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WATER, ENVIRONMENTAL, ENGINEERING & EARTH SCIENCE CONSULTANTS

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Date: 26 February 2007

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Attention: Mr. Greg Seymour

HYDROLOGICAL REPORT ON THE ENVIRONMENTAL IMPACT ASSESSMENT PHASE FOR THE ESKOM PUMPED STORAGE PROJECT IN THE STEELPOORT RIVER: PROJECT LIMA.

Herewith please find Report No BOH.06.121 with regards to the Hydrological characteristics for the mentioned project.

Yours faithfully

André Pretorius
Hydrological Engineer

Mark Stewart
Project Manager

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REPORT NO BOH.06.121

SURFACE WATER REPORT FOR THE ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED ESKOM STEELPOORT PUMPED STORAGE SCHEME: PROJECT LIMA

PRELIMINARY HYDROLOGICAL STUDY

Project Lima.

REPORT NO: BOH.06.121

Client: Bohlweki Environmental (Pty) Ltd.

PO Box 11784

Vorna Valley

MIDRAND

1686

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This report is not to be used for contractual or engineering purposes unless the Report is designated "FINAL"

By

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EXECUTIVE SUMMARY

ESKOM is currently in the process of planning the construction of a 1 000 MW pumped storage scheme along the escarpment between the Nebo Plateau and the Steelpoort River valley, close to the town of Roossenekal in the Limpopo Province (1: 50 000 Topographical Map Series 2529 BB Roossenekal).

This scheme will comprise of a hydroelectric power generation project, consisting of instream (other than the planned De Hoop dam) as well as an off-channel water storage dams. The locality as well as the storage capacity of these dams has been finalised, and a detailed feasibility study has been initiated in order to determine the optimum storage required with the relevant cost-benefit to the scheme.

It is proposed that the hydroelectric power generation process will be that of a pumped storage scheme. This is mainly because of the limited opportunities of generating hydropower from South African rivers. Surplus electricity generated from the thermal power stations during off-peak periods (usually at night), and for which there is no other use and which otherwise would be wasted, is used to pump water to high elevations from where it is then released to generate electricity for the peaks in demand. The effective use of hydro power stations requires them to operate intermittently for only a few hours a day during the peak demands for electricity.

No water quality sampling was available from the screening study, and therefore no background data was obtained for the Steelpoort River and its tributaries. All hydrological data was based on preliminary desktop analyses for the purposes of the Screening and Environmental Impact Assessment Studies. The "*Project Lima Supplementary Feasibility Study- Phase 1 Site Selection Study Main Report Volume 1"* conducted by BKS Palace Consortium during May 2006 as well as the Steelpoort Pumped Storage Scheme Phase 2:-*Hydrology*, conducted by BKS Palace Consortium during January 2007 was consulted for the purposes of this study.

A number of potential sites was identified and ranked during the Screening Study where-after the most suitable site was selected. These studies were undertaken by BKS Palace consortium. GCS (Pty) Ltd, were asked to only assess the Site A Option 3 since it was selected as the preferred site. This Option comprises of one upper off-channel storage reservoir as well as one instream lower reservoir.

This Report only covers potential surface water impacts that this development may have on surface water resources. The potential impacts for the preferred identified site were discussed based on current available information. It was found that most hydrological impacts as a result of this development would be medium, and much localised.

1 INTRODUCTION

ESKOM is in the process of planning the construction of a 1 000 MW pumped storage scheme along the escarpment between the Nebo Plateau and the Steelpoort River valley, close to the town of Roossenekal in the Limpopo Province (1: 50 000 Topographical Map Series 2529 BB Roossenekal).

This scheme will comprise of a hydroelectric power generation project, consisting of instream as well as off-channel water storage dams. Figure 1 below illustrates such a scheme.

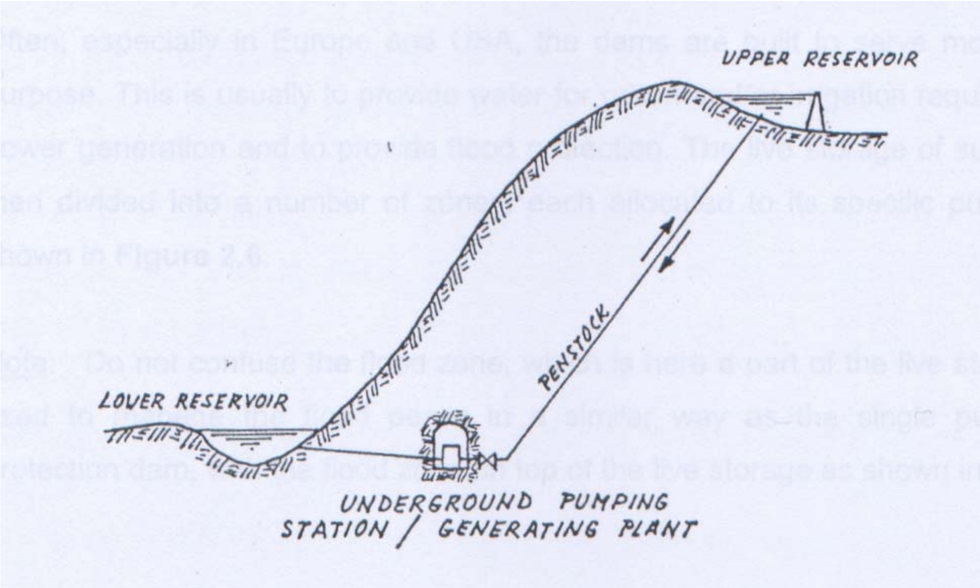

Figure 1 The schematic layout of a pumped storage scheme

No surface water quality sampling was conducted during the Screening Study, therefore no background data was obtained for the Steelpoort River and its tributaries where the activities are planned.

All hydrological data was based on desktop analyses for the purposes of the Environmental Impact Assessment Study. The "*Project Lima Supplementary Feasibility Study- Phase 1 Site Selection Study Main Report Volume 1"* conducted by BKS Palace Consortium during May 2006 as well as the Steelpoort Pumped Storage Scheme Phase 2:-*Hydrology*, conducted by BKS Palace Consortium during January 2007 was consulted for the purposes of this study.

This report only covers potential surface water impacts that this development may have on surface water resources.

1.1 Study Area

The study area comprises of various properties, which is located within the B41D Quaternary Catchment.

The properties involved are Portion 1 of the farm Keerom 151 JS for the upper off-channel reservoir and Portions 1, 3, 4, 5 and 7 of the farm Luiperdshoek 149 JS for the lower reservoir. Please refer to **Figure 2 for the layout of the scheme.**

The regional geology within the Quaternary Catchment comprises basic/mafic and ultramafic intrusive rocks. Soils in this region vary from moderate to deep sandy loam, with steep relief. Vegetation for this area comprises of savannah (Simplified Acock's Veld Types). The erodibility index is high (Value between 3 and 5) and has an estimated sediment yield (Region 1) which is in the order of 40 000 tonnes per annum. Preliminary studies regarding the sediment yield conducted for the proposed De Hoop dam indicate that the sediment yield for this region may be in the order of 250 $t/km^2/a$, for the Steelpoort River, and 300 $t/km^2/a$ for other minor streams.

The geology of the study area consists of granophyre in the upper section, leptite in the steeper middle section, and ferrogabbro in the lower section. The upper and middle sections have medium deep soils with rocky areas, and the lower parts of the study area deeper free draining soils. The upper and lower sections were considered to consist of permeable soils, while the steeper middle section was considered to consist of semi-permeable soils (1:250 000 Geological Map Series 2528 Pretoria).

1.2 Rainfall and Evaporation Data

Desktop rainfall and evaporation calculations and analyses were conducted during the Environmental Impact Assessment and results were compared with previous studies conducted by BKS Palace Consortium as part of their Hydrological Assessment.

Rainfall data was obtained from two meteorological stations namely Tautesberg (SAWS No 0553461) and Roossenekal (Department of Water Affairs and Forestry B4E004P01). Monthly S-Pan Evaporation Data was obtained from the Department of Water Affairs and Forestry Hydrological Information database for Roossenekal B4E004S01.

Tuatesberg has a mean annual precipitation (MAP) of 680 mm per annum and is located at 1652 meters above mean sea level, while Roossenekal has a MAP of 679.2 mm. Mean annual evaporation (MAE) for Roossenekal is measured at 1635.5 mm.

Rainfall values from Tautesberg were used in all calculations, while evaporation values from Roossenekal were used. The rainfall station at Tautesberg was considered to be more relevant to the study area.

Table 1 and **Figure 2** below illustrate the comparison between the mean monthly and annual rainfall and evaporation values.

Table 1: Mean Monthly Rainfall and Evaporation for the B41C Quaternary Catchment.

