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WP13380

GROUNDWATER PROTECTION ZONES REPORT

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Literature Review and Data Gathering Report	RDM/WMA05/00/GWSW/0222
Gap Analysis Report	RDM/WMA05/00/GWSW/0322
Hydrocensus Report	RDM/WMA05/00/GWSW/0422
Water Resources Assessment Report	RDM/WMA05/00/GWSW/0522
Quantified Recharge and Baseflow Report	RDM/WMA05/00/GWSW/0123
Groundwater Quality Categorisation Report	RDM/WMA05/00/GWSW/0223
Protection Zones Report	**RDM/WMA05/00/GWSW/0323**
Surface-Groundwater Interaction Report	RDM/WMA05/00/GWSW/0423
External Reviewer Report	RDM/WMA05/00/GWSW/0523
Capacity Building and Training Report	RDM/WMA05/00/GWSW/0623
Main Report on Surface-Subsurface Interactions	RDM/WMA05/00/GWSW/0723
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TABLE OF CONTENTS

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Study Context

The purpose of the NWA (1998) is to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways which take into account amongst other factors: promoting equitable access to water; redressing the results of past racial and gender discrimination; promoting the efficient, sustainable and beneficial use of water in the public interest; facilitating social and economic development; protecting aquatic and associated ecosystems and their biological diversity and; meeting international obligations (NWA, 1998). Chapter 3 introduces a series of measures which together are intended to protect all water resources.

The Chief Directorate: Water Ecosystems Management (CD: WEM) is tasked with the responsibility to coordinate all Reserve determination studies which have priority over other uses in terms of the NWA.

This study intends to determine and quantify groundwater and surface water interactions and identify protection zoning to prevent the disturbance of the ecological integrity of ecosystems where such interactions occur. A feasibility study undertaken by the Department of Water and Sanitation (DWS) in 2007 and the National Water Resource Strategy II identified the need for surface-subsurface interaction studies in the lower Vaal. The purpose of such studies would be understanding subsurface processes when determining the Reserve.

1.2 Aims and Objectives of the Project

The need to undertake significant groundwater-surface water interaction studies became apparent to the DWS due to the need to understand the groundwater balance when determining the Reserve. Groundwater not only provides for dispersed water supply needs, but also make significant contributions to the ecological reserve, as well as to Basic Human Needs for future water supply. The main objectives of the study are:

- Review existing water resource information;
- Conduct a hydrocensus on an institutional level;
- Conduct a water resource assessment of surface water, groundwater, baseflow, abstraction, surface and groundwater balance, present status category;
- Quantify aquifer parameters and describe aquifer types;
- Determine groundwater-surface water interactions both in terms of quality and quantity to determine protection zones;
- Capacity building and skills transfer to DWS staff.

The project timeframe is 24 months, starting from November 2021-November 2023.

1.3 Purpose of Report

This report is submitted to Department of Water and Sanitation (DWS) by WSM Leshika Consulting to identify priority areas where groundwater-surface interaction is important and zones which need to be protected.

1.4 Approach

Catchments which need to be protected have been delineated by:

- Aquifer vulnerability
- Baseflow indices, indicating the significance of baseflow which could be depleted by abstraction.
- Declines in water level indicating existing over abstraction.
- Stress Indices of catchments

Water supply boreholes which need to be protected have been delineated by:

- A buffer zone based on capture zone around the borehole, which is determined from recharge and registered abstraction rate.

1.5 Structure of Report

Chapter 2 summarises the methodologies and data used to identify protection zones. **Chapter 3** provides a summary of the relevant aspects of the study area. **Chapter 4** provides maps of the recommended protection zones based on groundwater quality protection, groundwater quantity, and baseflow protection.

2 PROTECTION ZONE METHODOLOGIES

2.1 Groundwater Quality

Protection zones can be considered at various scales.

2.1.1 Local Quality Protection of Water Supply Points

At a local scale, groundwater protection zoning is a supplemental methodology for groundwater management that incorporates land use planning. Land use is managed to minimise the potential of groundwater contamination by human activities that occur on or below the land surface. Approaches to such local protection zone delineation range from relatively simple methods, based on fixed distances from water sources, through more complex methods based on travel times and aquifer characteristics, to more sophisticated modelling approaches of groundwater flow and contaminant kinetics.

The number of zones defined to cover the different levels of protection varies. These include; i) an operational zone immediately adjacent to the site of the borehole, well field or spring to prevent rapid ingress of contaminants or damage to the site; ii) an inner protection zone based on the time expected to reduce pathogen presence to an acceptable level (often referred to as the 'microbial protection area'); iii) an outer protection zone based on the time expected for dilution and effective attenuation of slowly degrading substances to an acceptable level. A further consideration in the delineation of this zone is sometimes also the time needed to identify and implement remedial intervention for persistent contaminants; iv) a much larger zone sometimes covers the total capture area of a particular abstraction where all water will eventually reach the abstraction point. This is designed to avoid long term degradation of quality.

