively.

EC values analysed for the LS1 grab sampling program indicated typical values between 20 and 95 mg/l. The majority of sampling points lie below the 70 mg/l limit, however a number of exceedances from this level were encountered during January 2002.

As shown in the storm analysis of Storm event 1, EC values do significantly reduce during storm overflow events, however the one incident does not present sufficient information to make definitive statements in this regard.

In summary therefore, with regards to EC, it seems that values typically fall within the WQO limit of 70 mg/l, but that that exceedances do occur at times.

Sodium

The WQO for sodium at this eastern discharge point is 50 mg/l. This value is half of the SADWS MGV of 100 mg/l and therefore very strict.

Sodium concentrations measured during rainfall events at LS1 show typical values between 0 and 55 mg/l with only a few values exceeding the 50 mg/l limit.

In conclusion therefore, with regards to Sodium, it seems that values of discharged waters are mostly within the WOO limit of 50 mg/l. It is recommended that the WQO for Sodium be revisited to bring it more in line with SADWS MGL.

Potassium

The WQO for potassium in this catchment corresponds to the value quoted in the Preliminary Reserve and Class Determination for the quaternary catchment, namely 46 mg/l.

Potassium concentrations measured at LS1 during overflow events showed typical values between 0 and 20 mg/l. The values in all of the samples taken during the year of analysis were well below the WQO limit of 46 mg/l.

In conclusion therefore, with regards to Potassium, there seems to be no problem with water qualities discharged into the Leeuspruit and that the levels fall well below the WQO limit of 46 mg/l.

Chlorides

The WQO for chlorides being discharged into the Leeuspruit is 80 mg/l. The SADWS MGV for chlorides is 250 mg/l. The WQO limit for discharge to Leeuspruit is therefore well below the SADWS MGV and deemed very strict.

Chloride values analysed during rainfall events indicate values typically between 0 and 70 mg/l with only one value exceeding the WQO limit of 80 mg/l.

In conclusion therefore, with regards to Chlorides, there seems to be no problem with the water qualities discharged during storm events over the Frikkie Meyer weir. It is recommended that the WQQ for Chlorides be revisited to bring it more in line with SADWS MGV.

Sulphates

The WQO for sulphates in the water flowing over the Frikkie Meyer weir is 100 mg/l, while the SADWS MGV and MAV are 200 mg/l and 600 mg/l respectively.

Sulphate concentrations obtained from the LS1 grab sampling program indicates typical values ranging between 50 and 300 mg/l with three values exceeding the limit substantially at 650 to 750 mg/l. Therefore, there seems to be a problem with regards to sulphates when considering a WQO limit of 100 mg/l.

When considering the sources from where the sulphates originate, the Steelserv area stands out in particular with concentrations measured up to 2700 mg/l in the shallow seepage water. The pathway from the Steelserv area to the Frikkie Meyer weir must be via groundwater to the marshy area upstream of Frikkie Meyer weir. This is because the boundary wall that was constructed during 2001 restricts surface water runoff from this area. Evidence of white patches on surface between Frikkie Meyer weir and the works boundary confirms this view. Seepage water emanating on surface within the area was also noticed during visits to the site.

Measures therefore need to be taken to restrict sulphate rich water from exiting the site through the pathway of groundwater, whereby the discharge concentrations over the weir can be limited.

In conclusion therefore, with regards to sulphate, there exists a problem with water exceeding the WQO limit for sulphate being discharged over the weir. Measures therefore need to be put in place whereby sulphate rich water is prevented from reaching the Frikkie Meyer weir both during dry and wet weather conditions. A review of the WQO limit with regard to SADWS MGV is also warranted for sulphate values.

Nitrates, nitrites and ammonia

The WQO for nitrates and nitrites combined is 5 mg/l. The WQO for ammonia is also 5 mg/l. The SADWS values for these parameters are listed in the following table:

	SADWS - MGV	SADWS – MAV
Nitrates	5	9
Nitrites	6	10
Ammonia	1	2

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Nitrate values obtained from analysis of the LS1 data indicates typical values between 0 and 3.8mg/l. Nitrite values typically lie between 0 and 1 mg/l and the combined nitrate/nitrite values are all below the WQO limit of 5 mg/l. Again, the current WQO for nitrates and nitrites is less than half the SADWS MGV of 11 mg/l and therefore very strict.

Ammonia levels obtained from LS1 data indicates typical values between 0 and 2 mg/l with one value exceeding 3 mg/l. All levels recorded for ammonia lie below the WQO of 5 mg/l. The WQO for Ammonia is lenient when compared to the SADWS limits.

In conclusion therefore, with regards to nitrates and nitrites, there seems to be no problem with the water discharged during wet weather conditions over the Frikkie Meyer weir and the WQO of 5 mg/l can be adhered to.

With regard to ammonia, there seems to be no problem and values do not exceed the current WQO limit of 5 mg/l during spill events at Frikkie Meyer weir.

Fluorides

The WQO for fluorides is 1 mg/l. The SADWS MGV and MAV are 1 mg/l and 1.5 mg/l respectively.

Values obtained from the LS1 sample analysis indicate Fluoride levels typically between 0.25 and 1 mg/l with 4 exceedances of the WQO limit of 1 mg/l.

In conclusion therefore, with regards to Fluoride, values for water discharged over the weir are typically in range of the WQOs, however careful monitoring would be required to prove that Fluorides are not a problem in stormwater discharged over the Frikkie Meyer weir.

Iron

The WQO for iron in the water flowing over the Frikkie Meyer weir is 0.1 mg/l. The SADWS MGV and MAV are 0.1 mg/l and 1 mg/l respectively.

Values obtained from LS1 samples indicate typical Iron levels between 0.1 and 1 mg/l with a few values exceeding this limit. Iron levels are therefore a problem and need to be addressed when considering measures at the Leeuspruit area.

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There is a distinct possibility that the source of Iron reaching Frikkie Meyer weir is related to the same source that creates a sulphate problem at the weir. This source is the Steelserv area. Analyses of the shallow groundwater samples indicate Iron levels of up to 87 mg/l with an average of 31 mg/l. The values are orders of magnitude higher than the WOO level of 0.1 mg/l. The pathway for Iron from the Steelserv area to the Frikkie Meyer weir is through groundwater and should be addressed when considering measures within the general eastern area of the site.

In conclusion therefore, with regards to Iron, there seems to be a definite problem with Iron being discharged over the weir during rainfall events. This problem needs to be addressed when measures for the eastern slag area are considered.

Manganese

The WQO for manganese is 0.05 mg/l. The SADWS MGV and MAV for manganese are 0.05 mg/l and 1 mg/l respectively.

Values obtained from analysis of the LS1 samples indicate typical values for Manganese ranging between 0 and 0.2 mg/l with the majority of values falling below 0.1 mg/l. This indicates that there is a problem with Manganese levels in the water discharged over the Frikkie Meyer weir. Again, the source of the Manganese is most probably from the Steelserv area where values of up to 8.6, with an average of 2.4 mg/l have been recorded. Pathway is as for Sulphates and Iron through shallow groundwater.

In conclusion therefore, with regards to manganese, there seems to be a problem with manganese discharged over the weir during storm runoff events, which needs to be addressed in consideration of alternatives.

Chromium

There was no WQO for chromium in the expired water permit. The WQO for chromium in the current water licence is 0.5 mg/l. The SADWS MGV and MAV for this parameter are 0.01 mg/l and 0.02 mg/l respectively. The WOO level for chromium is therefore much higher than the SADWS levels.

Chromium levels obtained from samples taken at LS1 lie predominantly at 0 and in three occasions at 0.1 mg/l. With a WQO limit of 0.5 mg/l, there seems to be no problem with chromium levels in the waters discharged over Frikkie Meyer weir.

In conclusion therefore, with regards to chromium, there seems to be no problem with chromium levels well below the WQO level of 0.5 mg/l. It is recommended that chromium in future be deleted from the list of parameters to be analysed at Frikkie Meyer weir.

Cyanide

Cyanide levels are not specified in IVS's water licence. The SADWS MGV and MAV for cyanide are 0.2 mg/l and 0.3 mg/l respectively.

Cyanide levels obtained from analysis of the LS1 samples indicate typical levels between 0 and 0.1 mg/l. All samples gave results laying below the SADWS MGV of 0.2 mg/l.

In conclusion therefore, with regards to Cyanide, there seems to be no problem with water quality levels all below the SADWS MGV of 0.2 mg/l. It is recommended that Cyanide be deleted from the list of parameters analysed for at LS1.

Phosphorus

Soluble orthophosphates are specified in the water licence as having to be below 0.1 mg/l. No limits for Phosphate are specified in the SADWS.

Phosphate values measured at LS1 indicate typical levels between 0.1 and 0.4 mg/l. Most of the samples therefore exceeded the WQO for Phosphate at the Frikkie Meyer weir.

The WQO limit for Phosphate at the Rietspruit side of the works is 1 mg/l. The WQO limit set therefore seems very strict and should considered to be revisited to a more realistic value of say 0.5 mg/l.

In summary therefore, with regards to Phosphate, values exceed the WQO limit of 0.1 mg/l constantly, however a review of the limit to a more realistic value of 0.5 mg/l should be considered.

Zinc

The WQO for zinc is 0.3 mg/l. The SADWS MGV and MAV for zinc are 1 mg/l and 5 mg/l respectively.

Zinc values obtained from analysis of the LS1 data indicates are typically laying between 0 and 0.8 mg/l. The values are however all below the SADWS MGV of 1 mg/l. As for Phosphate, it seems that the WQO for Zinc is very strict and a review of the standard is recommended.

In conclusion therefore, with regards to Zinc, values obtained for water discharged over Frikkie Meyer weir exceed the WQO limit of 0.3 mg/l and therefore pose a problem. The WQO is however very strict and a review of the WQO limit is recommended.

Calcium, Magnesium & Alkalinity:

Only three sample values exist for all of the three elements and these were taken before the licence conditions into existence. Although the values measured seem to be high in relation to the WQO, too little information is available to comment on the data. Furthermore, the levels again seem to be very strict compared to the SADWS limits. It is recommended that the analysis for Calcium and Magnesium be included in the list of elements analysed for at the LS points.

Total Alkalinity is determined from compounding Calcium and Magnesium values and therefore can also not be commented on at this stage.

The water quality results reviewed in the foregoing paragraphs will now be discussed in terms of the dominant sources of the various contaminants.

Integration of Eastern Discharge Results

In the foregoing section regarding the water qualities in the eastern catchment of the IVS Works the various sources of water that reach the Leeuspruit Sump and the Frikkie Meyer weir were reviewed. During dry-weather conditions the NWAK, Vaal Dam canal and Steelserv/Hecketts South areas discharge water to the Leeuspruit Sump. During low intensity rainfall events, runoff from the Leeuspruit catchment upstream of the Frikkie Meyer weir flows towards the weir, from where it is pumped to the Leeuspruit sump. If the intensity of the rainfall is increases sufficiently, water will spill over from the NWAK and Leeuspruit Sump towards the Frikkie Meyer weir. As soon as the flow towards the Frikkie Meyer weir becomes more than the pumps at the weir can manage, then water will start overtopping the weir and a spill event occurs.

After reviewing the LS1 water quality analysis results, which is a summary of water quality data obtained during spillage events over the Frikkie Meyer weir, it is evident that a number of water quality parameters are problematic when compared to the WQOs for the eastern catchment.

The problematic parameters (excluding those for which the WQOs are extremely strict), are sulphates, iron, manganese and zinc.

The water emanating from the NWAK is relatively uncontaminated and, under dry-weather conditions, flows towards the Leeuspruit Sump. This is the best quality water in the eastern catchment in terms of EC.

