A Hydrological Study of Surface Water Runoff on the Farms

Aan De Valsch Rivier 186 and Horeb 149, Riversdale, Western Cape

Prepared by

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1. Introduction

This report has been prepared for PHS Consulting and documents the results of a hydrological assessment undertaken by Creo Design (Pty) Ltd ("Creo") on Portion 3 of the farm Aan de Valsch Rivier 186 and Farm Horeb 149 some 20 km northeast of Riversdale in the Western Cape Province of South Arica. The assessment covers the prevailing hydrological conditions in the catchment area upstream of the southern limit of the properties with special reference to the total annual discharge of the catchment area.

The objective of this investigation is to report on the discharge available at the two farms from runoff from the upstream catchment area. In addition, an opinion is presented on the contribution of the catchment area to the water requirement of the farming activities on the properties under discussion.

1.1. Scope of the Assessment

The tasks performed during this assessment were as follow:

- Perform a desktop study of the area under investigation for the purpose of establishing a basic appreciation of the study site and its immediate surrounding areas as well as the geological, hydrological & geohydrological setting of the area.
- Do a GIS based estimation of the catchment area feeding the properties.
- Determine the catchment discharge.
- Conduct a site visit to survey the area.
- Compile an inclusive hydrological report covering aspects that might influence the hydrological parameters of the study site and discharge regime of the catchment area.

2. Methodology

The hydrological assessment consists of the following:

1. Desktop study that investigates the geographical setting of the area, the climate, and the drainage basin substrate geology.
2. Determination of the catchment area and catchment discharge.
3. A site visit on 10 September 2025 to investigate the area and to determine the local conditions.

Detail descriptions of the methods employed, and execution of these studies are discussed in section 4 of this report.

3. Desktop Study

3.1. Location of Area

The assessment area is situated approximately 20 km northeast of Riversdale in the Western Cape Province of South Arica. The area under investigation is located on the remainder of portion 3 of the farms Aan de Valsch Rivier 186 and Horeb 149 in the Riversdale District. The catchment area is located on the southern slopes of the Langeberg with the Vals River and its headwater tributaries draining in a south easterly direction (Figure 1). The slopes in the catchment area ranges from very steep in the northern part of the catchment area to steep with deeply incised valleys in the southern part of the catchment area. The highest point in the catchment area, at the northernmost boundary is 972 m above mean sea level (mamsl) with the lowest point, the southern boundary, being 221 mamsl.

The catchment area is located on the western flank of the Gouritz River Valley and lies within Quaternary catchment H70H and forms part of the Breede-Gouritz Water Management Area.