Month	Rainfall (mm) Tautesberg (SAWS 0553461) (1904-1999)	S-Pan Evaporation (mm) Roossenekal (B4E004S01) 1971-2005)
January	122.4	172.0
February	94.1	152.2
March	78.7	143.6
April	40.5	116.3
May	15.5	101.7
June	6.2	84.2
July	5.2	91.9
August	7.3	119.2
September	20.0	150.8
October	59.7	169.9
November	111.6	164.9
December	117.9	174.9
Mean Annual (mm)	**679**	**1636**

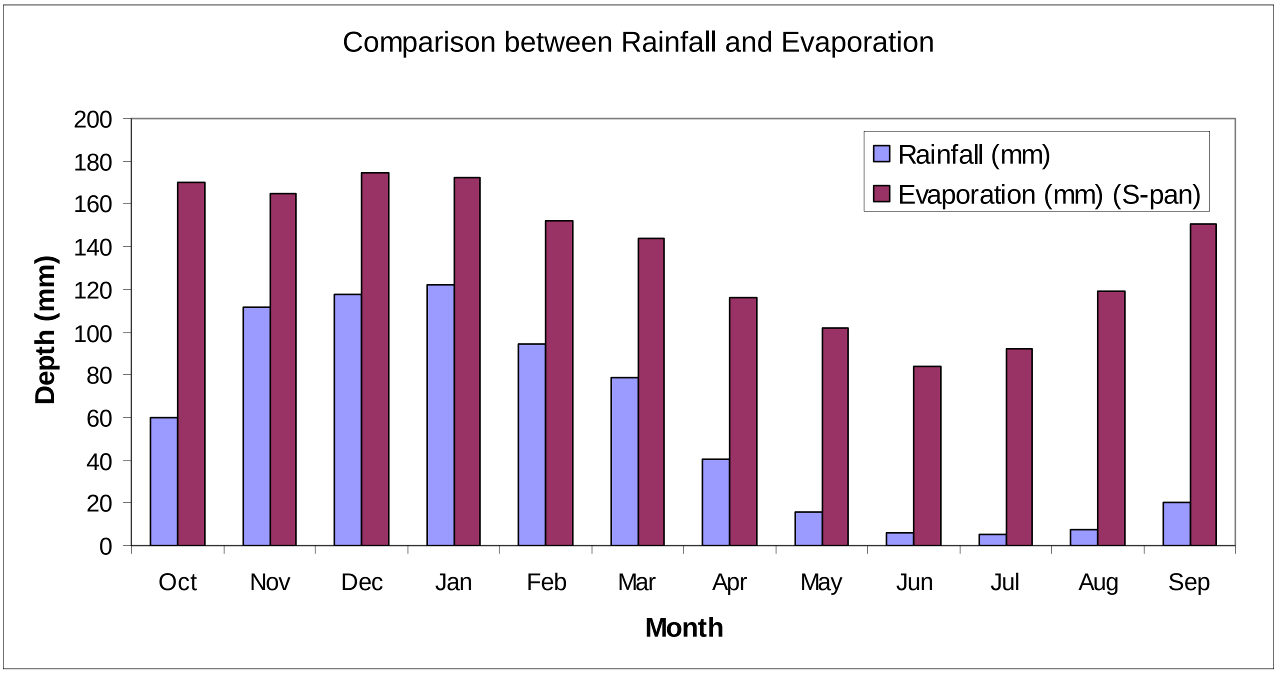

Figure 2: Comparison between Rainfall and Evaporation

Design Rainfall depths for a 24-hour (1 day) storm duration was obtained from various weather stations, situated close to the study area, and are listed in **Table 2** for the various return periods.

Table 2: Design Rainfall Depths

Station Name	Altitude (m)	MAP (mm)	Return Period (years)						
			2	5	10	20	50	100	200
Roosenekal (SAWS no. 0553672 W)	1440	668	50	69	83	97	116	131	147
Tonteldoos (SAWS no. 0553859 W)	1807	762	56	74	87	100	118	132	147
Ga-Sekukuneland (SWAWS no. 0593015 W)	1260	552	49	68	81	95	113	129	145
Glen Cowrie Mission “Morg” (SAWS no. 0592560 W)	1478	637	48	66	79	92	111	126	141
Note: Values was obtained from Design Rainfall Depths at Selected Stations in South Africa (Smithers, J.C. and Schulze, R.E., 2000b.)									

1.3 Surface Water Quantity

1.3.1 Catchment Boundaries

The study area is located within the Steelpoort River Catchment and its tributaries. The Steelpoort River catchment drains in a northerly direction and eventually flows into the Olifants River.

The study area is situated in the headwater to middle reaches of the tributary where most of the river flow is generated by direct precipitation. The headwater and upper regions are usually primary areas of sediment, supplied through weathering and down slope movement of weathered material. The confluence with the Steelpoort River is located approximately 300 m further downstream from the proposed lower reservoir.

The boundaries of the study catchment are occupied by some rural residential related activities, small scale farming activities, as well as game farming areas. The affected watercourse that would be impacted upon would be the Steelpoort River (and possibly the Olifants River).

Site A, Option 3, also known as the southern site, is located close to the current De Hoop Dam scheme was proved to be most feasible site, after the completion of the screening process, by BKS Palace Consortium. The site lends itself to both on and off-channel options for both the upper and lower reservoirs. **Figure 3** below illustrates the Catchment boundaries

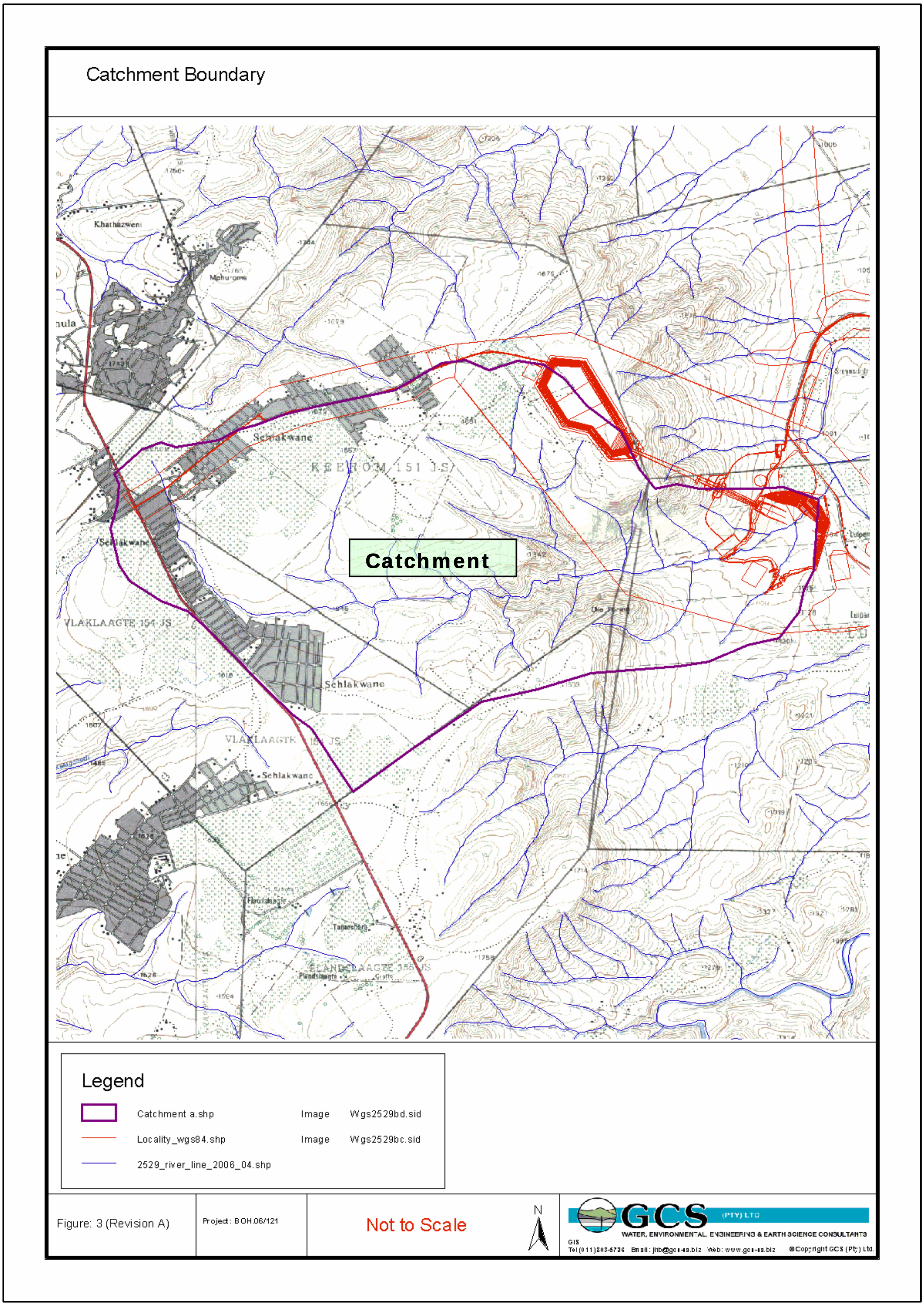

Figure 3: Illustration of the Catchment boundary

1.3.2 Virgin Mean Annual Runoff

The virgin mean annual run-off (MAR) for both Quaternary Catchment areas has been estimated. Water Research Commission publications *(Surface Water Resources of South Africa 1990- Volume 1)* were used to obtain the MAR for each Quaternary drainage regions. The B41D Quaternary Catchment has an estimated MAR of 16.6 x10^6 m^3 per annum.

The WRSM 2000 Model (Water Resources Simulation Model 2000) was used to model rainfall-runoff for the study area. Only rainfall-runoff simulations for the lower reservoir have been conducted. It was found that obtained results correspond closely with results obtained during the Hydrological Study conducted by BKS Palace Consortium. **Please note** that rainfall-runoff modelling for this study was conducted for the hydrological period from 1904 to 1999, while the study conducted by BKS Palace consortium was for the period from 1971 to 2003. The results between the two studies are illustrated in **Table 3** below. The model results may be indicating higher low flows than actually occur in the river. It should be noted that the results are based on regional parameters for the whole quaternary catchment (403 km^2), as there are currently no observed data against which to calibrate the model. These regional parameters do not take into account the processes that occur in smaller sub- catchments, such as seepage into the channel bed and banks during low flows.