The water in the Vaal Dam canal, Leeuspruit Sump and at the Frikkie Meyer weir are similar in terms of EC. The water that passes over the weir is however generally of better quality than the other two sources.

From these analyses it seems as although a possible source of non-compliance at the Frikkie Meyer weir is the Leeuspruit Sump. The one parameter that exceeded the WQO significantly at the Frikkie Meyer weir at times was the sulphate concentration, which rose to above 700 mg/l. Even though the comprehensive analyses at the Leeuspruit Sump were for a different period, the highest sulphate concentration recorded was 196 mg/l, and the water quality over time is relatively constant. It therefore seems unlikely that the Leeuspruit Sump resulted in these high sulphate concentrations.

In addition, on analysis of Storm event 4, it became evident that even when the Leeuspruit Sump did not spill, there was still an exceedance on some variables analysed at LS1, particularly sulphates and iron. The only source which could possibly contribute to this situation, was the catchment upstream of the weir outside of the boundary wall on the IVS works. The south-eastern boundary wall prevents any surface water flow from the Hecketts South and Steelserv areas from entering the area between the Leeuspruit sump and the Frikkie Meyer weir. The possibility of a source of contaminated water coming from the Frikkie Meyer catchment was subsequently investigated.

After integrating the surface water results with the groundwater and source characterisation results, it became evident that rain and process water discharged onto the surface of the Hecketts South and Steelserv areas infiltrates the groundwater regime. The water table in this area is very shallow and water levels of 1m below ground level were encountered in test pits excavated to the east of the Steelserv area. Water quality results from samples taken from the test pits are shown in **Table 48** above. The natural drainage path of groundwater in the area is in a north-easterly direction towards the Frikkie Meyer weir. This water decants to surface in the marshy area to the south-west of Frikkie Meyer weir. Under dry conditions, water from this area evaporates and white salt deposited on the surface of the ground occurs. Groundwater seeping

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onto surface there is highly contaminated with sulphates, iron, manganese and sodium due to its contact with BOF slags and other raw and processed materials in the areas of origin. When rainwater subsequently falls within this marshy area, the clean rainfall dissolves the salts and flows towards the weir.

In order to address this surface water problem in the eastern catchment, the source of the problem – Steelserv and Hecketts South - must be addressed effectively. The objectives and measures required to achieve this will be reviewed in **Section 5** and **Section 6** of this document.

In conclusion therefore, with regards to the eastern discharge point at Frikkie Meyer weir, the following comments can be made:

1. Although data available for the eastern catchment is limited and often incomplete or unreliable, still a reasonable understanding of the behaviour of and interface between surface and process waters could be obtained.
2. The Leeuspruit sump and Frikkie Meyer weir combined do not have the capacity to store water related to any significant rainfall event return period. These facilities merely act as dry weather flow discharge management facilities as well as to hold back contaminated runoff emanating from the first flush of a rain event. Spillages over these facilities will therefore occur regularly.
3. On analysis of the water quality data available, it seems that a few water quality parameters exceed the WQOs set for the eastern discharge. Of these, some are exceeded because the limits are set extremely strict. Others are not in compliance due to a source that has not been addressed to date.
4. On basis of the analysis performed, it is recommended that rather than capturing water from the catchment, whereby runoff is reduced to the receiving environment, that the sources of pollution contributing to the non-compliance parameters be addressed and that water that is in compliance be released over the weir into the environment.
5. That monitoring at the eastern catchment be more stringently done, including calibration of instruments, servicing thereof and increased reliability of data transfer and record keeping. Only reliable data can determine whether the infrastructure operates as it should and where improvements are required.
6. That the grab sampling program a Frikkie Meyer weir be replaced with a continuous sampler that can obtain samples of water as soon as spillage over the weir occurs.

Interface between Process and Surface Water

Surface water refers to all water that occurs on the surface of the earth. Water in a dam or a holding facility is therefore also classified as surface water. This means that in the case of IVS all water flowing in stormwater drains, or as overland flow on veld or dump areas, or water stored in dams is classified as surface water.

Process water or effluent is defined as water that has been used in a process and of which the quality has been altered. This therefore includes:

(i) Taking water into a plant;

(ii) Putting the water through a process;

(iii) Discharging the water as an effluent from a process.

From a surface water perspective, the process is viewed as a "black box". What enters the black box is surface water (intake water), and what exits the black box is surface water. The internal water management within the process (black box) is described in the process water specialist study as part of the Master Plan.

Process water that exits the black box to become surface water is termed effluent. Effluent water can be classified either as contaminated or uncontaminated. The degree of contamination of the effluent water that exits a process is important, since it provides an indication of the fitness of use of the water for humans and the environment, and the risks associated with this water.

Within a Works such as IVS, process and surface waters are integrally linked. Surface water becomes process effluent when it enters IVS. This effluent is subsequently treated and becomes surface water again.

At present both stormwater and treated process water is released from the Works at the western discharge point. As a result of commitments made by IVS to DWAF, the surface water released from IVS will comprise only of uncontaminated stormwater by the end of 2005. The Works will then be classified as a zero effluent discharge (ZED) facility. This operational practice will dramatically alter the operational activities, environmental management and discharge characteristics of IVS. It means that during dry-weather conditions there will be no water released from the site into the Rietspruit canal. All effluent within the Works will have to be treated and reused in process.

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What is of importance is that a separation between process and surface water is required for a site like IVS to become a ZED facility. Although historically this has not happened, it is foreseen that such separation will take place in future. Only when this separation has been completed, can a true distinction be made between process and surface water. The philosophy for management of waters in the future will be as follows:

- No process water shall be discharged into a surface water canal or dam.
- Dams shall be classified as either surface water or process water dams.
- Surface water shall become process water as soon as it is abstracted from a stormwater holding dam.
- Ground water shall become process water as soon as it is abstracted from a borehole.
- All process water must be kept within a pipe, a sump or a dam and all areas where process water spillages can occur, must be bunded, with abstraction sumps and pumps back into process.

The measures described hereinafter will indicate how this can be obtained.

The various management areas identified in the Master Plan will now be reviewed in terms of their influence on surface water within IVS.

2.3.6 Consolidated Residue Management Facility

The consolidated residue management facility (CRMF) was proposed due to the management and regulatory difficulties associated with numerous diverse yet relatively localised residue sites, waste facilities and dumps within the north-western quadrant of the site (see **Figure 3**). The consolidated residue management facility consists of various sub-areas, which include:

- Dam 10;
- Dams 1-4;
- Existing waste dump;
- Maturation ponds;
- Dam 11;
- Raw materials stockpiles;
- Processed materials stockpiles;
- Sludge dams; and
- Redundant blast furnace sludge dams.

The CRMF lies within the western catchment of the site, which drains predominantly towards the Rietkuilspruit. That portion which does not drain to the Rietkuilspruit drains into storage

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facilities within the catchment. The surface area of the CRMF is approximately 773 ha. This brown-field area is situated to the north of the CPA, and is situated in the north-western quadrant of the site. Surface water from outside of the CRMF drains into the area, predominantly from the eastern boundary of the CRMF where it interfaces with the Kiewiet area.

The goal of the consolidation of the various components within this area is that it is managed as a unit under a single permit. In terms of surface water it means that runoff water from the site will be managed within the site and monitored at the points that it leaves the CRMF. There are three possible water outlet points identified from the CRMF. These are:

- The Hattingh canal;
- A new water outlet point West of dam 10;
- Possible spillages or controlled water outlet from Du Preez dam.

The various components of the CRMF will now be reviewed individually.

Existing Waste Dump

This dump was started in 1943 and was used as a depository for solid residues and sludges over the years. It comprises an area of 179 ha, with a volume of 26.7 million m³. It has attained a maximum height of 40 m. The dump is unlined, and the different materials disposed to it are not segregated. The material is transported to the dump by rail, and is subsequently placed by wheeled vehicles. The dump has a high infiltration rate. Runoff from the uncapped dump will be contaminated, as surface water comes into contact with the waste body. Two phases of rehabilitation of the dump have been planned. These phases termed the 8-year and 20-year plans relate to final volumes of 35.4 and 46.5 million m^3 respectively.

An unlined pollution control dam for stormwater (Du Preez dam) is located immediately adjacent to the dump on the north-western side. This dam consists of a central sump and a basin arrangement covering a footprint of 9 ha, with a capacity of approximately 120 000 m^3. The dam is used for the management of storm events. It is operated empty, thereby effectively reducing the risk of both overtopping as well as infiltration to groundwater. Du Preez dam is capable of accommodating the 1:50 year flood when pumping only at 50 % capacity to Dams 1-4. The cut-off canals leading towards Du Preez dam are about 2 m deep, as are the bentonite slurry trenches adjacent to the canals.

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Dam 10

Historically Dam 10 was utilised for the disposal of effluent water from different parts of the process. This dam was predominantly used as an evaporation dam for the process waters as well as contaminated stormwater. Dam 10 also obtained leachate water from the cutoff trenches around the dump at Du Preez dam. Water from dam 10 was pumped to Dams 1-4. Dam 10 was originally constructed as a series of smaller dams separated by earthen berms.

Currently no effluents or leachates are pumped into Dam 10 anymore. The dam still contains a water body consisting of historic effluent. This water is either evaporated from the dam surface or being pumped back into process for treatment.

The dam has a surface area of approximately 64 ha, and slopes from a depth of 0 m in the east to approximately 6 m deep on the western side. The dam has a capacity of approximately 1 000 000m^3, but has no spillway or lining. The dam wall on the western side was built from slag and carries the rail line to the residue transfer station situated to the south of the existing waste dump. There is a shallow drainage canal adjacent to the dam on the western side of the dam wall. Water in this canal is collected at the West Bank pump house, and pumped back to the dam.

The dam has a limited rainfall catchment area due to the Hattingh canal. Dam 10 falls within the CRMF, and within the western catchment of the site. The dam is not registered with DWAF Dam Safety Office.

Dams 1-4

Dams 1-4 have a surface area of about 86.7 ha, and a volume of approximately 1 000 000 m^3. This dam comprises of three non-equally sized cells (cell 1 = 42.0 ha; cell 2 = 19.7 ha; cell 3 = 12.0 ha; cell 4 = 13.0 ha). Dams 1-4 do not have a spillway, and the maximum depth to overflow is about 4 m. This dam is situated within the western catchment of the site, within the CRMF, and holds predominantly inorganic effluent water. The dam is not registered with the DWAF dam safety office, and has a catchment area of approximately 183 ha. Inputs into Dams 1-4 are from the Du Preez dam pump house, Dam 10 and runoff resulting from rainfall within its own catchment. Seepage water is collected in a trench to the west of the dams. This water is pumped back into Dams 1-4 from a seepage pump house.

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Maturation Ponds

The Maturation Ponds have a surface area of about 38.3 ha, and a volume of approximately 700 000 m^3. This dam comprises of three non-equally sized cells (cell 1 = 12.3 ha; cell 2 = 13.0 ha; cell 3 = 13.0 ha). The Maturation Ponds do not have a spillway, and the maximum depth to overflow is about 4 m. This dam is situated in the western catchment, within the CRMF, and holds predominantly organic effluent water. The dam is not registered with the DWAF dam safety office, and has a catchment area of approximately 69 ha. Inputs into the Maturation Ponds are mainly organic effluents from the Coke ovens and runoff resulting from rainfall within its own catchment. Seepage water is collected in a trench to the west of the ponds, and pumped back into the Maturation Ponds.