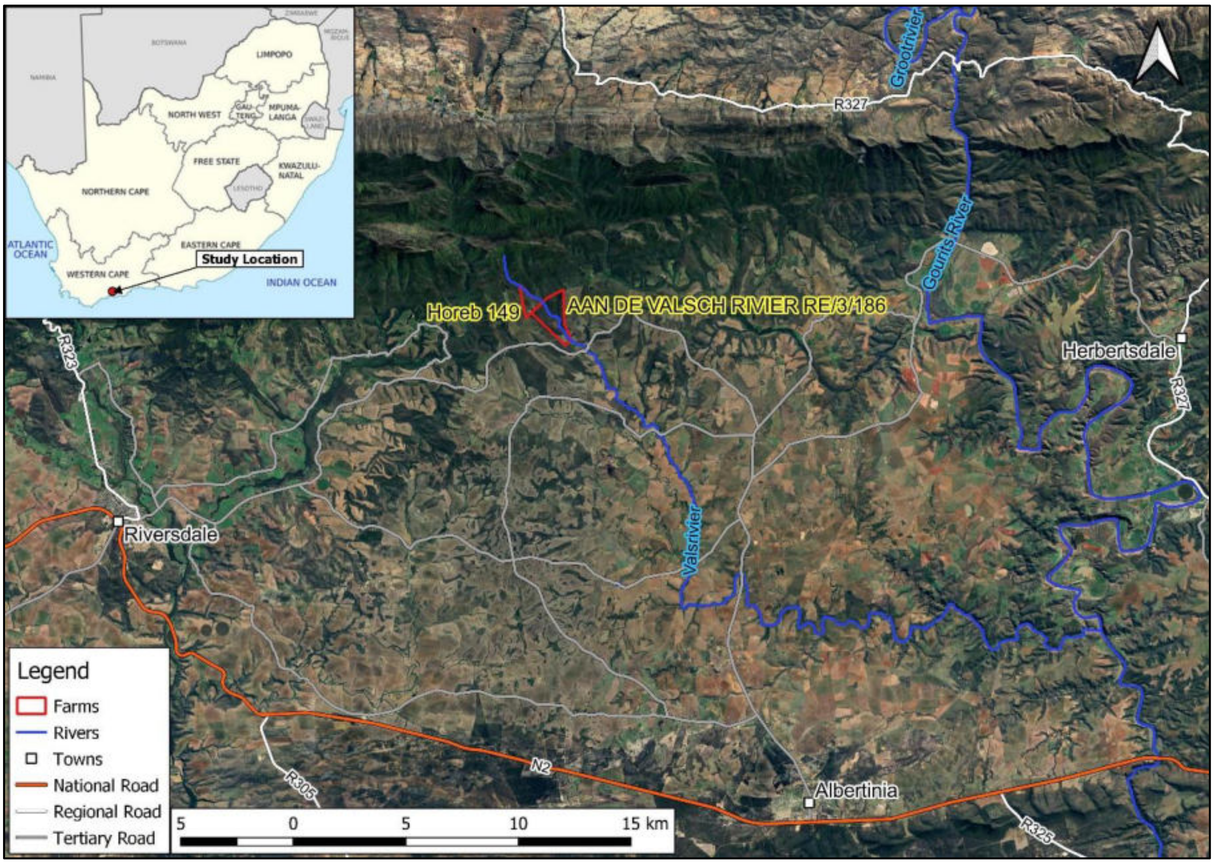

Figure 1: Locality of the two farms.

3.2. Climate

The region has a predominantly Mediterranean climate, characterized by hot, dry summers and mild, wet winters. The average annual maximum and minimum temperatures is 25°C and 11.6°C respectively.

The summer months of December, January and February are hot and dry, while the winter months of June, July and August are cold and rainy. The area is located in a winter rainfall region; however, rainfall occurs throughout the year with the wetter months being March to November. The average rainfall is approximately 635 mm per annum with the maximum mean occurring in March and October and the minimum mean in December.

3.3. Topography and Drainage

The topography of the catchment area ranges from very steep mountain slopes to rolling hills on the southern portion of the catchment area with well-incised river valleys occupied by almost exclusively non-perennial streams. These numerus drainage systems are tributary streams feeding the semi-perennial Vals River, a tributary of the Gouritz River (Figure 1).

3.4. Geology

3.4.1. Regional Geology

The regional geology of the area under investigation comprises of the Palaeozoic aged Cape Supergroup. The succession of sandstone, shale and minor conglomerate were deposited between ~500 Ma and ~330 Ma and unconfromably overlies a Precambrian-Cambrian basement. Regionally the Cape Supergroup is overlaid by Cenozoic sediments of the Grahamstown Group.

The Cape Supergroup in the region comprise of the Table Mountain Group and the Bokkeveld Group. The older Table Mountain group is sandstone dominated with minor shale and is overlain by the Bokkeveld Group consisting of shale and sandstone. The Witteberg Group overlies the Bokkeveld Group and consist of sandstone and mudrock, however, it only outcrops in small areas to the north of the investigated area (Thamm & Johnson, 2006).

3.4.2. Local Geology

The geology underlying the property under investigation comprise of rocks of the Table Mountain Group and Bokkeveld Group. Outcropping in the northern portion of the catchment area is the Peninsula Formation of the Table Mountain Group. The Peninsula Formation mainly consists of white, coarse-grained to fine-grained, quarzitic sandstone (Thamm & Johnson, 2006).

In the southern portion of the catchment, area rocks of the Ceres Subgroup of the Bokkeveld Group constitute the substrate geology. The Ceres Subgroup mainly consists of Mudrock, shale, siltstone, feldspathic arenite and wacke (Thamm & Johnson, 2006). The arenite and wacke units occur as well-defined sandstone layers interbedded in mudstone and shale units.