Table 3: Mean Annual Runoff comparison

Catchment	MAR BKS Palace Consortium (Jan 2007)	MAR This Study
Lower Reservoir	1.1 x$10^6 m^3$/annum	1.6 x$10^6 m^3$/annum

Note: No actual stream flow data was obtained during this study to calibrate the model.

It can be seen from the above that the study area contributes between 6 % and 9 % to the MAR of the B41D Quaternary Catchment. **Table 4** below illustrates the Estimated Mean Monthly and Annual run-off

Table 4: Estimated Mean Monthly and Annual run-off for the study area

Estimated Mean Monthly and Annual Run-off																	
Study Area			Area (km^2)	Runoff in mm	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	MAR
					1.23	5.22	7.06	10.44	8.90	7.06	3.99	1.84	1.23	0.92	0.61	0.61	49.11
Stream	Catchment	Flow At			Average Monthly Runoff calculated as % of runoff modelled for Study Area (Mil m^3)												
Trib of Steelpoort	A	A	33.5000		0.04	0.17	0.24	0.35	0.30	0.24	0.13	0.06	0.04	0.03	0.02	0.02	1.6

Figure 4 below illustrates the seasonal distribution between rainfall and runoff for the study area

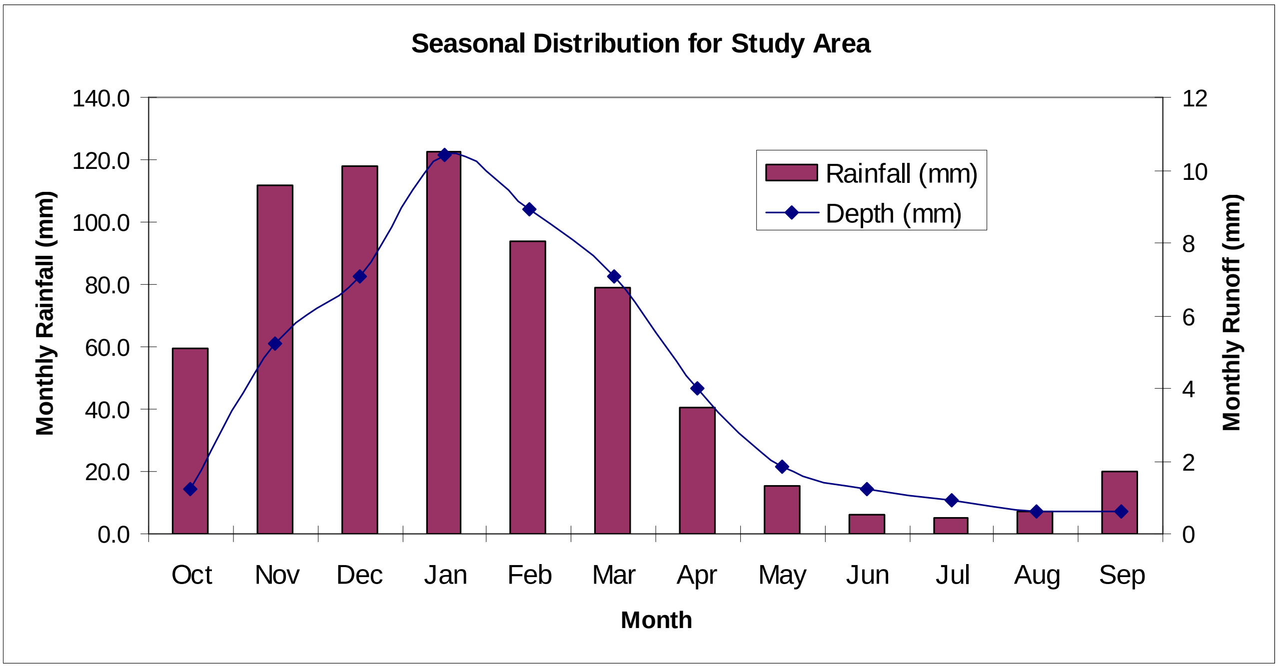

Figure 4: Seasonal distribution between rainfall and run-off for the study area

Table 5 below illustrates the low flow duration frequency for various return periods for the study area

Table 5: Low flow duration frequency for various return periods

Duration	Cumulative flows for return periods of :-					
	10 years		20 years		50 years	
	%MAR	Mil m^3	%MAR	Mil m^3	%MAR	Mil m^3
1-month	1.5	0.024	1.300	0.021	1.200	0.019
3-month	5	0.080	4.500	0.072	4.200	0.067
6-month	12	0.192	11.000	0.176	10.500	0.168
9-month	26	0.416	23.000	0.368	21.000	0.336
1-year	46	0.736	40.000	0.640	36.000	0.576
2-year	120	1.920	100.000	1.600	90.000	1.440
3-year	220	3.520	180.000	2.880	160.000	2.560
MAR	1.600	Mil m^3				

Figure 5 below illustrates the simulated historic flow sequence for the catchment in the study area from the period 1904 to 1999

The lowest simulated flow (base yield) occurred during 1965 when 240,000 m^3/annum was recorded. The highest simulated flow occurred in 1917 when 10,330,000m^3/annum was recorded.

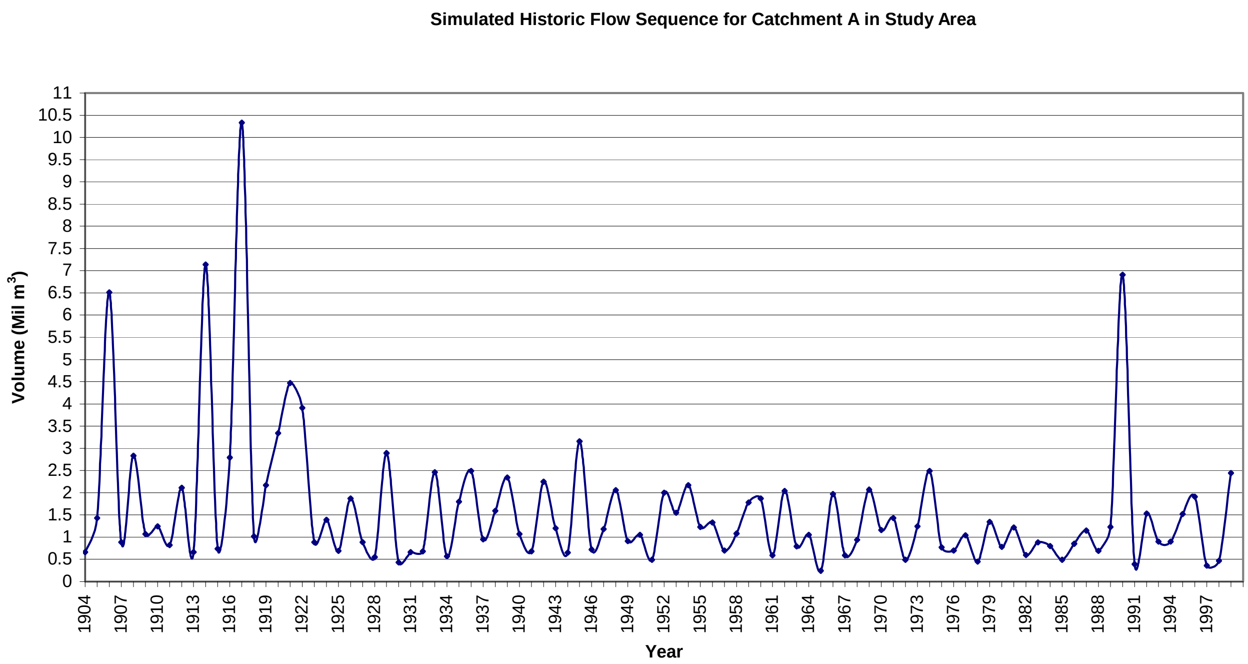

Figure 5: Simulated historic flow sequence

Figure 6 below illustrates the cumulative yearly flows for the study area for the period 1904 to 1999.