Raw and Processed Material Stockpiles

The following activities occur within the raw material stockpile areas:

- Tipping of coal and fine ore for the sinter plant;
- Crushing and screening station;
- Mixing bed stacking and reclaiming;
- Coal blending yard;
- Coal stacking area stacker reclaimer;

The raw material stockpiles constitute an operational area within the CRMF. The designated access road into the CRMF is situated between the coal stacking area and the sinter mixing beds. The Hattingh canal flows next to this access road, and extends to the south-eastern extremity of the existing waste dump. The raw material stockpiles constitute an area of approximately 26 ha (coal stacking area + sinter mixing bed). Conveyor infrastructure is situated to the south of the operational area, and extends into Works.

The coal stacking area is constructed on top of a clay layer. At present any surface water, or shallow seepage water that is captured by the sub-surface drain system, is routed directly into the Hattingh canal. This area is partially bunded. The sinter mixing bed is lined and has a seepage system with a collection sump. The area is however not bunded, and surface water is not directed to the collection sump.

The processed material stockpiles lie within the CRMF in the western catchment of the site, and consist of a:

- Coke storage area of approximately 17.3 ha;
- Mill scale storage area of about 15.6 ha;

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- BOF sludge, constituting an area of about 5.9 ha.

Coke is transported to its storage area by means of road. This storage area is situated to the north of Dam 10, and to the south-east of the existing waste dump. This area is not lined or bunded and surface water becomes contaminated when it comes into contact with the coke. Stormwater draining from this area flows towards Dam 11 and Dam 10.

The mill scale is currently transported to and from the eastern side of the dump (west of the Maturation Ponds) by rail. The mill scale area is unlined and unbunded, and surface water becomes contaminated when it comes into contact with the products. This water flows overland and uncontrolled into the Hattingh canal.

The blast furnace slag storage area is situated to the north-east of the existing waste dump, south of the Cyferpan area. Hecketts make aggregate from this material and transport it from a dedicated gate situated on the northern boundary of IVS, adjacent to the Cyferpan area. Blast furnace slag is transported to the site by means of rail in hot-tip pots, and the aggregate is transported from the site by road. The hot-tip rail passes diagonally through the existing waste dump. This rail is a major limiting factor in terms of air space at the existing waste dump, and alternative routes will be proposed later in this document.

BOF sludge is stored in an area to the east of the coke storage area. This area is unlined, and unbunded. Surface water becomes contaminated on contact with this material. The water flows from this area in two directions, towards Dam 11 and the Hattingh canal.

Sludge Dams

The sludge dams comprises of two areas where sludge has been disposed. These are the Old Maturation Ponds and the CETP Sludge Dams. Both facilities lie within the western catchment of the site within the CRMF. CETP sludge is no longer disposed into the Old Maturation Ponds, while the CETP Sludge Dams are still used for this purpose.

The Old Maturation Ponds are situated to the north of the CETP. This area comprises of three non-equally sized cells (cell 1 = 3.7 ha; cell 2 = 6.0 ha; cell 3 = 9.9 ha). These unlined dams were utilised for the disposal of sludge underflow emanating from the CETP. The estimated depth of the facility is 3 m. Sludge settled in the sludge dams, where after the water ran off into the Burnes Memorial Canal. The water quality discharged from this facility was the same as that which was discharged from the clarifiers at the CETP.

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The CETP Sludge Dams are situated immediately east of Dam 10, and are still operational. This area comprises of seven equally sized cells, with areas of approximately 12.5 ha each. Earthen walls divide the cells. The sludge dams are unlined, and are utilised for the disposal of sludge underflow emanating from the CETP. The estimated depth of facility is 3 m. Sludge settles out in the sludge dams, where after the surface water is evaporated. Seepage from the CETP sludge dams flows into Dam 10.

Hattingh Canal

The Hattingh canal was built during 2001/2 to replace the under-designed Burnes Memorial canal. The Hattingh canal is a trapezoidal concrete canal approximately 2m deep, with 1:1 side slopes. It is constructed with a longitudinal slope of 1:750 and has a total length of 800 m. The canal extends from the south-eastern side of the existing waste dump, and exits into the 900 mm diameter North Works blow-down canal. It forms an effective drain for much of the stormwater emanating from the CRMF.

A continuous monitoring station was installed and commissioned near the end of the Hattingh canal during February 2002. The instrumentation measures flow depth, pH and EC at the point where surface water exits the site. No data is available for the period of analysis (March 2001 to February 2002), however results from the station subsequent to February 2002 is listed in **Table 53**. The water is of poor quality, with the dominant elements being sulphates, chlorides and calcium.

Table 53: Summary of Water Qualities and Flows in the Hattingh Canal

	Mar 02	Apr 02	May 02	Jun 02	Jul 02	Aug 02	Sep 02	Oct 02
95-Percentile Flow (m^3/h)	341.0	339.9	324.4	323.4	335.2	324.6	346.1	333.9
Median Flow (m^3/h)	320.5	326.2	320.4	319.6	319.9	320.2	321.3	324.4
95-Percentile EC (mS/m)	430.9	486.5	487.8	588.5	552.0	560.3	613.5	527.1
Median EC (mS/m)	359.4	425.1	472.5	420.2	526.8	473.8	581.4	471.7

The poor water quality in this canal is predominantly due to the ingress of shallow groundwater from areas such as the coal stacking area, the coke storage area, the Old Maturation Ponds and the sinter blending area. In addition surface water runoff becomes contaminated when it comes into contact with other raw and processed material stockpiles within the CRMF, as well as the existing waste dump.

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There is a constant dry-weather flow in the Hattingh canal during the winter months. The flow in the canal is typically in the order of 40 m^3/h.

Even though this canal transfers poor quality water at present, it is considered to be an important stormwater canal within the proposed CRMF. Various environmental management measures are proposed later in this document in order to ensure that only uncontaminated stormwater emanates from this canal in the future.

2.3.7 Consolidated Plant Area

The consolidated plant area (CPA) consists principally of the North and South Works of IVS (see **Figure 2**). The CPA is approximately 875 ha in area. The CPA consists predominantly of impervious surfaces and has a high runoff yield. The CPA is therefore a dominant contributor to stormwater flows received at the outlet points. This area is also the predominant area where surface water and effluent interface.

The most important surface water monitoring points within IVS are the western and eastern discharge points. These have been dealt with in detail under the western and eastern discharge points above. There are also several continuous monitoring points within the Works which are utilised for the management of surface waters and for the compilation of a mass balance for the site. Three of these monitoring points have been evaluated in the assessment of the flow quality and quantity emanating from the eastern catchment (Leeuspruit Sump, Steelserv Sump, NWAK and Vaal Dam canal). The flows and water qualities at the other 19 internal monitoring points will be reviewed briefly in this section in order to provide an indication of the major sources of runoff and the associated water qualities within the Works. For more detailed information regarding the water and salt balance within the site the reader is referred to the Master Plan Process Water Specialist Report (document number: IVS/MP/030).

Fourteen stormwater canals exist in the South works area. Thirteen of these drain to the TETP in the western catchment (S1, S2, ... S13), and one to the Leeuspruit Sump in the eastern catchment (S14). The North Works has three stormwater drains, and one effluent canal. The three stormwater canals (N1, N2, N4) drain towards Leeuspruit Sump, while the effluent canal forms the North Works blow-down canal, flowing in a westerly direction towards TETP. The positions of the internal monitoring stations within the Works not previously discussed in this report are provided in the following table:

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Table 54: Position of Continuous Monitoring Points within CPA

	Local Grid		L.O. 29 Grid	
	X	Y	X	Y
Analysis House 1	-797.601	2163.209	-80,132.43	2,949,639.90
Analysis House 2	-334.536	2168.6	-80,127.02	2,950,102.89
Analysis House 3	-135.712	2286.818	-80,008.81	2,950,301.68
Analysis House 5	-781.178	1898.475	-80,397.12	2,949,656.33
End of North Works Blow-down	-1062.3	1655.3	-80,640.27	2,949,375.26
Vaal Dam Canal	-638	-1699.1	-83,994.12	2,949,799.65
North Works Runoff Canal	-638	-1734.9	-84,029.92	2,949,799.65
Air Products Drain	570.2	1757.9	-80,537.61	2,951,007.50
Coke Ovens Drain	-792.1	822.2	-81,473.23	2,949,645.46
Hot Mills South Drain	25.3	1067.9	-81,227.53	2,950,462.72
CMGM (North Works Blow-down)	-1319.2	-374.8	-82,670.06	2,949,118.50
Hattingh Canal	-1214.2	630.2	-81,665.22	2,949,223.43

The canals listed in this table will not all be reviewed in this section. Those canals that have flows and water qualities that contribute significantly to the input into the TETP will be reviewed briefly in this section.

Analysing House 1

Analysing House 1 is utilised to monitor the flows in three stormwater canals that flow towards the TETP. They are the:

- Coke Ovens Canal (AH1a / S4);
- CETP Canal (AH1b / S2); and
- Direct Reduction Canal (AH1c / S1 and S3).

Only manganese is monitored on a continuous basis in the Coke Ovens Canal. The manganese concentration is typically just above 1 mg/l, although "spikes" of up to 12 mg/l do occur. Flows in the canal are typically in the region of 180 m^3/h.

Flow, EC, pH, fluorides and manganese are monitored in the CETP Canal. The water in this canal emanates from the outflow of the CETP and is a major source of fluorides, chlorides, manganese, iron and sulphates at the western discharge point of the Works. The flow volume emanating from this canal is in the order of 200 to 250 m^3/h.

Flow, EC and pH are monitored in the Direct Reduction Canal. The water in this canal is of relatively poor quality, and this canal is a source of chlorides and iron at the TETP. The EC in this canal is typically in the order of 200 mS/m, and the flow is in the order of 460 m^3/h.

Analysing House 2

Analysing House 2 is utilised to monitor the flows and qualities in three drains that flow towards the TETP. These include the:

- South Dam Inlet Canal (AH2a / S7, S8, S9, S10 and S11);
- Blower House Canal (AH2b / S6); and
- Blast Furnace Canal (AH2c / S5).

The South Dam Inlet Canal (SDIC) comprises of the flows of the BOF and continuous casting line (S10), the combination mill line (S9), the hot mills line (S8), the plate mill line (S7) and the secondary metallurgy line (S11). The EC in the SDIC is typically about 90 mS/m, and the flow ranges from 80 m^3/h to 120 m^3/h. Fluoride levels are typically about 1.5 mg/l to 2 mg/l.

The EC in the Blower House canal is typically below 80 mS/m, while the flow in the canal is typically in the order of 100 m^3/h. The major source of water in this canal is from the Cold Mills.

The Blast Furnace canal transfers water from the Slag Granulation and Blast Fumace areas. These areas are a dominant source of ammonia and sulphates within the Works area. EC values in this area range from 100 mS/m to 150 mS/m. Flows vary between approximately 150 m^3/h and 200 m^3/h. The ammonia concentration in this canal is typically about 15 mg/l, and the sulphate concentration greater than 200 mg/l.

Analysing House 3

Analysing House 3 is utilised to monitor the flows in the Open Canal (AH3a / S12 and S13). During the year of analysis the EC in the Open Canal typically ranged from 150 mS/m to 200 mS/m. This canal is a source of fluorides, sulphates, chlorides and sodium at the TETP. Flows in this canal, which include flows from Air Products, V1, V2 and V3 and EAF Slag Cooling, are typically in the region of 55 m^3/h.

Analysing House 5

Analysing House 5 was utilised to monitor the flows in the line leading from the Coke Ovens to Dam 10. This line is no longer utilised, and is therefore redundant.

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The process water line that flows from the North Works to join the Direct Reduction line is termed the North Works Blow-down line.