On the flatter parts on old land surfaces preserved on the plateau at the foot of the Langeberg between river valleys the rocks of the Cape Supergroup are overlain by Quaternary aged well-consolidated silcretes belonging to the Grahamstown Formation.

4. Hydrological Surveys

The hydrological survey performed by Creo at the catchment area had to determine:

1) the surface area of the catchment feeding the two farms.
2) the rainfall related discharge to the farms.

4.1. Estimation of Catchment Area Surface

The estimation of the catchment area was done using the GIS software QGIS. A Digital Elevation Model (DEM) of the area was obtained from NASA Earthdata and was used as reference for the elevation of the area. Using the DEM and the geospatial data analysis platform WhiteboxTools for QGIS, the watershed boundary was established and in the process the catchment surface area that feeds the property were estimated. The total estimated surface area of the catchment was determined to be 13 225 141.07 m^2 (1 322.5 ha). Figure 2 indicates the watershed boundaries and extent of the catchment area.

4.2. Discharge Received at the Lowest Point on the Property

In the absence of flow gauges in the stream feeding the property a discharge calculation method had to be used that makes use of rainfall data. A universal runoff computation method generally used to calculate runoff rates and volumes for small catchment areas using rainfall data, the associated Modified Rational Method, is generally accepted as a method used for this type of discharge estimation (Thompson, 2006).

This calculation method uses an empirical linear equation to compute the runoff rate from a small catchment area during a selected period of uniform rainfall intensity.

Use of the Rational Method is ideal for small drainage areas with generally uniform surface cover and topography (LMNO Engineering, 2025).

One of the main parameters in the Rational Method equation is the runoff coefficient. Here, the major variables affecting the rational method runoff coefficient value for a catchment are:

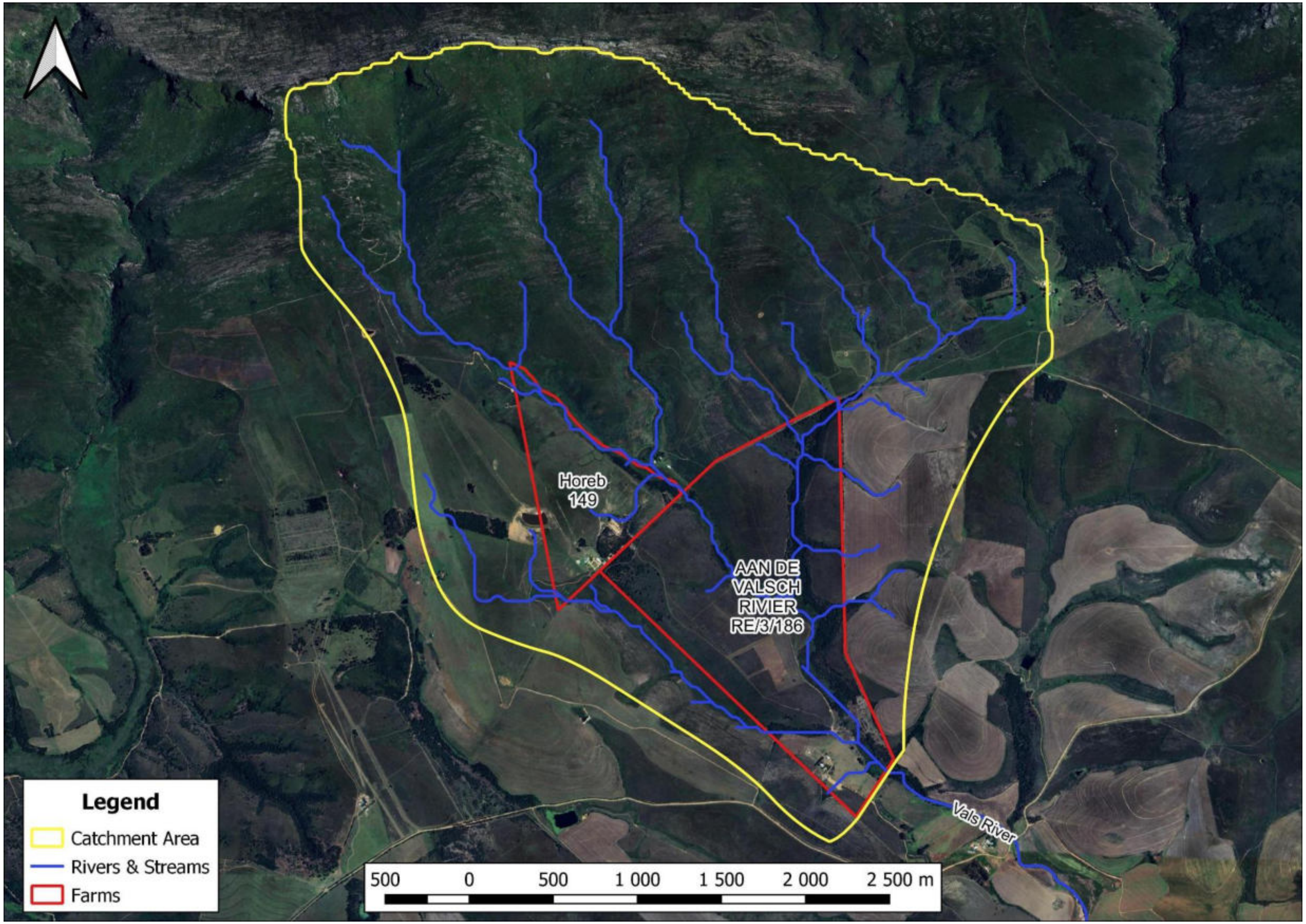

Figure 2: Map indicating the extend of the catchment area feeding the properties.

- land use,
- slope of the watershed and,
- soil type.

These factors constitute the physical interpretation of the runoff coefficient for a catchment and determine the fraction of rainfall on that catchment that becomes water runoff available to the downstream drainage basin.

The interaction of the runoff coefficient parameters is only fully appreciated if the influence of each of these parameters are fully appreciated:

Land Use: Surfaces that are relatively impervious like rocky outcrop and paved roads have runoff coefficients approaching one. Surfaces with vegetation to intercept surface runoff and those that allow infiltration of rainfall have lower runoff coefficients.

Slope: A catchment area with a greater slope will allow for less time for precipitation to infiltrate the soil resulting in more water runoff and thus a higher runoff coefficient than an area with a lower slope. Also, the uniformity of slopes is an important consideration. Here the slopes are generally steep (Figure 3).

Soil Type: Soils that have a high clay content don't allow very much infiltration and thus have relatively high runoff coefficients, while soils with high sand content have higher infiltration rates and low runoff coefficients.

4.3. Cumulative Annual Discharge

For the calculation of the cumulative annual discharge of the catchment area, the amount of the rainfall that actually becomes runoff needs to be estimated. The following key data sets were used for the calculation:

- Annual rainfall (P) in millimetres = 635 mm
- Catchment area (A) in square meters = 13 225 141.07 m^2

Runoff coefficient (C) — a dimensionless number between 0 and 1 that represents the fraction of rainfall that becomes runoff. The number is determined by conditions in the catchment area such as land use, soil type, vegetation, and slope, in this case 0,35.

For the calculation the rainfall data was converted from millimetres per annum to meters per annum and the catchment area is in square meters for the discharge volume calculation.

Formula for the discharge calculation:

{Annual Discharge (Q)} = P x A x C

- Total discharge of the catchment area in cubic meters per year (m^3/year)

  = **2 939 287,6 m^3**.