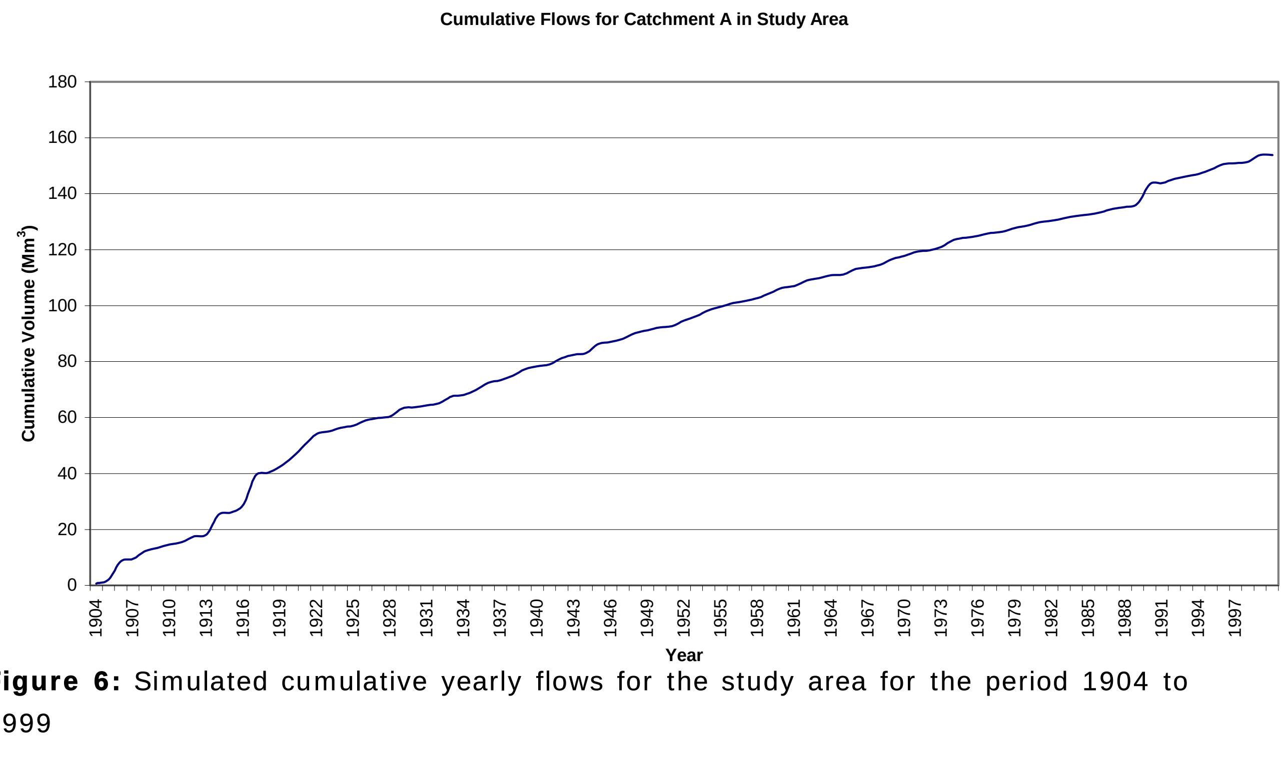

Figure 6: Simulated cumulative yearly flows for the study area for the period 1904 to 1999

1.3.3 Flood Peaks and Volumes

Flood calculations were determined during the feasibility process. Water storage reservoirs are classified according to Chapter 12 of the National Water Act, 1998 (Act 36 of 1998) and relevant Government Notices, as dams with a Safety Risk. Social, economic, and environmental impacts were considered during the classification process. Freeboard and spillway sizes have been determined according to the relevant guidelines such as the SANCOLD (South African Commission on Large Dams) publications.

Erosion protection must be implemented at the riverbanks, spillways, downstream slopes as well as the toe's of the relevant reservoirs in the event of the Steelpoort River being in flood. These have been included within the design reports of BKS Palace Consortium.

1.4 Normal Dry Weather Flow

The normal dry weather flow is defined as that flow that is exceeded 70% of the time. Based on the flow duration curve, the flows exceeded 70% of the time, or the normal dry weather flows, for the catchment were determined.

The shape of the flow duration curve gives a good indication of a catchment's characteristic response to its average rainfall history. The initially steeply sloped curve is as a result of variable discharge, usually from small catchments with little or no storage, where the stream flow reflects a direct rainfall pattern. Flow duration curves that have a very flat slope indicate little variation in the flow regime.

Figure 7 below illustrate the flow duration curve for Catchment A in the study area

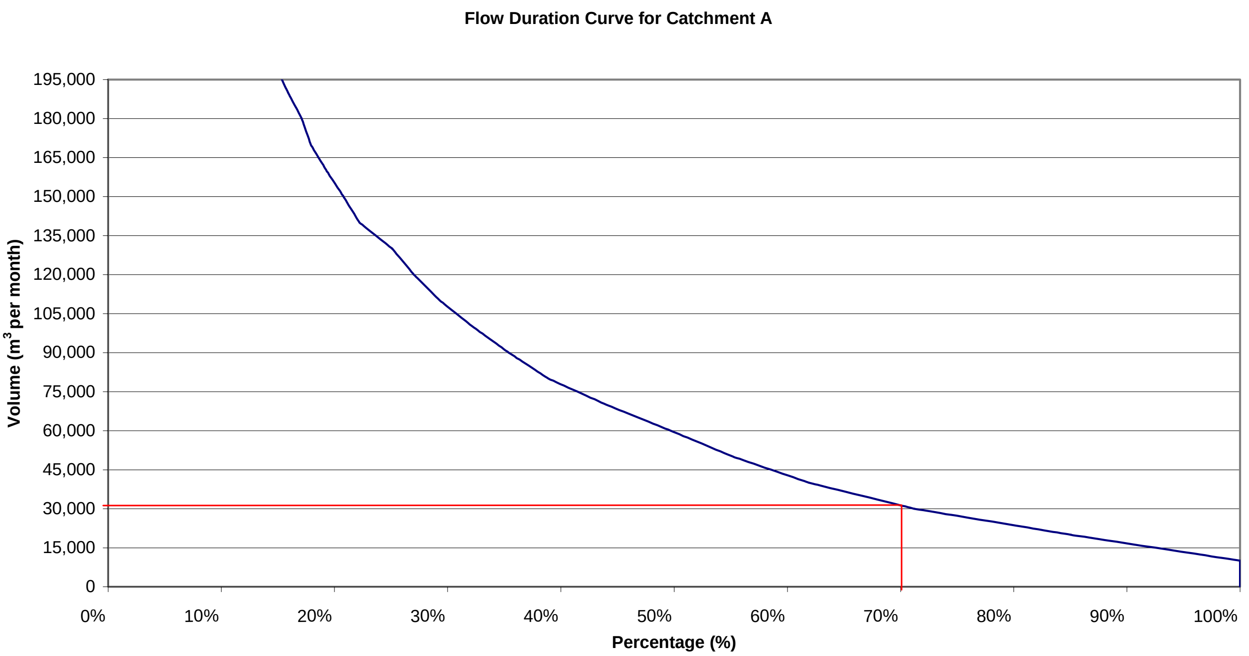

Figure 7: Flow duration curve for Catchment A in the study area

On the basis of the annual curve, the normal dry weather flow for the study area is equal to:

- Catchment **A** (Tributary of the Steelpoort River): approximately 30 000 m^3/month (360 000 m^3/year).

1.5 Ecological Flow requirements

Hydrologic design for water use is closely regulated by the legal framework of water rights, especially in arid and semi arid regions.

The database at the Department of Water Affairs and Forestry was consulted regarding a completed Reserve Determination for the B41D Quaternary Catchment. Unfortunately, no Reserve Study has been initiated[1].

Table 6 below illustrates the completed Reserve Determinations

Table 6: Completed Reserve Determinations

Quat ID	EWR Site	Coordinates	PESC	EISC	REC	MAR ($10^6 m^3$)	% MAR	Section 21 Water uses	Level (category)	APPROVED
B41C			C	Moderate	C	17.8	22.8	f, g, i	Desktop	2001/08/14
B41C			C	Moderate	C	17.8	22.82	25(2) b	Desktop	2001/05/08
B41J	9	S24 46 30.0; E30 09 54.0	D	High	D	171.6	15.2	a b c f g h i	Comprehensive	2001/08/31
B41K	10	S24 29 47.4; E30 23 56.4	D	High	D	406.2	12.1	a b c f g h i	Comprehensive	2001/08/31

PESC: Present Ecological Status
EISC: Ecological Sensitivity
REC: Recommended Ecological Status

Based on existing Reserve Determination studies conducted for the B41 Secondary Catchment, the following assumptions / proposals are discussed:

- The catchment of the study area is largely undeveloped and it can be assumed that the ecological water requirements would fall within a Category B or C, which is fairly unmodified. It is quite possible that the Sehlakwane Township discharges effluent into the tributaries, thus having an impact on the receiving water bodies. This impact has, however, not been quantified.

- It is proposed that 27 % of the Mean Annual Runoff be released for ecological purposes, but this has to be verified by the Department of Water Affairs and

[1] **Note: No reserve Determination has been conducted a fact highlighted during the proposed De Hoop Dam Project. It is likely that this study is underway and that this data should be used as input into this study, once available.**

Forestry. The proposed ecological requirement would amount to 432 000 m^3 per annum. Please refer to **Appendix A** for a detailed Table.

Figure 8 below illustrate the comparison between the proposed Ecological Flow Requirement and the Annual Flows. **Please note** that these are only proposed flows.