North Works Blow-down Line

The North Work Blow-down line is a 900 mm diameter concrete pipe drain that flows from the North Works to join up with the Direct Reduction line in the South Works. The flow in this canal is typically in the region of 200 m^3/h. The water is of relatively good quality with a median EC of about 70 mS/m.

2.3.8 Slag Processing Areas

There are two slag processing areas situated in the South Works within the Consolidated Plant Area.

South-western Slag Processing Area

This slag processing area is situated to the south of the Electric Arc Furnace (EAF). This area is utilised for slag cooling and scrap cutting and cooling. The scrap-cutting carousel includes oxygen lancing under a roof.

Within this area is a pit that is utilised for slag cooling. The pit is unlined.

Surface water becomes contaminated when it comes into contact with the stockpiles around the pit. A berm has been constructed at the edge of the embankment, but this berm does not extend to the north-west of the pit. An open earthen trench is situated at the base of the embankment, to the west of where the slag cooling activities take place. This trench captures surface water and shallow groundwater seepage from the south-western slag processing area. A pump transfers water from this trench back to the pit.

To the west of this area is an open veld area. This area was saturated with water seeping from the slag cooling pit prior to the construction of the trench and berm. Since the construction of the trench and berm this area has been dry, but there is evidence of historic salt depositions within this area. These salts are dissolved by rainfall runoff, and this open veld area could therefore be a source of surface water contamination.

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South-eastern Slag Processing Area

This slag processing area is operated by Steelserv. This area consists of two sub-areas, namely the Steelserv area and the Hecketts South area. Both are situated in the south-eastern corner of the CPA.

Hecketts South is situated on the southern boundary fence of the Works and has dimensions of approximately 1150 m by 170 m. The Hecketts South area has been utilised for the stockpiling of scrap metal and slags. During 2001 the clearing of this area was initiated, and the area has been progressively cleaned up from the eastern end. When the first 400 m had been cleared, this area was shaped and made free draining and a 200 mm layer of topsoil was placed on the surface. The purpose of this action was to minimise infiltration and ponding within the area, and to maximise runoff from the area as well as to rehabilitate the area.

The Steelserv area is situated immediately north of the Hecketts South area, and has dimensions of approximately 1300 m (east to west) by 420 m. The Steelserv area consists of the following components:

- Steelserv slag processing plant;
- Scrap metal yard;
- Cleared scrap metal yard;
- Hot metal pits;
- Hot slag pits;
- Scull yard;
- Brick yard;
- BOF slag;
- Scrap yard;
- Steelserv sump;
- South-east boundary flow containment wall;
- Steelserv boundary canal.

The water qualities emanating from the Steelserv and Hecketts South areas were reviewed when the eastern discharge point of the Works was evaluated. In this evaluation it was shown that the Hecketts South and Steelserv areas are major contributors to the exceedance of water quality standards at the Frikkie Meyer weir. Water from these two areas flow below the surface towards the open veld west of Frikkie Meyer weir and salt deposits are evident on surface in this area. These deposits are dissolved during rainfall events, whereby the water qualities reporting to Frikkie Meyer weir are compromised. The major components of this water include sulphates, sodium, fluorides and iron.

2.3.9 TETP/MTP Area

The infrastructure within this area was described briefly in the assessment of the flow quantities in the western catchment of the IVS Works. The TETP area includes the lowest point in the western catchment, and therefore forms the outlet of this catchment. Thirteen drains from the South Works, and one from the North Works, flow towards the TETP area. The water from the stormwater drains flow into the north and south buffer dams. These dams are balancing dams for the TETP, and act as silt collection facilities. The dams capture all dry-weather and first flush flows. The TETP is a treatment facility consisting of a series of ten sand filters operating in parallel.

The TETP area has been chosen as the preferred site where the Main Treatment Plant (MTP) will be situated. The MTP is the water treatment infrastructure required for the Works to meet the ZED in 2005 according to the water licence requirements. A basic layout drawing of the MTP infrastructure is shown in **Figure 4**. This figure shows that the MTP infrastructure will be integrated with the existing equipment and infrastructure at the TETP. For more details regarding the background, motivation and design of the MTP infrastructure the reader is referred to the Master Plan Process Water Specialist Report (document number: IVS/SR/030).

2.3.10Open Veld Areas

There are four open veld areas within the IVS Works. These are the:

- Kiewiet open veld area;
- Central open veld area;
- South-western open veld area;
- South-eastern open veld area.

Kiewiet Area

The Kiewiet area comprises of an area of approximately 385 ha. Surface water flows into the eastern and western catchments from this area since the watershed falls within this area. Surface water is not managed within this area, and overland flow occurs through the pastures. Surface water exits the Kiewiet area at two points. The first is at the south-eastern extremity of the Kiewiet area, where the water passes under the access road leading to the Northern Gate of IVS (where this road has its junction with the Frikkie Meyer Boulevard). Secondly, overland flow

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from the Kiewiet Area flows over the western boundary of this area into the CRMF. The Kiewiet site was previously used by Iscor as an irrigation area for organically contaminated water however this practise has been abolished in 1982. There are several borrow pit areas on the site, some of which are currently still in use.

The Kiewet area has recently been joined to the Cyferpan area by a thin strip of land north of Dams 1-4. The Kiewiet area is utilised as a pastureland for game farming, and is managed by Ferroland. Both natural and planted (artificial) pastures have been established. The dominant soil forms in this area are the Hutton, Avalon and Bainsvlei forms. The stock watering provision within this area is supplied by means of small earthen dams. The combined area of the Kiewiet and Cyferpan areas is approximately 780 ha. For more details on the type and numbers of game, the reader is referred to the Land Use and Land Capability Master Plan Specialist Report (document number: IVS/SR/032).

Central Open Veld Area

This open veld area comprises of approximately 123 ha and is administered by Central Services. The dominant activity within this area is rail transport where a network of rail lines enter/exit the North Works. Also situated within this area are some tar tanks and the so-called Cooper's Hill. Cooper's Hill is a historic topsoil stockpile area of approximately 1.8 ha in size. There are no buildings in this area.

South-western Open Veld Area

This manicured grassed park includes an area of almost 48 ha. It includes the main access road into the IVS Works, as well as the so-called Ellis Park dam which is approximately 2.3 ha in size. The area is managed by Central Services, and includes only one building (a pump house for the fountain) and a recreational lapa adjacent to the dam. Part of Eskom's power line servitude passes through this area.

South-eastern Open Veld Area

This area is important from a surface water perspective since its lowest point forms the origin of the Leeuspruit. The area includes infrastructure for the management of surface water in the eastern catchment of IVS as described earlier in this report. Apart from the water management infrastructure, other activities in this area include a nursery of approximately 1.5 ha in the northern corner of this site, "Boeredienste" (farming services - where agricultural lime was produced) and switchyard "D" (a power supply substation to the site) are situated within this area. "Boeredienste and switchyard "D" have been decommissioned.

2.4 Rietkuilspruit / Rietspruit System

The Rietkuilspruit and Rietspruit systems form part of the receiving environment for surface water on the western side of the IVS Works. Treated effluent and stormwater flow from the Works into the Rietspruit canal. Water flows for approximately 5 km in the canal before it enters the Rietkuilspruit. The Rietkuilspruit flows for a further 1.3 km to the West before it joins into the Rietspruit. The Rietspruit and Rietkuilspruit catchments are described in **Section 2.2.2** and **Section 2.2.3** respectively. The water quantities and qualities associated with each of these catchments will now be reviewed.

2.4.1 Rietkuilspruit

The primary source of water, for the Rietkuilspruit, at the point where it enters its natural drainage path is a stormwater canal from the town of Vanderbijlpark. This water flows towards IVS from the south, along the south-western boundary of the Works. At a point approximately 400 m north of the TETP the stream turns and follows its natural drainage path. There are two existing dams along the length of the Rietkuilspruit. A third dam situated upstream from the two existing dams was decommissioned during 2001.

Water Quantity

The Rietkuilspruit is a small stream with little to no flow during dry weather conditions. No flow monitoring takes place in this stream. IVS monitors their surface water release into the Rietspruit canal and the volume of water that flows from the Rietspruit canal into the Rietkuilspruit is therefore known.

Water Quality

There are eleven grab sample monitoring points within the Rietspruit/Rietkuilspruit system. Seven of these monitoring points are in the Rietkuilspruit, three are in the Rietspruit and one is in the Rietspruit canal. The analyses of water quality from the monitoring point in the canal (RS7) have already been reviewed in the evaluation of the water qualities at the western discharge point of the Works.

The seven grab sampling points in the Rietkuilspruit include RS0, RS1 RS2, RS3, RS4, RS5 and RS8. The position of the points are indicated on **Figure 1** RS0 was introduced during

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February 2002. This point is situated in the Rietkuilspruit upstream of the IVS works. Only a limited amount of data is therefore available for the year of analysis. The water quality results at RS0 give an indication of what the quality of the water is before it flows past the IVS works.

RS1 is situated at the point where the stream turns ninety degrees from the south-western perimeter of the Works and where it flows under the Golden Highway. RS2 is the grab sampling point where the first dam in this catchment was situated before it was decommissioned. RS3 and RS4 are monitoring points at the second and third dams in the Rietkuilspruit catchment respectively. RS5 and RS8 are situated in the Rietkuilspruit before and after the confluence of this stream with the Rietspruit canal respectively. The analyses of the water samples at these monitoring points are contained in **Appendix 5**.

Also contained in **Appendix 5** are box and whisker plots for each water quality parameter. These graphs represent the various water quality parameters in the Rietkuilspruit as the water flows in a westerly direction, utilising the data from the grab sampling points in the receiving environment. In these graphs, the maximum, 95-percentile, median and minimum concentrations are plotted for each grab sampling point. RS1 is the point in the stream where the Rietkuilspruit turns and flows under the Golden Highway. From this point the flow follows the natural drainage path to the west. The monitoring points in the Rietkuilspruit and canal are presented first, followed by the three monitoring points in the Rietspruit.

For a review of the EC qualities for the monitoring points in the Rietkuilspruit, refer to the EC plot for the Rietspruit/Rietkuilspruit system. It is evident from the plot that the water quality in the Rietkuilspruit progressively deteriorates as the water flows from RS1 to RS4. Also shown is the Preliminary Reserve and Resource Class Determination water quality limit for EC. The limit corresponds to a TDS value of 1000 mg/l (EC = 154 mS/m).

The EC value decreases as the water flows from RS4 to RS5. From RS5 to RS8 the water quality improves significantly. It is between these points that water from the Rietspruit Canal enters the spruit. Since the volume emanating from the canal is significantly more than the flow volume in the stream, the poor quality water in the Rietkuilspruit is diluted to almost the same quality water obtained in the canal.

When reviewing the other parameters analysed for at these points it is evident that several parameters which constitute the dissolved salts show the same trend of water quality deterioration along the length of the Rietkuilspruit. Parameters which exhibit this trend include:

- Calcium;

- Magnesium;
- Chlorides;
- Sodium;
- Sulphates; and
- Manganese.

There is clearly a source of contamination along the path of the Rietkuilspruit in the vicinity of RS3 and RS4. There are no surface water inflows into the Rietkuilspruit along its path through the agricultural holdings.

A possible source of this deterioration in quality along the stream was sought in the sediments of dam 1 (before it was decommissioned). The results analyses on the sediments, which are contained in **Appendix 19**, indicate that the sediments are not contaminated and can therefore not explain the that there must be another source of contamination within the Rietkuilspruit catchment.