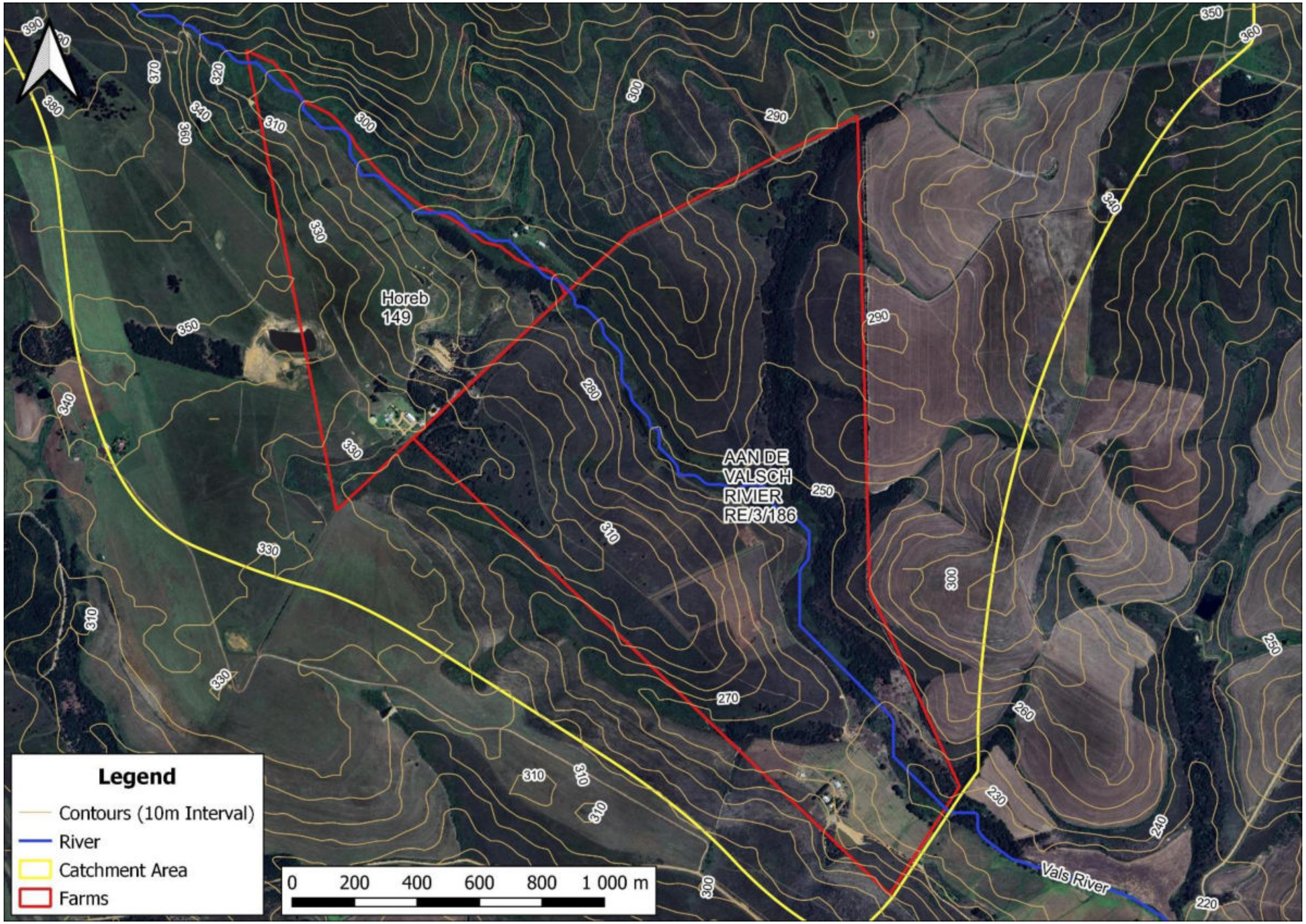

Figure 3: Contours on the property indicates steep slopes and a high gradient in the river course.

This discharge figure represents the total annual runoff after factoring in annual evapotranspiration and groundwater infiltration into the soil as well as the effect vegetation and catchment area slope have on overall infiltration.

5. Base Flow Estimation

Base flow in a river is the delayed groundwater and delayed surface runoff that sustains flow between rain events in rivers. Two main data sets are needed for the estimation of base flow namely:

1. hydrological data (flow over time) and,
2. catchment characteristics (physical properties of the basin).

Calculating base flow in the headwater reaches of the Vals River the specific parameters required vary by the calculation method used:

5.1. Primary Hydrological Data (Time-Series)

- **Streamflow Hydrograph:** A continuous record of discharge (e.g., in (m^3/s) over time is the fundamental basis.
- **Precipitation:** Rainfall amounts and timing are needed to identify when direct runoff events begin and end.