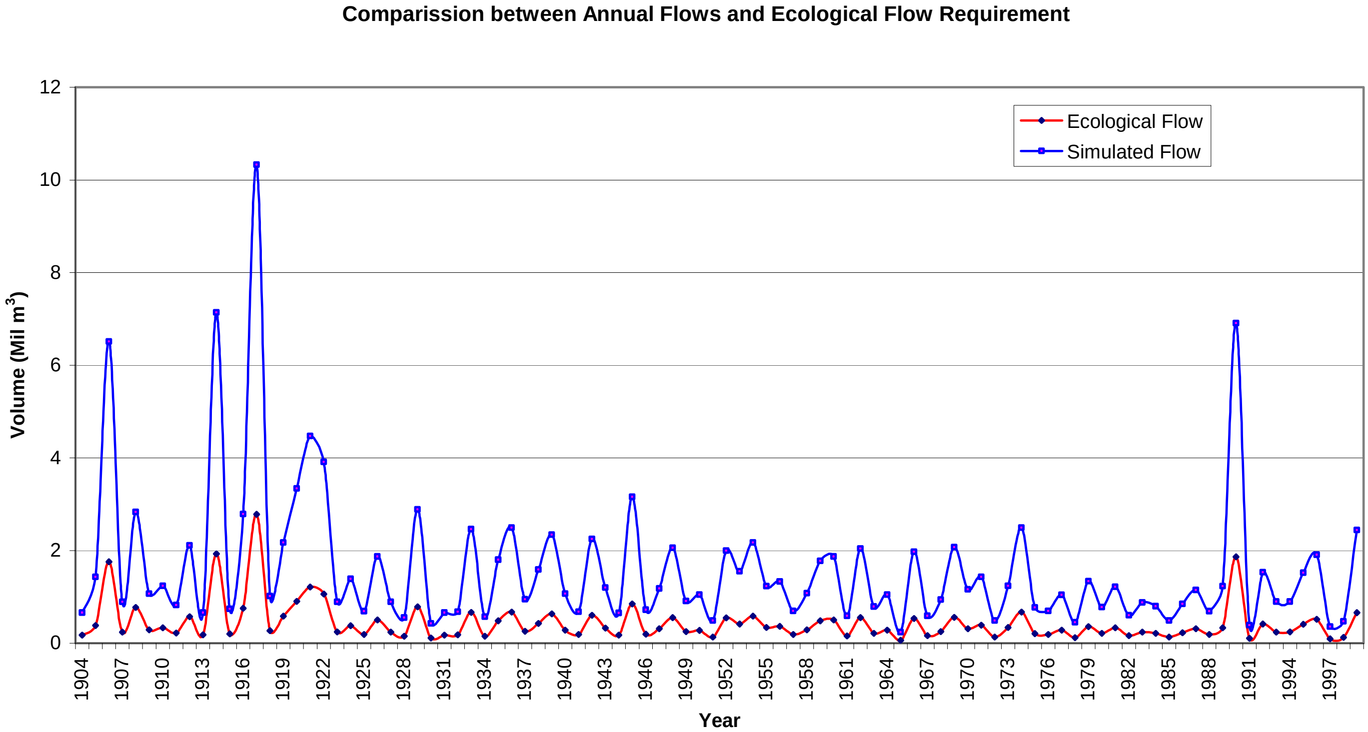

Figure 8: Comparison between Annual flows and proposed Ecological flow requirement

1.6 Seepage from Reservoirs

The estimated seepage loss for the upper reservoir, as determined by BKS designers, is expected to be 440 m^3 per day, while the estimated seepage loss for the lower reservoir will be 68 m^3 per day. This gives a total envisaged seepage loss of 508 m^3 per day (185 547 m^3 per annum).

The estimation of seepage losses are based on Permeability (K) values of 10^{-7} m/s and 10^{-8} m/s, as assumed by the BKS Palace Consortium Study. It is envisaged that the permeability of the weathered zones may be higher. It does, however, provide an order of magnitude of losses that can be expected.

Table 7: Summary of proposed releases for ecology and seepage from reservoirs

Summary	
Proposed ecological requirement	432 000 m^3 per annum
Seepage	185 547 m^3 per annum
Releases	246 500 m^3 per annum

Seepage water can be used to supplement the proposed Ecological Reserve, but 246 500 m^3 per annum would be released from the reservoir by either spills or controlled releases to augment deficits in the Ecological Reserve.

1.7 Drainage Densities

Drainage density is defined as the length of drainage per unit area. The term was first introduced by Horton (1932), and is determined by dividing the total length of streams within a drainage basin by the drainage area. A high drainage density reflects a highly dissected drainage basin, with a relatively rapid hydrologic response to rainfall events, while a low drainage density means a poorly drained basin with a slow hydrologic response.

The 1:50 000 scale topographic map (2529 BB Roossenekal) was used to determine the drainage densities and these are summarised in **Table 7.**

Table 8: Drainage Densities

Description	Drainage Density (km/km^2)
Catchment **A** (Sub-Catchment containing study area)	1.25

1.8 Potential Impacts of Proposed Activities.

The proposed water storage reservoirs will consist of concrete faced rock-fill dams. It is anticipated that the surface areas of the upper reservoirs will be in the order of 63.5 ha, while the lower reservoir would be 57 ha.

It is also anticipated that an initial start up volume of 15 x10^6 m^3 would be required for these dams and that 2 191 x10^6 m^3 per annum would be required as top-up water due to evaporative and seepage losses.

It is also anticipated that water would be supplied to local communities along the Nebo plateau from this Pumped Storage Scheme, but these volumes are still unknown. Make –up water would be pumped from the De Hoop Dam in a pipeline to the water storage reservoirs.

Potable water will be required for construction purposes as well as for the construction camp during the construction phase. These volumes will be abstracted over the whole length of the construction period. It is, however, still unclear how large the workforce will be and what the level of service will be. It is currently unknown whether the water will be abstracted from groundwater resources or from surface water resources. This needs to be addressed.

1.8.1 Potential Impacts on Hydrology

The damming up of small tributaries is expected to negatively impact on the current hydrological regime and future hydrological functioning.

One of the main impacts of impoundments is that they change the timing, size, and frequency of flow and flood events in the river. Altered flow patterns also lead to changes in sediment dynamics, habitat integrity, thermal, and chemical (abiotic) conditions in rivers. Fluctuating discharges constantly change conditions through each day and season, creating mosaics of areas inundated and exposed for different lengths of time. The resulting physical heterogeneity determines the local distribution of species: higher physical diversity enhances biodiversity.

The foreseen impacts on the Ecological and Basic human needs portions of the Reserve will be negligible, since water released by the relevant reservoirs will be intercepted by the De Hoop dam, and may be lost due to evaporation, seepage or releases from the dam.

Most water losses in the reservoirs would occur due to evaporation of water from the open water bodies. Some seepage and frictional (losses inside the system) losses will also occur. These losses will be quantified during the detailed design process. It is quite possible that water emanating from the dam wall as a result of seepage through the internal drainage system, will be measured and discharged back to the receiving water bodies. This volume may be small and can be considered as neglectable.

The study area contributes between 6 % and 9 % to the MAR of the B41D Quaternary Catchment and this water may be lost only during the initial filling of the reservoirs.

1.8.2 Increased Run-off from surface areas.

Increase in run-off and flow velocities are expected as a result of the increased impermeable surface areas and mitigation measures should be implemented to prevent the degradation of the watercourses. Soil conservation measures should be implemented at identified areas. Storm water collection and conveyance systems should be engineered designed.

1.9 Rating system used to classify impacts

Rating Matrix for ECOLOGICAL INSTREAM FLOW REQUIREMENTS Impacts	
Interception of normal runoff as well as required flood events required for ecology	
Criteria	**Rating**
Extent	2
Duration	3
Intensity	3
Probability of occurrence	4
TOTAL	**12**
This impact is rated as a **HIGH** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Design outlet works, for ecological releases 2. Establish, implement and monitor the ecological reserve 3. Flow measurement of releases Set management objectives for the ecological reserve	
Criteria	**Rating**
Extent	1
Duration	3
Intensity	2
Probability of occurrence	3
TOTAL	**9**
This is rated as a **MEDIUM** NEGATIVE Impact after the implementation of mitigation and management measures.	

Rating Matrix for RIVER DIVERSIONS DURING CONSTRUCTION Impacts	
Ecological and hydrological impact associated with the diversion of a watercourse	
Criteria	**Rating**
Extent	1
Duration	2
Intensity	2
Probability of occurrence	3
TOTAL	**8**
This impact is rated as a **MEDIUM** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Should be engineered designed to allow for the free movement of runoff water 2. Should be engineered designed to prevent degradation of water courses such as the forming of erosion 3. Should be designed to mitigate biological loss and habitat	
Criteria	**Rating**
Extent	1
Duration	2
Intensity	2
Probability of occurrence	2
TOTAL	**7**
This is rated as a **LOW** NEGATIVE Impact after the implementation of mitigation and management measures.	

<table>
<tr><th colspan="2">Rating Matrix for STREAM / DRAINAGE LINE CROSSINGS - TEMPORARY Impacts</th></tr>
<tr><td colspan="2">Impacts on natural hydrology due to access roads and the upgrading thereof</td></tr>
<tr><th>Criteria</th><th>Rating</th></tr>
<tr><td>Extent</td><td>1</td></tr>
<tr><td>Duration</td><td>2</td></tr>
<tr><td>Intensity</td><td>2</td></tr>
<tr><td>Probability of occurrence</td><td>3</td></tr>
<tr><td>TOTAL</td><td>8</td></tr>
<tr><td colspan="2">This impact is rated as a MEDIUM Negative Impact before the implementation of mitigation and management measures.</td></tr>
<tr><td colspan="2">Mitigation and Management measures:
1. Adequate drainage systems at river crossings to prevent damming up and backwater at upstream sides.
2. Sufficient drainage systems should be designed as not to choke watercourse.
3. Erosion protection at approaches and drainage systems, to prevent sediment entering water bodies and to prevent erosion
4. Protection downstream to prevent scour and to keep flow velocities down
5. Adequate discharge capacities in the event of flooding
6. Environmental monitoring (Environmental Management Plan)</td></tr>
<tr><th>Criteria</th><th>Rating</th></tr>
<tr><td>Extent</td><td>1</td></tr>
<tr><td>Duration</td><td>1</td></tr>
<tr><td>Intensity</td><td>1</td></tr>
<tr><td>Probability of occurrence</td><td>2</td></tr>
<tr><td>TOTAL</td><td>5</td></tr>
<tr><td colspan="2">This is rated as a LOW NEGATIVE Impact after the implementation of mitigation and management measures.</td></tr>
</table>

Rating Matrix for STREAM CROSSINGS - PERMANENT Impacts	
Impacts on natural hydrology due to access roads and the upgrading thereof	
Criteria	**Rating**
Extent	1
Duration	4
Intensity	1
Probability of occurrence	4
TOTAL	**10**
This impact is rated as a **MEDIUM** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Regular inspections at river crossings (Environmental Management Plan) 2. Regular maintenance 3. Adequate discharge capacities in the event of flooding	
Criteria	**Rating**
Extent	1
Duration	1
Intensity	1
Probability of occurrence	2
TOTAL	**5**
This is rated as a **LOW** NEGATIVE Impact after the implementation of mitigation and management measures.	