Integration between the surface water findings and those obtained from the geohydrological and toxicological studies showed that the source is likely to be contaminated groundwater situated to the south of the Rietkuilspruit. This area was previously used as an irrigation area for the small holding owners. The water used for irrigation originated from the Rietspruit canal. The source of the contaminated groundwater is a historic one, since all irrigation practices have been discontinued in the area. For a detailed description of the groundwater system and its dinamics in the area, the reader is referred to the Master Plan specialist reports on geohydrology and source characterisation.

The Rietkuilspruit flows into the Rietspruit. The effect of water quality and quantity contribution of the Rietkuilspruit on the Rietspruit is now reviewed in more detail.

2.4.2 Rietspruit

The Rietspruit catchment is described in **Section 2.2.2**. The flow volumes in this river, together with the associated water qualities, will be reviewed in this section.

Water Quantity

Rand Water monitors a gauging station in the Rietspruit. This weir, known as RV2, is situated approximately 1.3 km north of Loch Vaal, approximately 200m below the confluence of the Rietspruit and the Klein Rietspruit. The catchment areas of the Rietspruit and Klein Rietspruit

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are approximately 1398 km^2 and 199 km^2 respectively. If assumed that the flow measured at RV2 is proportional to the the catchment areas, it means that 12.5% of the water volume measured cones from the Klein Rietspruit and 87.5% from the Rietspruit. Due to continuous inflows from, for instance the Rietspruit canal and the Vanderbijlpark sewerage treatment works, this split would probably be closer to 7% from the Klein Rietspruit and 93% from the Ritspruit.

Flow data for the Rietspruit has been obtained from Rand Water for the monitoring point RV2. **Table 55** provides the maximum, minimum and average flows provided by Rand Water for each month during the year of analysis. Utilising the average values the monthly total flows were estimated. All of the data obtained from Rand Water for the monitoring point RV2 is contained in **Appendix 7.**

Table 55: RV2: Summary of Flows in the Rietspruit

Date	Average flow (m^3/s)	Maximum flow (m^3/s)	Minimum flow (m^3/s)	Total Flow (m^3)
Mar 2001	2.66	3.81	1.82	7 124 544
Apr 2001	2.49	2.98	1.69	6 454 080
May 2001	3.09	3.81	2.23	8 276 256
Jun 2001	2.78	3.81	2.09	7 205 760
Jul 2001	2.42	3.47	1.96	6 481 728
Aug 2001	2.29	2.83	1.69	6 133 536
Sep 2001	2.47	3.81	1.69	6 402 240
Oct 2001	2.56	3.81	1.32	6 856 704
Nov 2001	3.29	3.81	1.96	8 527 680
Dec 2001	3.71	3.81	2.83	9 936 864
Jan 2002	2.66	3.81	1.44	7 124 544
Feb 2002	3.4	3.81	2.09	8 225 280
Total				**88 749 216**

The total volume of water measured at RV2 in the Rietspruit was approximately 88 749 216 m^3. The total volume of water discharged during the year of analysis at AH4 was approximately 18 124 683 m^3. If the flow at RV2 is split to 7/93%, it means that the total runoff from the Rietspruit would have been approximately 82 536 770 m^3. The flows in the Rietspruit would therefore be almost five times greater than in the Rietspruit canal.

Water Quality

When evaluating the water qualities in the Rietspruit the applicable WQOs or target water quality concentrations for the catchment should be taken into account. One set of values against which the water qualities in the Rietspruit can be evaluated is the Water Quality Reserve

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values contained in the Preliminary Reserve and Resource Class Determination. In addition, interim and management target water quality values have been set for the Vaal River at the Barrage. These values are contained in **Table 56**.

Table 56: Vaal Barrage Water Quality Objectives

Parameter	Units	Preliminary Reserve and Class Determination	Interim Target	Management Target
Chlorides	mg/l	200	75	50
Electrical Conductivity	mS/m	154	70	30
Iron	mg/l	-	1	0.5
Manganese	mg/l	-	0.2	0.15
Nitrates and Nitrites	mg/l	-	6	3
Sodium	mg/l	166	100	50
Sulphates	mg/l	360	200	100
Ammonia	mg/l	< 0.1	1	0.5
Calcium	mg/l	80	150	70
Potassium	mg/l	46	25	15
Magnesium	mg/l	17	70	30
Chromium (total)	mg/l	-	0.05	0.03
Zinc	mg/l	-	0.2	0.1

It is important to note that IVS are not the only contributors to the salt load in the Rietspruit. Several mining, industrial and agricultural enterprises exist within the catchment, and form part of the WUA, Rietspruit Forum. Lists of the interested and affected parties within the catchment that form part of the Rietspruit Forum are contained in **Appendix 20**. Of the grab sampling points in the Rietspruit one is upstream of the confluence of the Rietspruit and Rietkuilspruit (RS6), and two are downstream (RS9 and RS10). The positions of these monitoring points are shown on **Figure 1**. The data appertaining to these monitoring points is contained in **Appendix 5**. Also contained in this appendix are box and whisker plots per parameter for all of the monitoring points, as well as graphs of the each water quality parameters for each sampling point during the year of analysis.

In addition to the data collected from IVS, grab sampling data is also available in the Rietspruit from Rand Water. The following table, **Table 57**, presents a summary of the water qualities in the Rietspruit, as monitored at Rand Water's monitoring point RV2. These statistical values were calculated from the bi-weekly grab sampling data obtained from Rand Water for the year of analysis. Various other water quality parameters were also monitored in the Rietspruit. These include other physical, microbial and biological constituents. This data is contained in **Appendix 5**.

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Table 57: RV2: Summary of Water Qualities in the Rietspruit

Parameter	Units	Maximum	95-percentile	Median	10-percentile
Electrical Conductivity	mS/m	105	98.75	85	43
Dissolved Oxygen	mg/l O_2	11	6.295	4.2	0.5
Hardness	mg/l $CaCO_3$	330	308.5	265	130
M Alkalinity	mg/l $CaCO_3$	125	105	93	71
PH	-	8.3	8.2	7.7	7.3
TDS	mg/l	1500	710	590	290
Aluminum	mg/l	0.33	0.278	0.1	0.1
Boron	mg/l	0.64	0.4485	0.1	0.1
Bromide	mg/l	3.3	1.9425	0.455	0.25
Calcium	mg/l	90	87.85	71.5	31
Chlorides	mg/l	125	115	75	24
Copper	mg/l	0.05	0.05	0.05	0.05
Fluorides	mg/l	11	3.44	0.73	0.44
Iron	mg/l	0.24	0.1285	0.05	0.05
Potassium	mg/l	13	12	8.5	5.1
Magnesium	mg/l	27	25.85	21	13
Manganese	mg/l	0.25	0.1785	0.05	0.05
Sodium	mg/l	66	55	39.5	12
Ammonia	mg/l	3.6	2.35	0.27	0.05
Nitrite	mg/l	2.8	0.666	0.28	0.03
Nitrate	mg/l	8.4	8.1	5.25	1.3
Phosphorus	mg/l	2.7	2.2	1.4	0.25
Silicon	mg/l	7.3	6.8	5	22
Sulphates	mg/l	240	228	180	3
Zinc	mg/l	1.2	0.101	0.05	0.05
Cadmium	mg/l	0.05	0.05	0.05	0.05
Cobalt	mg/l	0.06	0.06	0.06	0.06
Chromium	mg/l	0.05	0.05	0.05	0.05
Molybdenum	mg/l	0.05	0.05	0.05	0.05
Nickel	mg/l	0.05	0.05	0.05	0.05
Lead	mg/l	0.05	0.05	0.05	0.05
Vanadium	mg/l	0.05	0.05	0.05	0.05
COD	mg/l	33	30.8	19	10
DOC	mg/l	21	10.525	6.35	4.5
TOC	mg/l	9.3	9.025	6.45	3.4

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A review of the water qualities in the Rietspruit, contained in this table will be evaluated in the following section. In this section an analysis will be performed of the change in water quality in the Rietspruit as a result of the flow from the Rietkuilspruit (and Rietspruit canal).

Dilution Analysis

Two sets of dilution analyses have been performed at the confluence of the Rietkuilspruit and Rietspruit. For the initial analysis the grab sampling data from RS6, RS8 and RS9 was used. For the second dilution analysis the flow and water quality data from AH4, and the flow and grab sampling data from Rand Water's point RV2 was used. The two sets of data have been evaluated simultaneously, per element.

Appendix 8 contains box and whisker plots for monitoring points RS6, RS8, RS9 and RS10. These plots represent the maximum, 95-percentile, median and minimum water quality parameter values for the year of March 2001 to February 2002. The grab sampling points in the Rietspruit/Rietkuilspruit System are located as follows:

- RS8 – This monitoring point is situated in the Rietkuilspruit after the confluence with the Rietspruit Canal, but before the confluence with the Rietspruit;
- RS6 – This monitoring point is situated in the Rietspruit before this river's confluence with the Rietkuilspruit;
- RS9 – This monitoring point is situated in the Rietspruit, downstream of RS6, and after this river's confluence with the Rietkuilspruit;
- RS10 – This monitoring point is situated in the Rietspruit downstream of RS9.

Also contained in **Appendix 8** are line graphs indicating the median levels of the various water quality parameters throughout the year of analysis as determined using AH4 and RV2 data. There are several assumptions that were made when this data was evaluated, and these must be considered in conjunction with the presented results. These assumptions include the following:

- No flow data is available for the Rietkuilspruit. The flow volume emanating from the Rietspruit canal is assumed to be the combined flow of the Rietkuilspruit and the Rietspruit canal. This assumption is justified by the fact that the flow in the Rietkuilspruit is very low in comparison with that in the canal during dry weather conditions (when the samples were taken).
- The water qualities at AH4 have been taken to represent the water qualities in the Rietkuilspruit just before the confluence of this stream with the Rietspruit. This was done to use the combined flow and water quality data from AH4. This assumption is justified

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by the similarity in the water qualities at RS7 and RS8, due to the significant dilution of flow in the Rietkuilspruit.

- The flows in the Rietspruit at RV2 represent the combined flows in the Klein Rietspruit and the Rietspruit. The flow volume in the Rietspruit before the confluence of these two rivers was determined by reducing the total monthly flow proportionately utilising the ratio of the two river's catchments. This assumption was utilised due to the direct relationship between the estimated runoff from a catchment and its surface area with bias towards flow in the Rietspruit due to reasons explained above.
- The water qualities determined at RV2 are assumed to be the same as those directly downstream of the confluence of the Rietspruit and Rietkuilspruit. This assumption was made due to the absence of better data that was associated with the flows monitored by Rand Water. It could be argued that RS9 or RS10 data could have been utilised, but this was not done in order that the two methods of dilution analysis could be compared.
- Where no grab sampling data was available for a specific water quality parameter, the concentration was assumed to be equal to that of the previous month.

Utilising the AH4 and RV2 data, it was determined that the flow in the Rietspruit immediately after the confluence is approximately 4.3 times greater than the flow in the Rietkuilspruit. Only four water quality parameters have been evaluated utilising this method in order to provide a comparison to the RS6, RS8, RS9 and RS10 data.

The impact of the Rietkuilspruit on the Rietspruit will now be reviewed, per water quality parameter, with reference to the aforementioned dilution analyses.

<u>pH</u>

The pH is very constant in the Rietspruit and the Rietkuilspruit. The water is slightly alkaline, with a median pH value in the region of 7.5.

<u>Electrical Conductivity</u>

The EC in the Rietkuilspruit (RS8) is above the Preliminary Water Quality Reserve value of 154 mS/m (1000 mg/l), although the EC in the canal predominantly complies with the WQO for the western release. The EC in the Rietspruit before the confluence is predominantly below 70 mS/m, and this value is raised to approximately 90 mS/m after the confluence.