With each protection zone comes specific land use constraints. These constraints are of increasing strictness moving from the outer protection zone to the wellhead operational zone.

Differentiated protection, as defined in Section 26.2 of the NWA, aims to protect resources with the highest importance. Not all water resources can be protected to the same degree due to financial and human capacity constraints. Through the Reserve concept, drinking water and ecosystems have the highest level of protection in the NWA.

In this study, the total capture zone has been considered (zone iv), which is the largest protection zone based on the capture zone over which a borehole captures water. This is defined as:

Capture Zone = abstraction / Recharge.

Quaternary recharge was used, as derived in DWS (2023), and the subsequent area converted to a radius. Only boreholes registered for water supply were considered. Abstraction was based on WARMS registered annual abstraction.

2.1.2 Regional Aquifer Pollution Vulnerability

Some aquifers are susceptible to contamination from surface due to shallow groundwater tables, thin soil cover, coarse soils with low clay content and unconfined aquifer conditions. Fractured aquifers allow rapid entry and migration of contaminants via preferred pathways and have the potential to contaminate vast areas along the fracture network.

Groundwater vulnerability was considered in terms of the DRASTIC method of assessment of the intrinsic vulnerability of an aquifer to contamination from the surface (Lynch et al. 1997). The method considers various factors which control the vulnerability of an aquifer to contamination from surface.

The DRASTIC Approach to aquifer vulnerability assessment is based on superimposing various layers of data with prescribed ratings. The final outcome/rating is then used to categorise the level of vulnerability. Higher ratings are associated with aquifers that have higher vulnerability and susceptibility to contamination from the surface. The term DRASTIC originates from the following layers:

D - Depth to groundwater

R - Recharge rate (net recharge)

A - Aquifer media; Obtained from Geological maps

S - Soil media; obtained from the soils data set, (WR2012, RSA) intersected with geology

T – Topography; obtained from GRAII and from a 20 m DTM

I - Impact on vadose zone; obtained from Geological maps

Each of these layers is assigned a value based on a rating (r) and a weight (w). These layers are adjusted by a weighting factor and summed to calculate the DRASTIC index. The DRASTIC formula for groundwater in South Africa according to Lynch *et al*. (1997) is as follows:

DRASTIC INDEX = DrDw + RrRw+ ArAw+ SrSw+ TrTw+ IrIw

Where:

Depth to groundwater = (Dw)

Recharge = (Rw)

Aquifer media = (Aw)

Soil media = (Sw)

Topography (% slope) = (Tw)

Impact of vadose zone = (Iw)

The weights of each of the above-mentioned terms are shown in **Table 2-1**.

Table 2-1 DRASTIC Ratings and Weighting

Depth to groundwater (mbgl)	Rating	Weighting	Recharge (mm/a)	Rating	Weighting	Aquifer	Rating	Weighting
<1.5	10	5	0 - 5	1	4	Karstic (dolomite)	10	3
1.5 to 4.5	9		5 - 10	3		Intergranular	8	
4.5 to 9	7		10 - 50	6		Fractured	6	
9 to 15	5		>50	8		Fractured and weathered	3	
15 to 22.5	3							
22.5 to 30	2							
>30	1							
Topography Slope rating (%)	**Rating**	**Weighting**	**Impact of vadose zone**	**Rating**	**Weighting**	**Soil**	**Rating**	**Weighting**
0-2	10	1	Gneiss, Basalt, Dolerite, schist/amphibolite	3	5	Loamy Medium Sand (LmS)	6	2
2-6	9		Mudstone/shale, sandstone/shale	3		Sand	10	
6-12	5		Karoo (Sandstone)	5		sandy clay (Sacl)	5	

12-18	3		Granite, amphibolite, felsite, Syenite, Norite	6		sandy clay loamy (SaClLm)	5	
			Dolomite	10		sandy loamy (Salm)	6	
			Quartzite	8				
			Kalahari (sand)	10				

A DRASTIC index below 80 is considered low vulnerability to insignificant, and a rating of above 130 is very high vulnerability to extreme when above 150 (**Table 2-2**).

Table 2-2 DRASTIC Indices Classification

DRASTIC INDEX	Vulnerability
0-70	Insignificant
70-80	Very Low
80- 100	Low
100 – 120	Moderate
120-130	High
130 - 150	Very High
150 -200	Extreme

2.2 Groundwater Quantity Protection

In terms of groundwater quantity protection, groundwater abstraction must be considered in terms of recharge via a stress index, regional water levels and their potential decline, and the potential to impact on surface water resources and the environment in terms of baseflow reduction.