Rating Matrix for SPILLWAY - EROSION Impacts:	
The forming of erosion downstream of the spillway or stilling basin due to high uncontrolled flow velocities	
Criteria	**Rating**
Extent	1
Duration	1
Intensity	2
Probability of occurrence	2
TOTAL	**6**
This impact is rated as a **LOW** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Spillway and stilling basin to be designed according to acceptable engineering standards 2. Regular monitoring of possible forming of erosion or degradation of watercourses (Environmental Management Plan)	
Criteria	**Rating**
Extent	1
Duration	2
Intensity	1
Probability of occurrence	2
TOTAL	**6**
This is rated as a **LOW** NEGATIVE Impact after the implementation of mitigation and management measures.	

Rating Matrix for BORROW AREAS Impacts	
The ponding of water and probable flooding of borrow areas.	
Criteria	**Rating**
Extent	1
Duration	2
Intensity	2
Probability of occurrence	4
TOTAL	**9**
This impact is rated as a **MEDIUM** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Borrow areas should be placed outside the 1:100 year flood line. Where this is not possible, flood protection measures should be implemented and maintained in cases where borrow areas are within the 1:100 year flood line 2. Area should be made free draining after construction and landscaped to follow the natural topography.	
Criteria	**Rating**
Extent	1
Duration	1
Intensity	2
Probability of occurrence	2
TOTAL	**6**
This is rated as a **LOW** NEGATIVE Impact after the implementation of mitigation and management measures.	

<table>
<tr><th colspan="2">Rating Matrix for EVAPORATION Impacts</th></tr>
<tr><td colspan="2">Loss of water due to evaporation</td></tr>
<tr><th>Criteria</th><th>Rating</th></tr>
<tr><td>Extent</td><td>1</td></tr>
<tr><td>Duration</td><td>4</td></tr>
<tr><td>Intensity</td><td>1</td></tr>
<tr><td>Probability of occurrence</td><td>4</td></tr>
<tr><td>TOTAL</td><td>10</td></tr>
<tr><td colspan="2">This impact is rated as a MEDIUM Negative Impact before the implementation of mitigation and management measures.</td></tr>
<tr><td colspan="2">Mitigation and Management measures:
1. Keep surface areas of reservoirs to a minimum
2. Provide floating covers or buoys for upper reservoir to keep open water areas to a minimum</td></tr>
<tr><th>Criteria</th><th>Rating</th></tr>
<tr><td>Extent</td><td>1</td></tr>
<tr><td>Duration</td><td>3</td></tr>
<tr><td>Intensity</td><td>1</td></tr>
<tr><td>Probability of occurrence</td><td>3</td></tr>
<tr><td>TOTAL</td><td>8</td></tr>
<tr><td colspan="2">This is rated as a MEDIUM NEGATIVE Impact after the implementation of mitigation and management measures.</td></tr>
</table>

Rating Matrix for EXISTING WATER USERS - IRRIGATION Impacts	
Impacts on existing irrigation water users	
Criteria	**Rating**
Extent	2
Duration	2
Intensity	1
Probability of occurrence	2
TOTAL	**7**
This impact is rated as a **LOW** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Compensation Releases 2. Designing of suitable outlet works	
Criteria	**Rating**
Extent	2
Duration	1
Intensity	1
Probability of occurrence	1
TOTAL	**5**
This is rated as a **LOW** NEGATIVE Impact after the implementation of mitigation and management measures.	

Rating Matrix for RISK OF FLOODING OF THE STEELPOORT RIVER Impacts	
Risk of flooding during high flood periods can cause damage to the dam structure, which may cause the failure of the dam.	
Criteria	**Rating**
Extent	4
Duration	4
Intensity	3
Probability of occurrence	1
TOTAL	**12**
This impact is rated as a **HIGH** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Downstream slope, toe, outlet works, spillway, needs to be designed according to relevant engineering standards. 2. Construct dam structure outside relevant flood events 3. Emergency response and preparedness plans need to be developed for the dam. 4. Hydrological data and relevant flood evaluations should be addressed during the 5-yearly dam safety inspections.	
Criteria	**Rating**
Extent	3
Duration	4
Intensity	2
Probability of occurrence	2
TOTAL	**11**
This is rated as a **HIGH** NEGATIVE Impact after the implementation of mitigation and management measures.	

<table>
<tr><th colspan="2">Rating Matrix for RESERVOIR BREACH Impacts</th></tr>
<tr><td colspan="2">Impacts of Reservoir failure on Watercourses</td></tr>
<tr><th>Criteria</th><th>Rating</th></tr>
<tr><td>Extent</td><td>4</td></tr>
<tr><td>Duration</td><td>3</td></tr>
<tr><td>Intensity</td><td>3</td></tr>
<tr><td>Probability of occurrence</td><td>2</td></tr>
<tr><td>TOTAL</td><td>12</td></tr>
<tr><td colspan="2">This impact is rated as a HIGH Negative Impact before the implementation of mitigation and management measures.</td></tr>
<tr><td colspan="2">Mitigation and Management measures:
1. Engineered designed and construction supervision according to the guidelines of the South African Committee on Large Dams, and relevant engineering standards
2. Adequate operation and maintenance
3. Regular dam safety inspections
4. Early warning systems
5. Emergency Response and Preparedness plans
6. Review of dam design by Authorities or specialists to bring down the probability of occurrence</td></tr>
<tr><th>Criteria</th><th>Rating</th></tr>
<tr><td>Extent</td><td>4</td></tr>
<tr><td>Duration</td><td>3</td></tr>
<tr><td>Intensity</td><td>3</td></tr>
<tr><td>Probability of occurrence</td><td>2</td></tr>
<tr><td>TOTAL</td><td>12</td></tr>
<tr><td colspan="2">This is rated as a HIGH NEGATIVE Impact after the implementation of mitigation and management measures.</td></tr>
</table>

Rating Matrix for CONSTRUCTION CAMP DURING CONSTRUCTION - SEWAGE Impacts	
Impacts of sewage return flows on the Steelpoort River	
Criteria	**Rating**
Extent	1
Duration	2
Intensity	2
Probability of occurrence	4
TOTAL	**8**
This impact is rated as a **MEDIUM** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Adequate water treatment plant 2. Surface Water Quality Monitoring 3. Flow metering/measuring 4. Safe Disposal of sewage sludge	
Criteria	**Rating**
Extent	1
Duration	2
Intensity	1
Probability of occurrence	2
TOTAL	**6**
This is rated as a **LOW** NEGATIVE Impact after the implementation of mitigation and management measures.	

Rating Matrix for CONSTRUCTION CAMP DURING CONSTRUCTION – TAKING OF SURFACE WATER Impacts	
Taking of water for the construction camp and the impact on existing water users	
Criteria	**Rating**
Extent	1
Duration	1
Intensity	1
Probability of occurrence	4
TOTAL	**7**
This impact is rated as a **LOW** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Obtaining water from existing water users 2. Installing flow metering / measuring devices to stay within allocation 3. Reusing / Recycling of water 4. Maintain systems to reduce leaks 5. Training of workers on water conservation and demand management	
Criteria	**Rating**
Extent	1
Duration	1
Intensity	1
Probability of occurrence	4
TOTAL	**7**
This is rated as a **LOW** NEGATIVE Impact after the implementation of mitigation and management measures.	

Rating Matrix for SERVICE AND WASH BAYS (Polluted Runoff) – WATER QUALITY Impacts	
Impacts of oils, soaps, etc entering the Steelpoort River	
Criteria	**Rating**
Extent	1
Duration	2
Intensity	2
Probability of occurrence	3
TOTAL	**8**
This impact is rated as a **MEDIUM** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Designated areas for service bay and workshop 2. Adequate bunded and storage areas 3. Safe disposal of oils, grease and soaps off site 4. Environmental clean up procedures in the event of spillage 5. Separation of clean and dirty water catchments and the containment of dirty water	
Criteria	**Rating**
Extent	1
Duration	1
Intensity	1
Probability of occurrence	2
TOTAL	**5**
This is rated as a **LOW** NEGATIVE Impact after the implementation of mitigation and management measures.	

Rating Matrix for FLOODING OF CONSTRUCTION SITE BY SURFACE WATER BODIES impact	
Probable flooding of the Steelpoort River or by other watercourses	
Criteria	**Rating**
Extent	1
Duration	1
Intensity	3
Probability of occurrence	2
TOTAL	**7**
This impact is rated as a **MEDIUM** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Locality of construction sites should be above 1:100 year floodlines 2. Adequate engineered designed flood protection measures 3. Maintenance of flood protection measures	
Criteria	**Rating**
Extent	1
Duration	1
Intensity	1
Probability of occurrence	2
TOTAL	**5**
This is rated as a **LOW** NEGATIVE Impact after the implementation of mitigation and management measures.	

Rating Matrix for SEWAGE RETURN FLOWS FROM PERMANANENT BUILDINGS impact	
Return flows from permanent buildings into watercourses	
Criteria	**Rating**
Extent	2
Duration	3
Intensity	2
Probability of occurrence	3
TOTAL	**10**
This impact is rated as a **MEDIUM TO HIGH** Negative Impact before the implementation of mitigation and management measures.	
Mitigation and Management measures: 1. Community training and awareness 2. Water treatment options 3. Removal or re-routing of contaminant sources 4. Set environmental objective of the water quality	
Criteria	**Rating**
Extent	2
Duration	2
Intensity	1
Probability of occurrence	2
TOTAL	**7**
This is rated as a **LOW** NEGATIVE Impact after the implementation of mitigation and management measures.	

1.10 Conclusions

The study area is situated in the headwater to middle reaches of a tributary of the Steelpoort River, where most of the river flow is generated by direct precipitation.