The result from the AH4/RV2 analysis shows the same trend. Exceptions are during the months of December 2001 and January 2002 where the EC values in the Rietkuilspruit were below

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100 mS/m. This analysis indicates that, on average. the Rietkuilspruit raises the EC value (in mS/m) by approximately 37.7 %, and that this stream increases the total salt load in the Rietspruit by a factor of 1.9.

Sulphates

The sulphate concentration in the system indicates the same trend as the EC. The sulphate concentration in the Rietkuilspruit is typically about 300 mg/l (RS8). The typical sulphate concentration in the Rietspruit before the confluence was about 170 mg/l, and this value was raised to close to 200 mg/l after the confluence.

The AH4/RV2 analysis provides lower sulphate concentrations in the Rietkuilspruit. This is probably due to the assumption that neglects the actual Sulphate values measured in the Rietkuilspruit (which show high sulphate values before the confluence with the Rietspruit canal). The sulphate values in the Rietspruit before and after the confluence are however very similar to the results obtained from the RS monitoring point evaluation. These results indicate that the Rietkuilspruit increases the sulphate concentration in the Rietspruit by 19.4 %, and the sulphate load in the river by a factor of 1.6.

Chlorides

The chloride concentration at RS8 is typically about 220 mg/l. This water raises the chloride concentration in the Rietspruit from below 50 mg/l to just about 90 mg/l. This indicates that the chloride concentration in the Rietspruit is raised significantly by the Rietkuilspruit. The AH4/RV2 analysis indicates that the Rietkuilspruit significantly raises the chloride concentration in the Rietspruit. The average chloride level in the Rietspruit before and after the confluence was 29.4 mg/l and 78 mg/l respectively. This indicates that the average chloride concentration increased by a factor of 2.65.

Manganese

The manganese concentration in the Rietkuilspruit is typically about 0.2 mg/l, although the maximum level during the year was above 1 mg/l. This concentration raises the manganese level in the Rietspruit slightly. This data is based on annual data. The AH4/RV2 data, which is presented monthly, indicates that the Rietkuilspruit raises the manganese level in the Rietspruit for the first four months analysed. For the remaining months of the year (excluding January 2002) the manganese level in the Rietspruit actually improves as a result of the Rietkuilspruit flow.

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Iron

The RS data indicates that the iron levels in the Rietspruit are similar, but higher, to those in the Rietkuilspruit. Downstream of the confluence the iron levels are above 3 mg/l for at least 95 % of the time. This does not add up since the Rietspruit and its tributary at this point have significantly lower iron levels than measured downstream. The only explanation is that there must be an external source of iron between the confluence and the monitoring position RS9.

Other Parameters

Plots of the annual maximum, 95-percentile, median and minimum concentrations of several other parameters are included in **Appendix 8**. Many of these parameters exhibit the same trends as EC, sulphates and chlorides where the concentration of the specific parameter in the Rietspruit is raised significantly by the salt load in the Rietkuilspruit. Parameters for which this is true are fluorides, sodium, nitrates, nitrites, ammonia, calcium, magnesium, chromium and potassium.

2.5 Leeuspruit System

The Leeuspruit catchment has been described in detail in **Section 2.2.4**. IVS has six grab sampling points in the Leeuspruit, which the eastern catchment of the Works discharges into. The first of these, LS1, is situated immediately downstream of the Frikkie Meyer weir. This is the most important monitoring point for IVS in the Leeuspruit catchment, and has been reviewed in the analysis of the eastern discharge water quality.

The data obtained from the other five grab sampling points in the receiving environment of the eastern catchment is contained in **Appendix 10**. The water quality deteriorates as the flow moves down the Leeuspruit due to the presence of several industries, informal settlements and a sewage works in the catchment. These all contribute to the contamination in this river. From a surface water perspective, the impact of IVS on the Leeuspruit system is limited to LS1, and the other grab sampling data is therefore not evaluated in detail. This review of the Leeuspruit system forms the end of the baseline study for surface water. This baseline study essentially describes the current situation at IVS, or the current status of surface water qualities and flow volumes. The impacts associated with the data assimilated will now be ascertained from a surface water perspective.

3. IMPACT ASSESSMENT

The baseline investigation has shown that surface water emanates from the IVS Works. This water has an impact on two surface water systems, namely the Rietspruit/Rietkuilspruit and Leeuspruit systems. The impacts will be quantified individually.

3.1.1 Rietspruit

In terms of flow volume, approximately 18 124 683 m^3 flows down the Rietspruit canal annually. This discharge constitutes approximately 23 % of the volume flowing in the Rietspruit downstream of the confluence of the Rietspruit and Rietkuilspruit.

An analysis of the water qualities at the confluence of the Rietspruit and Rietkuilspruit indicated that on average the Rietkuilspruit raises the EC value (in mS/m) in the Rietspruit by approximately 37.7 %, and that this stream increases the total salt load in the Rietspruit by a factor of 1.8.

3.1.2 Rietkuilspruit

The typical dry-weather flow in the Rietkuilspruit amounts to a trickle. The flow from the Rietspruit canal is constant and the annual average daily flow amounts to approximately 2000 m^3/h. The discharge from IVS therefore has a major impact on the flow volume in the portion of the Rietkuilspruit between the confluence of this stream and the Rietspruit canal and the Rietspruit.

Historic irrigation with the effluent water from the Rietspruit canal in the Louisrus South area has resulted in groundwater contamination within this area. This contaminated groundwater is seeping into the Rietkuilspruit stream bed and causes a deterioration in the water quality in the Rietkuilspruit. The impact is predominantly between the second and third dams in the Rietkuilspruit.

Water emanating from the Rietspruit canal actually improves the water quality in the Rietkuilspruit in terms of concentration. It however adds significantly to the salt load in the stream due the significantly larger flow in the canal.

3.1.3 Leeuspruit

Due to the construction of the Frikkie Meyer weir and return pump house, the volume of water discharged from the Works has significantly decreased to the order of 11% of rainfall within the

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catchment. During dry-weather conditions there is zero flow from the Works into the Leeuspruit. During storm events the weir is overtopped and flow enters the Leeuspruit. A total of at least 194 388 m^3 was measured over the weir during the year of analysis, however this figure is subject to an unreliable data record.

In terms of water quality, the discharge over the Frikkie Meyer weir is generally in compliance with the water quality objectives for the eastern catchment. Parameters that do present problems include iron and sulphates.

4. RISK ASSESSMENT

In keeping with the risk based approach of the Master Plan investigation, a risk assessment was performed by Ockie Fourie Toxicologists (OFT) to quantify the potential risk of the water emanating from the Works on human health and the environment.

4.1 Human Health

In order to determine the chronic effect of the water emanating from the Works on human health the median concentrations of the analysed water quality parameters were evaluated. The potential risk quantification was performed for a 60 kg individual. It was assumed that this individual drank two litres of this water every day of their lives, for their whole lives.

Where possible the internationally published toxicological limits, as required by DWAF Minimum Requirements, were utilised for the analysis. Where these limits were not available the acceptable risk level was derived from the SADWS MGV by OFT. It must be noted that this method is very conservative, since these limits are often specified for nuisance and not toxicological reasons. The results of these analyses are contained in **Appendix 15**.

4.1.1 Vaal River

The Vaal River water is utilised as industrial intake water by IVS. In evaluating the potential chronic risk of Vaal River water to human health, it was determined that there is an acceptable risk to humans who drink this water.

4.1.2 Rietspruit

The potential risk associated with the water in the Rietspruit, both upstream and downstream of the confluence of this river and the Rietkuilspruit, was quantified (the data from grab sampling points RS6 and RS9 was utilised). It was determined that there is an acceptable risk to humans who drink the water in the Rietspruit, either upstream or downstream of the confluence of this river and the Rietkuilspruit.

When evaluating the results it was noted that the iron levels indicated an unacceptable margin of safety. Further investigation showed that because the ARL was derived from the SADWS MGV this risk quantification was extremely conservative. This was determined by comparing the acceptable daily intake value to the acute lethal dose for humans. This evaluation showed that it is impossible, for the iron concentrations in the Rietspruit, to acquire the lethal dosage of iron.

4.1.3 Rietkuilspruit

In the Rietkuilspruit it was found that there is a potential risk to humans who take this water in orally. The parameters that indicate this potential risk include chlorides, calcium, sulphates, fluorides, manganese and iron. The greatest potential risk to human health is associated with manganese.

4.1.4 Leeuspruit

In the Leeuspruit it was found that there is a potential risk to humans who take this water in orally. The risk in this catchment is associated with the iron levels in the water.

4.2 Environment

The potential risk of water in the Vaal River, Rietspruit, Rietkuilspruit and Leeuspruit to the environment was also quantified.

4.2.1 Vaal River

It was determined that there is an acceptable risk to the environment in terms of Vaal River water.

4.2.2 Rietspruit

It was determined that there is an acceptable risk to the environment in terms of Rietspruit water, both upstream and downstream of the confluence of this river with the Rietkuilspruit.

4.2.3 Rietkuilspruit

Similar to the quantification of the risk to human health of the water in the Rietkuilspruit, it was determined that water in this stream presents a potential risk to the environment. The parameters that indicate this potential risk include chlorides, calcium, sulphates, fluorides, manganese and zinc. The greatest potential risk to the environment is also manganese.

4.2.4 Leeuspruit

The cyanide levels in the water monitored passing over the Frikkie Meyer weir indicate that there is a potential risk to the environment.

5. MANAGEMENT OBJECTIVES

Within this section the management objectives appertaining to surface water within the site and its receiving environment will be reviewed. Environmental management objectives have been divided into two categories, namely:

- Primary surface water management objectives; and
- Secondary surface water management objectives.

Primary surface water objectives are generic for any industry and are non-value based. They are independent of any time frame, and are in keeping with the Acts, policies and regulations of the Republic of South Africa.

Secondary environmental objectives are site specific, and must support the primary objectives. These objectives are non-generic, and are often value based. Secondary objectives are dependent on the outcomes of the baseline investigation, impact assessment and risk assessment. Different objectives can be set for the short, medium and long term and these will form the basis upon which the environmental management measures will be proposed. Secondary objectives for a specific site are developed by the industry, consultants and regulating authorities.

5.1 Primary Surface Water Objectives

The primary objective in managing surface water at IVS is that any surface water flowing out of the Works into the receiving environment does not pose a potential unacceptable risk to human health or the environment.

5.2 Secondary Surface Water Objectives

Various site specific objectives have been set for IVS. These objectives will be described per management area. The first of these areas is the CRMF.

5.2.1 Consolidated Residue Management Facility

The main philosophy of the CRMF is to manage the site as a single unit under one permit. From a surface water viewpoint it is important to separate clean and dirty runoff, and to maximise the runoff of uncontaminated runoff from the site. In order to assist this goal the existing impacted areas will be either rehabilitated, or consolidated and placed on bunded impermeable surfaces in order to manage and limit their impact.

5.2.2 Consolidated Plant Area

The main site specific objective from a surface water perspective, within the South and North Works, is that stormwater and effluent flows are separated. Other goals within the plant are to maximise the reuse of effluent, and to minimise the intake of water. This will mean that less surface water is generated within the site. Bunding of potential sources of contamination at source in order to promote the runoff of uncontaminated storm flow is also recommended. A comprehensive environmental training program is proposed for employees of IVS whereby they obtain an understanding in the macro to micro management plans for the site.

5.2.3 Slag Processing Areas

The objectives within these two areas are to consolidate activities and prevent surface water ponding. In addition the surface water should be prevented from infiltrating into the ground and becoming groundwater, since this creates a transferral of secondary contamination. Surface water contaminated within these areas should be managed within these areas and not allowed to flow over the boundary of the respective slag processing areas.