5.2. Catchment Parameters (Physical & Empirical)

For graphical or automated separation techniques, these factors determine the shape of the recession curve and how long the watershed takes to drain:

- **Watershed Area (A):** Used in empirical formulas (e.g., ($n = A^{0.2}$) to estimate the time it takes for direct runoff to cease following a peak flow event.
- **Filter Parameter (alpha) or (beta):** Used in recursive digital filter models; this recession constant represents the groundwater flow attenuation.
- **Base Flow Index (BFI):** A ratio (BFI = frac {Qb}{Qt}) that estimates the proportion of total streamflow that is base flow.
- **Land Use & Cover:** Percentage of pervious/impervious area, soil type/saturation, and vegetation density, which dictate how much water infiltrates the groundwater table.

5.3. Common Calculation Approaches

A best fit model approach used here rely on specific parameters to isolate base flow. The graphical method (straight line, fixed base, variable slope) model used require identifying hydrograph turning points (the start of runoff and end of the storm event), smooth high-frequency quick flows, relying on long-term time series.

5.3.1. Calculate Direct Runoff

A first step in calculating base flow requires the estimation of direct runoff. The volume of direct surface runoff generated in the catchment is determined using the volumetric runoff formula:

$Q=(C \times P \times A)$

Where:

- $C = 0.35$ (Runoff coefficient)
- $P = 0.635$ m (Annual rainfall)
- $A = 13{,}225{,}141.07m^2$ (Catchment area)

$Q=0.35 \times 0.635m \times 13{,}225{,}141.07m^2 = 2{,}939{,}287.603m^3$

5.3.2. Determine Base Flow

Total river discharge (Q_{total} is the sum of direct runoff and base flow Q_{base}. Isolate the base flow by subtracting the direct runoff from the total discharge:

$Q_{total} = Q_{direct}+Q_{base}$

$Q_{base}=Q_{total} - Q_{direct}$

$Q_{base}=2{,}939{,}287.6m^3 - 2{,}939{,}287.603m^3 = 0\ m^3$

The base flow in the Vals River is approximately $0m^3$, indicating that all measured discharge originates purely from surface runoff and the calculated direct surface runoff completely accounts for the given total discharge volume.

5.4. Summery

The parameters given, represent a perfectly balanced system where 100% of the total measured streamflow is accounted for by direct stormwater runoff, leaving a base flow of zero.

While where it is possible to mathematically apply estimation techniques to any river data, standard baseflow estimation methods largely break down in small, steep catchments with thin soils and infrequent rainfall.

In hydrology, the fundamental assumption behind baseflow is that a sustained, slow-moving groundwater reservoir continuously feeds the river channel long after a rain event has ended. In the extreme catchment profile described, that physical mechanism scarcely exists. Instead, these streams are typically ephemeral or intermittent, meaning they flow only during or immediately after rainfall and remain dry for the rest of the period between rainfall events.

Although it is possible run base flow calculations for any river, the physical realities, however, of a small, steep, thin-soiled catchment mean that traditional baseflow concepts don't apply, and the estimated value is often physically negligible.

6. Conclusions

The catchment area that forms the subject of this study is relatively small covering an area of 1 322.5 ha in total on the southern slopes of the Langeberg. The catchment area is characterised by very steep slopes and very high gradient headwater streams draining the catchment area. Rainfall in this area average 635 mm per annum resulting in an estimated discharge volume of 2 939 287,6 m^3 per annum at the southern limit of the farm Aan de Valsch Rivier 186. This figure makes provision for evapotranspiration and soil infiltration losses with the discharge figure presented here being the actual runoff into the Vals River drainage course.

The existing surface water use allowance is set at 49 280 m^3 for the farm Aan de Valsch Rivier 186. A requirement for an additional 160 720 m^3 per annum surface water for planed irrigation development on the farm will bring the total surface water demand to 210 000 m^3 per annum. The runoff estimated in this study shows that this demand of 210 000 m^3 per annum represents some 7% of the estimated surface water discharge available at the farm. This will be sufficient to sustain the increased surface water requirement on the properties under discussion and allow for some 93% of the discharge to be still available to the downstream drainage system.

When dealing with zero base flow conditions in challenging environments such as in the headwaters of the Vals River, it should be considered to shift the strategy away from traditional daily continuous separation toward alternative frameworks.

In this instance it is proposed to accept a zero-baseline condition to prevail. For many ephemeral streams in arid or steep, hard-rock environments, the true baseflow should simply treated as zero. The streamflow is entirely event-driven as short-lived quick flow episodes.

Signature of the specialist:

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20 July 2026

7. References

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