The study has found that there are no fatal flaws or any intolerable impacts, which will result from the proposed project, with regards to the surface water aspects. Through carefully mitigation, correct management strategies, and auditing procedures, during the construction and operation phases, the envisaged associate impacts should be low. The impacts are, however, envisaged to be localised.

While the majority of the impacts will have a medium impact on the environment, all, but two, of them can successfully be mitigated to a low impact. The only two impacts that can not be mitigated are: -

- The risk of flooding during high flood periods that can cause damage to the dam structure, which may cause the failure of the dam
- And the impacts of reservoir failure on the downstream watercourses

While all necessary precautions can be taken, in the event of a disaster, the effect of the impacts on the downstream area will remain high.

Negative impacts resulting from the secondary construction activities (including but not limited to; burrowing, housing, sewage, and water abstraction), can all successfully be mitigated to low impacts of a temporary nature, and can successfully be rehabilitated to a state, according to the objective of the Environmental Management Plan, for the specific area.

The negative impacts resulting from the operation phase can all be mitigated through design, management strategies, and auditing procedures, to a lower status.

Data shortfalls were identified during this study and these should be addressed during the EIA phase. These include: -

- Hydrochemical baseline data
- Erosion prevention to be included in designs
- Revision of the B41D Reserve, once complete[2]
- Revision of seepage estimates
- Potable water usage and demands. Details of the on-site services should be addressed
- Soil conservation measures should be developed, implemented, monitored and maintained in a monitoring programme.

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[2] The combined impact of both the proposed De Hoop Dam and the proposed Lima Project needs to be assessed when reviewing the B41D reserve.

It can thus be concluded that the proposed project is feasible should the suggested management options be implemented and it is recommended that the proposed project be approved.

1.11 References

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- BKS Palace Consortium. Project Lima Supplementary Feasibility Study Phase 1 Site Selection Study. Main Report Volume 1. May 2006

- BKS Palace Consortium. Steelpoort Pumped Storage Scheme Phase 2 Hydrology. January 2007

- SANCOLD. 1991. Guidelines on Safety in Relation to Floods. December 1991. The South African Commission on Large Dams, Report No 4.

- Smithers, J.C. and Shulze, R.E., 2000b. Design rainfall and flood estimation in South Africa. WRC Report No 1060/1/03