5.2.4 TETP/MTP Area

At the western discharge point, the site specific objective is for the Works to be Zero Effluent Discharge. This means that no effluent will enter the Rietspruit canal. A second objective for this compliance point is to develop a stormwater monitoring point that will allow the real-time management of stormwater during storm events. This is necessary to allow water that complies with the WQOs to be discharged without being contained.

5.2.5 Kiewiet Area

In the Kiewiet area the site specific objective is that surface water flowing towards the CRMF from this area should be diverted from its flow path such that runoff generated within the Kiewiet area does not enter the CRMF.

5.2.6 Receiving Environment

The objective for the Rietkuilspruit is to prevent historic groundwater pollution from mixing with the surface water in the Rietkuilspruit. Further, the eastern and western discharges from the Works must be monitored in accordance with the current water licence, and the grab sampling programme in the Leeuspruit, Rietkuilspruit and Rietspruit must be maintained. The Rietspruit canal can be decommissioned since this structure is now redundant. Water can pass from the

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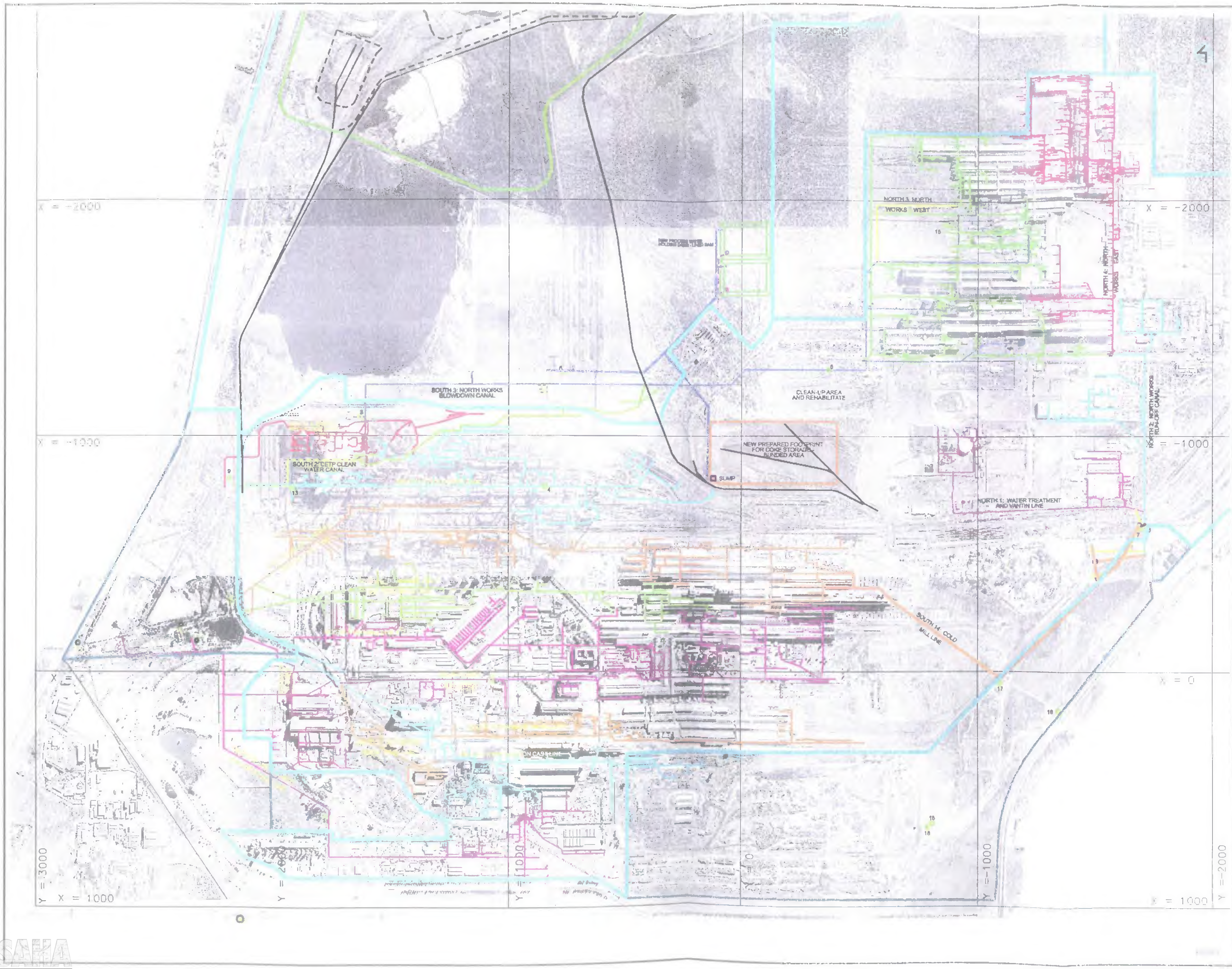

CLIENT

ISCOR flat steel

NOTES:

CO-ORDINATE SYSTEM ACCORDING TO ISCOR LOCAL GRID

LEGEND

Draft for discussion

COKIE FOURIE

PROJECT

ISCOR
VANDERBIJLPARK STEEL:
MASTER PLAN

DRAWING TITLE

MANAGEMENT AREA 2:
CONSOLIDATED PLANT AREA

DATE

SCALE

VAN RENSSEN & FORTUIN
CONSULTING ENGINEERS
RAADGEWENDE INGENIEURS

FIGURE 2

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NOTES:
CO-ORDINATE SYSTEM ACCORDING TO ISCOR LOCAL GRID

OCKIE FOURIE

PROJECT
ISCOR
VANDERBIJLPARK STEEL:
MASTER PLAN

DRAWING TITLE
MANAGEMENT AREA 1:
CRMF

SCALE 1:10000

VAN RENSSEN & FORTUIN
CONSULTING ENGINEERS

CVR — DESIGNED
GBS — CHECKED
JvdW — DRAWN
AO — CHECKED
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FIGURE 3

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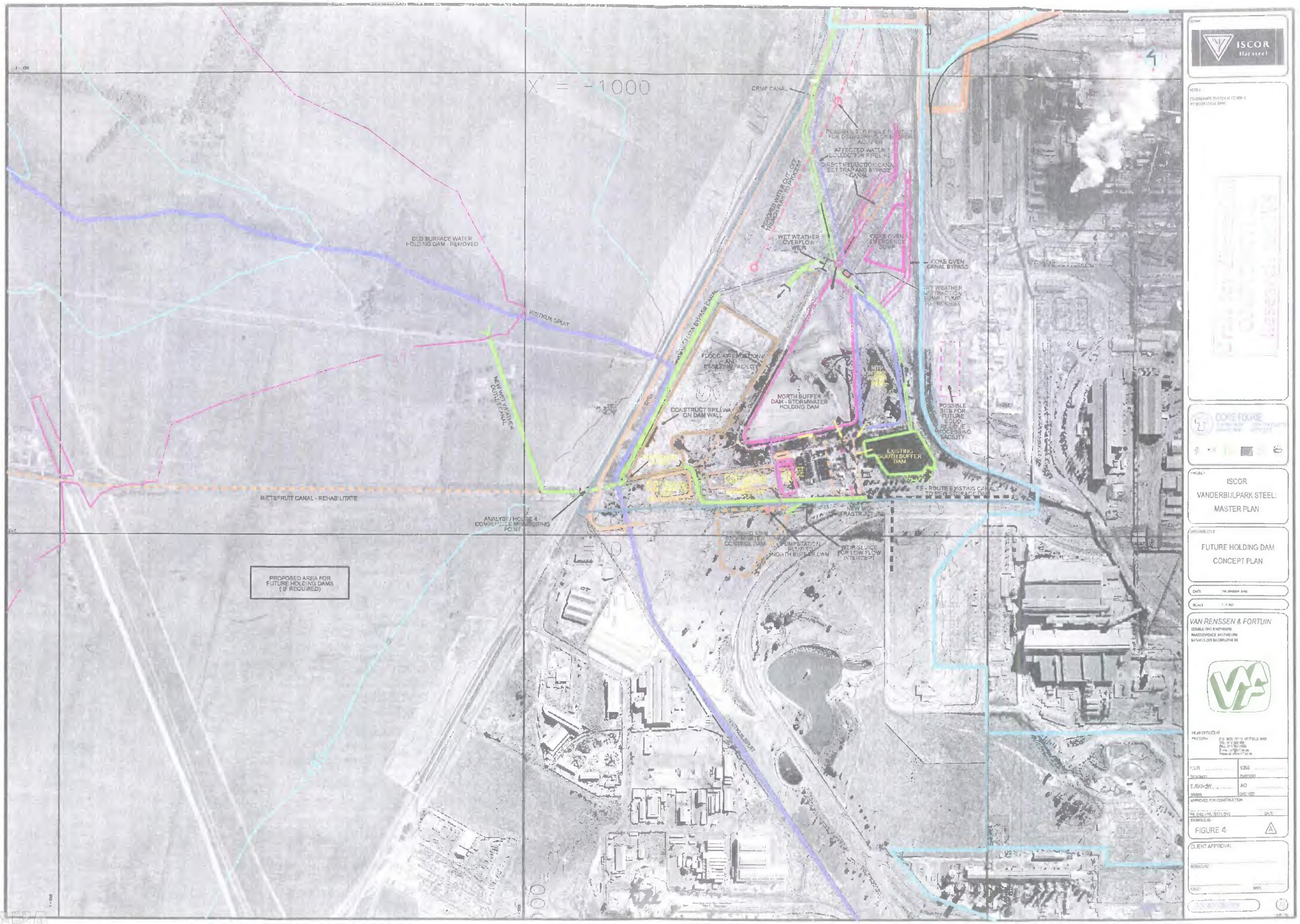
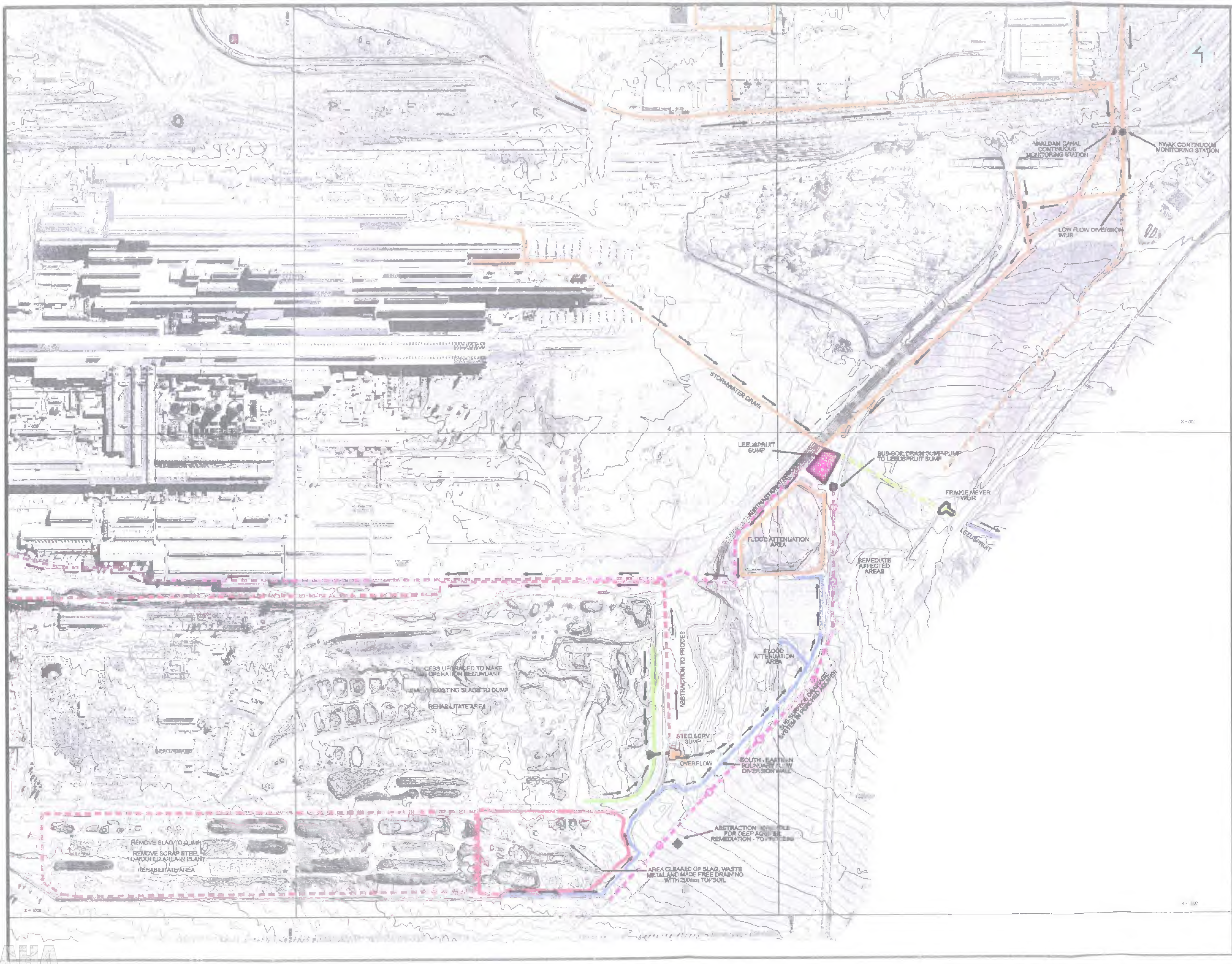


ISCOR flat steel
X = -1000
CRMF CANAL
AFFECTED WATER COLLECTION PIPELINE
DIRECT REDUCTION CANAL SILT TRAP AND BYPASS CANAL
WET WEATHER OVERFLOW WEIR
COKE OVEN EMERGENCY SUMP
COKE OVEN CANAL BYPASS
OLD SURFACE WATER HOLDING DAM - REMOVED
RIETKUIL SPRUIT
NEW WET WEATHER OUTLET CANAL
NORTH BUFFER DAM - STORMWATER HOLDING DAM
CONSTRUCT SPILLWAY ON DAM WALL
EXISTING SOUTH BUFFER DAM
POSSIBLE SITE FOR FUTURE SOLID RESIDUE PROCESSING FACILITY
RIETSPRUIT CANAL - REHABILITATE
PUMPSTATION PUMP TO NORTH BUFFER DAM
WEIR/SLUICE FOR LOW FLOW INTERCEPT
PROPOSED AREA FOR FUTURE HOLDING DAMS (IF REQUIRED)
ISCOR
VANDERBIJLPARK STEEL:
MASTER PLAN
FUTURE HOLDING DAM
CONCEPT PLAN
VAN RENSSEN & FORTUIN
FIGURE 4
CLIENT APPROVAL

SAHA



ISCOR

ISCOR
VANDERBIJLPARK STEEL:
MASTER PLAN

MANAGEMENT AREA 3:
SOUTH -EASTERN SLAG
AND OPEN VELD AREA

VAN RENSSEN & FORTUIN

CVR | OBS
EJB/AHW | AO

FIGURE 5

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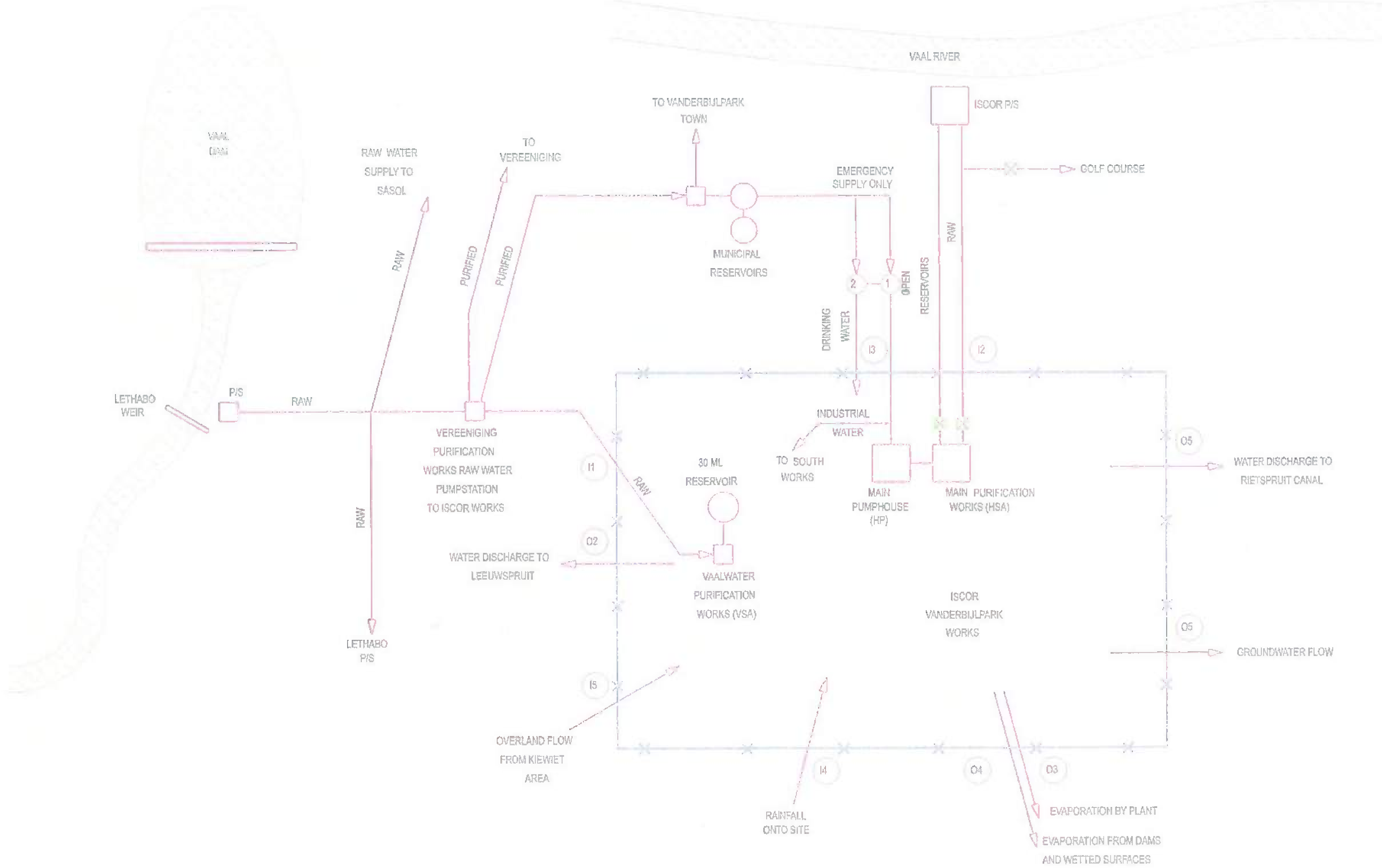

ISCOR flat steel

PROJECT

ISCOR VANDERBIJLPARK STEEL: MASTER PLAN

DRAWING TITLE

FIGURE 6 : OVERALL INDUSTRIAL SITE WATER BALANCE DIAGRAM

DATE

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FIGURE 6 A

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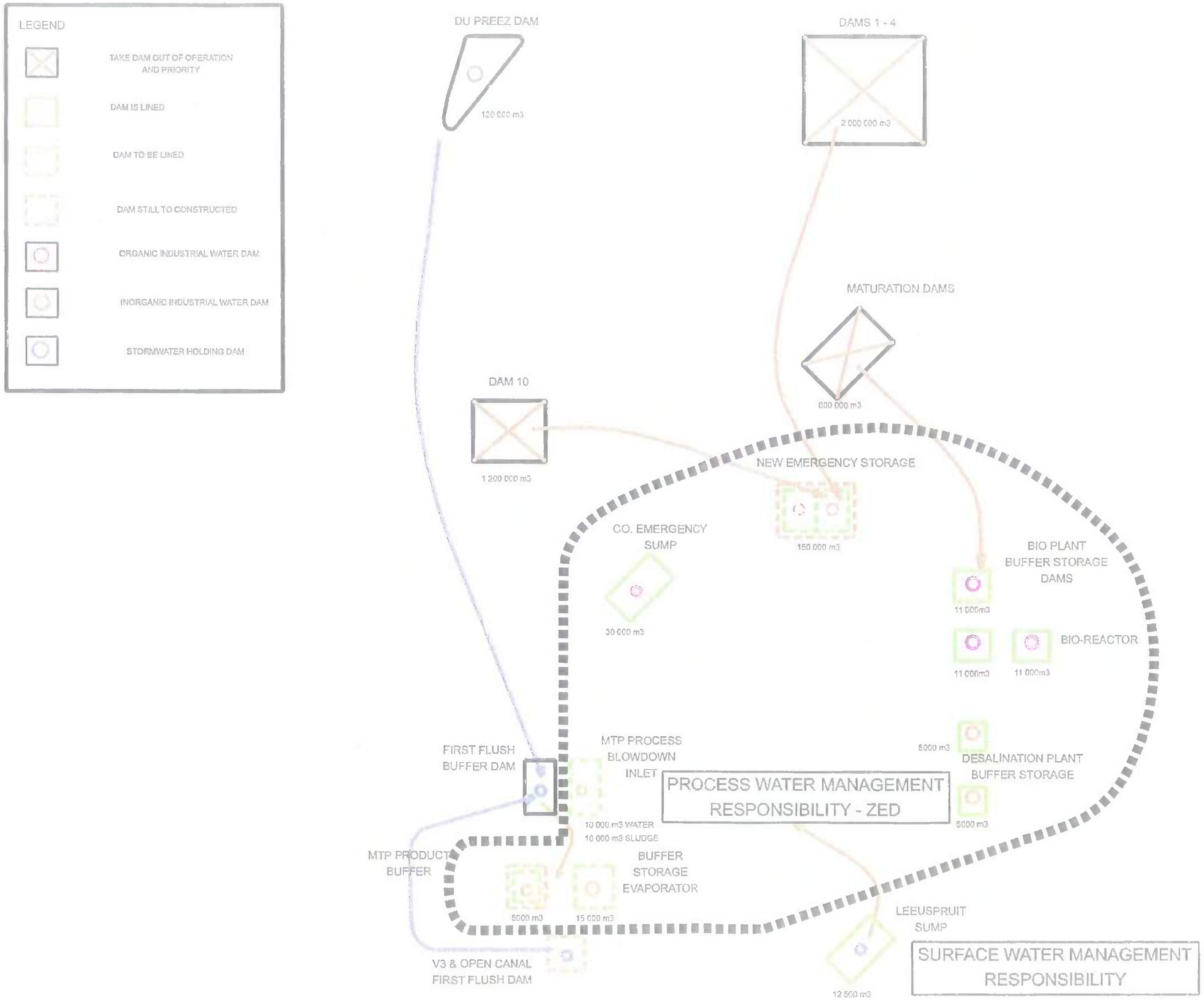

ISCOR flat steel

DOKE FOURIE

PROJECT
ISCOR
VANDERBIJLPARK STEEL:
MASTER PLAN

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FIGURE 7 : WATER STORAGE FACILITIES AT IVS

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FIGURE 7 A

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