Proposed Ecological Flow Requirement

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1904	0.0108	0.0027	0.0027	0.0135	0.0351	0.0324	0.0351	0.0243	0.0108	0.0054	0.0027	0.0027	**0.1782**
1905	0.0027	0.0081	0.1917	0.0891	0.0243	0.027	0.0162	0.0054	0.0027	0.0027	0.0027	0.0135	**0.3861**
1906	0.0432	0.0729	0.2106	0.5751	0.5967	0.1782	0.0351	0.0216	0.0081	0.0054	0.0054	0.0054	**1.7577**
1907	0.0189	0.0594	0.054	0.0324	0.0189	0.0189	0.0162	0.0081	0.0027	0.0027	0.0027	0.0027	**0.2376**
1908	0.0054	0.0162	0.0135	0.0351	0.054	0.4131	0.1674	0.027	0.0135	0.0081	0.0081	0.0081	**0.7695**
1909	0.0054	0.0081	0.0432	0.0945	0.0783	0.0324	0.0081	0.0027	0.0027	0.0054	0.0027	0.0027	**0.2862**
1910	0.0189	0.0405	0.0513	0.0567	0.054	0.0351	0.0189	0.0189	0.0162	0.0081	0.0081	0.0054	**0.3321**
1911	0.0135	0.027	0.0405	0.0297	0.0162	0.0243	0.0297	0.0189	0.0081	0.0054	0.0054	0.0027	**0.2214**
1912	0.0027	0.0054	0.0567	0.0675	0.243	0.1134	0.0351	0.0216	0.0108	0.0054	0.0054	0.0027	**0.5697**
1913	0.0054	0.0054	0.0108	0.0324	0.0432	0.0351	0.0189	0.0081	0.0054	0.0054	0.0054	0.0054	**0.1809**
1914	0.0027	0.0162	0.1026	0.5805	0.891	0.2727	0.0189	0.0054	0.0027	0.0108	0.0135	0.0081	**1.9251**
1915	0.0135	0.0162	0.027	0.0513	0.0297	0.0162	0.0189	0.0135	0.0054	0.0027	0.0027	0.0027	**0.1998**
1916	0.0027	0.0567	0.2889	0.135	0.0756	0.0594	0.0324	0.0216	0.0216	0.0162	0.0216	0.0216	**0.7533**
1917	0.0486	0.7776	0.405	0.8073	0.3105	0.2781	0.1161	0.0162	0.0054	0.0027	0.0081	0.0081	**2.7837**
1918	0.0081	0.0108	0.0297	0.1242	0.0594	0.0189	0.0081	0.0027	0.0027	0.0027	0.0027	0.0027	**0.2727**
1919	0.0027	0.2835	0.1323	0.0378	0.0351	0.0405	0.0243	0.0108	0.0081	0.0054	0.0027	0.0027	**0.5859**
1920	0.0189	0.081	0.0567	0.0324	0.1566	0.3699	0.1377	0.0243	0.0108	0.0081	0.0054	0.0027	**0.9045**
1921	0.0081	0.1242	0.1134	0.081	0.0702	0.5481	0.2079	0.0189	0.0081	0.0081	0.0108	0.0108	**1.2096**
1922	0.0216	0.0594	0.0567	0.6021	0.243	0.0378	0.0162	0.0054	0.0054	0.0054	0.0027	0.0027	**1.0584**
1923	0.0054	0.0189	0.0189	0.0189	0.027	0.0621	0.0432	0.0189	0.0108	0.0081	0.0054	0.0054	**0.243**
1924	0.0081	0.0567	0.0486	0.0297	0.0243	0.0405	0.0459	0.0351	0.0297	0.0243	0.0135	0.0189	**0.3753**
1925	0.0189	0.0297	0.0216	0.0162	0.0216	0.0162	0.0081	0.0135	0.0162	0.0108	0.0054	0.0081	**0.1863**
1926	0.0081	0.0135	0.0135	0.0243	0.1512	0.1161	0.0702	0.0324	0.0108	0.0243	0.027	0.0135	**0.5049**
1927	0.027	0.0243	0.0162	0.0459	0.054	0.0324	0.0162	0.0081	0.0054	0.0027	0.0027	0.0027	**0.2376**
1928	0.0027	0.0108	0.0189	0.0162	0.0162	0.0189	0.0216	0.0135	0.0081	0.0081	0.0054	0.0081	**0.1485**
1929	0.0459	0.0864	0.0729	0.3213	0.1431	0.0432	0.0297	0.0162	0.0054	0.0081	0.0081	0.0027	**0.783**
1930	0.0027	0	0.0081	0.0135	0.0162	0.0162	0.0189	0.0135	0.0054	0.0081	0.0081	0.0027	**0.1134**
1931	0.0027	0.0054	0.0108	0.0189	0.0216	0.0351	0.0324	0.0216	0.0135	0.0081	0.0054	0.0027	**0.1782**
1932	0.0108	0.0108	0.0189	0.0378	0.0378	0.0243	0.0162	0.0081	0.0054	0.0054	0.0027	0.0027	**0.1809**
1933	0.0027	0.297	0.1485	0.0621	0.0513	0.0405	0.027	0.0135	0.0081	0.0081	0.0054	0.0027	**0.6669**
1934	0.0027	0.0135	0.0378	0.0405	0.027	0.0108	0.0054	0.0027	0.0027	0.0027	0.0027	0.0027	**0.1512**
1935	0.0027	0.0027	0.0108	0.2133	0.1377	0.054	0.0216	0.0162	0.0108	0.0081	0.0054	0.0027	**0.486**
1936	0.0108	0.0405	0.054	0.324	0.1539	0.0432	0.0216	0.0108	0.0054	0.0027	0.0027	0.0027	**0.6723**
1937	0.0027	0.0054	0.0189	0.0243	0.027	0.0216	0.0621	0.054	0.0216	0.0108	0.0054	0.0054	**0.2592**
1938	0.0108	0.0135	0.027	0.0702	0.1593	0.0864	0.0243	0.0081	0.0027	0.0081	0.0081	0.0108	**0.4293**
1939	0.0135	0.0567	0.2565	0.1107	0.0324	0.0351	0.0351	0.0243	0.027	0.0216	0.0108	0.0081	**0.6318**
1940	0.0054	0.027	0.0621	0.0459	0.0297	0.027	0.0351	0.027	0.0108	0.0054	0.0054	0.0027	**0.2835**
1941	0.0027	0.0027	0.0108	0.0189	0.0162	0.0297	0.0243	0.0189	0.0243	0.0189	0.0108	0.0081	**0.1863**
1942	0.0054	0.027	0.027	0.0216	0.0243	0.0351	0.2538	0.1242	0.0297	0.0216	0.0189	0.0162	**0.6048**
1943	0.0162	0.0567	0.0459	0.0378	0.0621	0.0513	0.0243	0.0081	0.0054	0.0081	0.0054	0.0027	**0.324**
1944	0.0216	0.0297	0.0162	0.0297	0.0324	0.0189	0.0081	0.0054	0.0027	0.0027	0.0027	0.0027	**0.1728**
1945	0.0027	0.0054	0.0081	0.1377	0.4023	0.2079	0.0567	0.0162	0.0054	0.0027	0.0027	0.0027	**0.8505**
1946	0.0027	0.027	0.0324	0.0351	0.0351	0.0243	0.0162	0.0081	0.0054	0.0027	0.0027	0.0027	**0.1944**
1947	0.0027	0.0216	0.0486	0.0486	0.0351	0.0675	0.054	0.0189	0.0081	0.0054	0.0027	0.0027	**0.3159**
1948	0.0081	0.0189	0.0162	0.2862	0.1377	0.0324	0.0189	0.0135	0.0108	0.0054	0.0027	0.0027	**0.5535**
1949	0.0054	0.0486	0.054	0.0567	0.0297	0.0108	0.0135	0.0108	0.0054	0.0054	0.0054	0.0027	**0.2484**
1950	0.0027	0.0054	0.0189	0.027	0.027	0.0297	0.0351	0.0486	0.0378	0.0189	0.0135	0.0108	**0.2754**
1951	0.0162	0.0108	0.0135	0.0108	0.0162	0.0189	0.0135	0.0108	0.0081	0.0081	0.0054	0.0027	**0.135**
1952	0.0027	0.0189	0.0405	0.0297	0.2214	0.1296	0.0486	0.0243	0.0135	0.0081	0.0054	0.0027	**0.5454**
1953	0.0054	0.0405	0.0513	0.1242	0.0891	0.0405	0.0243	0.0162	0.0081	0.0054	0.0027	0.0054	**0.4131**
1954	0.0081	0.0378	0.0432	0.054	0.1998	0.1323	0.0567	0.0243	0.0135	0.0081	0.0054	0.0027	**0.5859**
1955	0.0054	0.027	0.0702	0.0567	0.0432	0.0405	0.0243	0.0189	0.0189	0.0135	0.0081	0.0108	**0.3375**
1956	0.0243	0.0243	0.0486	0.0432	0.0405	0.0648	0.0513	0.0243	0.0108	0.0081	0.0081	0.0135	**0.3618**
1957	0.0189	0.0135	0.0189	0.027	0.027	0.0216	0.0216	0.0162	0.0081	0.0054	0.0027	0.0054	**0.1863**
1958	0.0108	0.0243	0.0378	0.0675	0.0648	0.0351	0.0162	0.0108	0.0081	0.0054	0.0054	0.0054	**0.2916**
1959	0.0135	0.0486	0.0675	0.0486	0.0729	0.0756	0.0756	0.0459	0.0162	0.0081	0.0054	0.0027	**0.4806**
1960	0.0027	0.0324	0.1944	0.0891	0.0243	0.0243	0.0378	0.0351	0.027	0.0189	0.0108	0.0054	**0.5022**
1961	0.0135	0.0162	0.0378	0.0324	0.0135	0.0054	0.0108	0.0108	0.0054	0.0054	0.0054	0.0027	**0.1593**
1962	0.0027	0.2997	0.1404	0.0324	0.0135	0.0054	0.0054	0.0081	0.0135	0.0162	0.0108	0.0054	**0.5535**
1963	0.0054	0.0216	0.0324	0.0621	0.0432	0.0189	0.0108	0.0054	0.0027	0.0027	0.0027	0.0027	**0.2106**
1964	0.0432	0.0702	0.0621	0.0459	0.027	0.0108	0.0054	0.0054	0.0027	0.0027	0.0027	0.0027	**0.2808**
1965	0.0027	0.0108	0.0135	0.0108	0.0081	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	**0.0648**
1966	0.0054	0.0081	0.0486	0.1134	0.1026	0.0621	0.0756	0.0594	0.0243	0.0135	0.0135	0.0054	**0.5319**
1967	0.0081	0.0108	0.0189	0.0162	0.0108	0.0297	0.0297	0.0162	0.0081	0.0054	0.0054	0.0027	**0.162**
1968	0.0027	0.0189	0.0297	0.0216	0.0243	0.0567	0.0486	0.0216	0.0081	0.0054	0.0054	0.0054	**0.2484**
1969	0.0108	0.0189	0.3348	0.1323	0.0135	0.0135	0.0108	0.0054	0.0027	0.0027	0.0054	0.0054	**0.5562**
1970	0.0081	0.0216	0.0378	0.0702	0.0594	0.0297	0.0297	0.027	0.0162	0.0081	0.0054	0.0027	**0.3159**
1971	0.0081	0.0513	0.054	0.0945	0.0594	0.0297	0.0351	0.027	0.0135	0.0081	0.0054	0.0027	**0.3888**
1972	0.0027	0.0108	0.0135	0.0135	0.0162	0.0135	0.0216	0.0162	0.0081	0.0054	0.0027	0.0108	**0.135**
1973	0.0189	0.0297	0.0351	0.0486	0.0675	0.0513	0.0378	0.0216	0.0108	0.0054	0.0054	0.0054	**0.3375**
1974	0.0027	0.0162	0.0243	0.3105	0.1755	0.0594	0.0351	0.0216	0.0108	0.0081	0.0054	0.0027	**0.6723**
1975	0.0027	0.0081	0.0432	0.0459	0.0378	0.027	0.0162	0.0081	0.0054	0.0054	0.0027	0.0027	**0.2052**
1976	0.0027	0.0135	0.0162	0.0189	0.0135	0.0432	0.0432	0.0162	0.0054	0.0054	0.0054	0.0054	**0.189**
1977	0.0081	0.0135	0.0459	0.0567	0.054	0.0513	0.027	0.0108	0.0054	0.0027	0.0027	0.0027	**0.2808**
1978	0.0162	0.0243	0.0162	0.0135	0.0108	0.0081	0.0081	0.0054	0.0054	0.0027	0.0054	0.0054	**0.1215**
1979	0.0054	0.0756	0.0783	0.0621	0.0567	0.0378	0.0189	0.0081	0.0054	0.0027	0.0027	0.0054	**0.3591**
1980	0.0054	0.0513	0.0621	0.0351	0.0243	0.0135	0.0054	0.0027	0.0027	0.0027	0.0027	0.0027	**0.2106**
1981	0.0081	0.0162	0.1161	0.0783	0.0351	0.0162	0.0108	0.0135	0.0108	0.0108	0.0081	0.0081	**0.3321**
1982	0.0081	0.0108	0.0135	0.0216	0.0162	0.0243	0.0216	0.0135	0.0108	0.0081	0.0081	0.0054	**0.162**
1983	0.0135	0.0594	0.0567	0.0351	0.0216	0.0162	0.0108	0.0054	0.0027	0.0054	0.0054	0.0054	**0.2376**
1984	0.0162	0.027	0.0324	0.0297	0.0405	0.0297	0.0108	0.0081	0.0081	0.0054	0.0054	0.0027	**0.216**
1985	0.0054	0.0054	0.0405	0.0351	0.0135	0.0081	0.0054	0.0054	0.0027	0.0054	0.0027	0.0027	**0.1323**
1986	0.0027	0.0135	0.0432	0.0594	0.0351	0.027	0.0189	0.0054	0.0027	0.0027	0.0027	0.0108	**0.2241**
1987	0.0162	0.0513	0.0729	0.0675	0.0324	0.0189	0.0189	0.0135	0.0081	0.0054	0.0054	0.0054	**0.3159**
1988	0.0189	0.0162	0.0216	0.0297	0.0351	0.0216	0.0108	0.0081	0.0081	0.0081	0.0054	0.0027	**0.1863**
1989	0.0108	0.0405	0.0405	0.0621	0.0513	0.0351	0.0324	0.027	0.0162	0.0081	0.0054	0.0027	**0.3321**
1990	0.0027	0.0108	0.3429	0.6129	0.27	0.4266	0.1593	0.0135	0.0081	0.0081	0.0054	0.0027	**1.863**
1991	0.0027	0.0135	0.0324	0.0216	0.0108	0.0054	0.0027	0.0027	0.0027	0.0027	0.0027	0.0054	**0.1053**
1992	0.0108	0.0108	0.0243	0.1512	0.1107	0.054	0.0243	0.0108	0.0054	0.0054	0.0027	0.0027	**0.4131**
1993	0.0081	0.0324	0.054	0.0351	0.0405	0.0351	0.0162	0.0054	0.0027	0.0027	0.0027	0.0027	**0.2376**
1994	0.0054	0.0081	0.0216	0.0189	0.0189	0.0486	0.0594	0.0351	0.0135	0.0054	0.0054	0.0027	**0.243**
1995	0.0027	0.0135	0.0189	0.0297	0.1269	0.0999	0.0459	0.027	0.0162	0.0135	0.0108	0.0054	**0.4104**
1996	0.0162	0.2349	0.1215	0.0432	0.0216	0.0216	0.0189	0.0135	0.0081	0.0054	0.0054	0.0027	**0.513**
1997	0.0081	0.0162	0.0162	0.0162	0.0108	0.0054	0.0027	0.0027	0.0027	0.0027	0.0027	0.0054	**0.0918**
1998	0.0108	0.0162	0.0135	0.0216	0.0189	0.0081	0.0054	0.0081	0.0081	0.0054	0.0054	0.0054	**0.1269**
1999	0.0081	0.0189	0.0594	0.0864	0.0972	0.2106	0.108	0.0378	0.0162	0.0108	0.0054	0.0027	**0.6615**
AVERAGE	0.0101	0.0449	0.0615	0.0922	0.0792	0.0630	0.0357	0.0174	0.0097	0.0074	0.0060	0.0052	**0.4323**
Depth (mm)	**0.31**	**1.38**	**1.89**	**2.83**	**2.43**	**1.93**	**1.10**	**0.53**	**0.30**	**0.23**	**0.18**	**0.16**	**13.27**
Min	0.0027	0	0.0027	0.0108	0.0081	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0648
Max	0.0486	0.7776	0.405	0.8073	0.891	0.5481	0.2538	0.1242	0.0378	0.0243	0.027	0.0216	2.7837