2.2.1 Impact of Abstraction on Baseflow

One of the consequences of the over abstraction of groundwater is a reduction of baseflow. Even if the aquifer is not stressed by over abstraction, an impact on baseflow above a certain limit may be considered undesirable (usually defined in Reserve investigations). Given the critical status of surface water resources in the Vaal-Orange Basin, the potential of groundwater abstraction to reduce baseflow, affecting environmental flows and the yield of dams or discharge of springs, baseflow reduction is an important factor to consider.

To quantify the potential of abstraction to reduce baseflow, a baseflow index was calculated by groundwater baseflow/groundwater recharge. The classification of risk based on this index is shown in **Table 2-3**. Where large fractions of recharge contribute to baseflow, the likelihood of baseflow reduction is high. Recharge and baseflow for Quaternary catchments were derived in DWS (2023) and are summarised by Quaternary in **Table 2-4.**

Table 2-3 Risk of Baseflow Reduction

Baseflow Index	Risk of Baseflow Reduction
0	Negligible
0-0.1	Insignificant
0,1-0.2	Low

0.2-0.4	Moderate.
0.4-0.5	Moderately High
0.5-0.7	High
0.7-0.8	Very High

Table 2-4 Recharge and baseflow

Quat	MAR (Mm^3/a)	Baseflow (Mm^3/a)	Recharge (Mm^3/a)	Groundwater Use (Mm^3/a)	Stress Index	Baseflow (% of MAR)	Baseflow Index
C31A	15.78	9.33	31.85	24.91	0.78	0.59	0.29
C31B	11.72	1.21	17.65	15.43	0.87	0.10	0.08
C31C	14.35	0.15	14.94	8.18	0.55	0.01	0.00
C31D	5.76	1.03	14.19	3.84	0.27	0.18	0.08
C31E	14.29	0.07	21.13	16.77	0.79	0.00	0.00
C31F	8.71	0.25	10.84	9.32	0.86	0.03	0.02
C32A	7.49	0	8.53	7.90	0.93	0.00	0.00
C32B	14.78	0.05	28.73	38.67	1.35	0.00	0.00
C32C	10.95	0.02	10.50	6.24	0.59	0.00	0.00
C32D	33.81	22.99	60.51	15.21	0.25	0.68	0.38
C33A	5.41	4.36	28.59	3.68	0.13	0.81	0.15
C33B	21.52	11.09	30.00	1.89	0.06	0.52	0.37
C33C	23.49	13.53	38.69	1.90	0.05	0.58	0.35
C91A	4.04	0.03	30.86	7.60	0.25	0.01	0.00
C91B	5.73	0.06	52.64	22.80	0.43	0.01	0.00
C91C	11.09	0.05	23.58	3.93	0.17	0.00	0.00
C91D	3.79	0	18.61	3.14	0.17	0.00	0.00
C91E	2.07	0	9.69	8.03	0.83	0.00	0.00
C92A	16.29	12.63	41.28	4.44	0.11	0.78	0.38
C92B	8.75	2.11	9.49	0.68	0.07	0.24	0.28
C92C	7.77	5.14	13.20	5.21	0.39	0.66	0.12
D41B	2.63	0.05	30.70	9.73	0.32	0.02	0.00
D41C	11.08	0.09	16.11	4.37	0.27	0.01	0.01
D41D	6.95	0.08	14.89	14.75	0.99	0.01	0.01
D41E	0.77	0	10.48	0.94	0.09	0.00	0.00
D41F	2.26	0	13.34	0.68	0.05	0.00	0.00
D41G	1.51	0.23	22.27	5.47	0.25	0.15	0.01
D41H	3.27	0.01	21.47	10.89	0.51	0.00	0.00
D41J	4.26	3.06	34.78	26.22	0.75	0.72	0.09
D41K	3.63	0.02	9.19	8.52	0.93	0.01	0.00
D41L	19.32	19.13	92.32	15.14	0.16	0.99	0.21
D41M	0.78	0	5.12	1.97	0.38	0.00	0.00
D42C	1.07	0	16.92	2.76	0.16	0.00	0.00
D73A	0.31	0.33	5.23	47.52	9.09	1.00	0.06

D73C	0.3	0	7.15	0.61	0.09	0.00	0.00
Total	305.73	107.1	815.46	359.36			

2.2.2 Stress Index

The groundwater stress index is used to reflect water availability versus groundwater used. The Stress Index for an assessment area is defined as follows:

- Stress Index = Groundwater use/Recharge.

In calculating the Stress Index, the variability of annual recharge is taken into account in the sense that not more than 65% of average annual recharge should be allocated on a catchment scale without caution and monitoring (stress index = 0.65).

Stress index is calculated as groundwater use relative to **aquifer recharge** Groundwater use was determined in DWS (2022) by WARMS registered lawful water use, hydrocensus, plus Schedule 1 water use. Classification of stress is based on the DWS methodology (**Table 2-5**).

Table 2-5 Classification of groundwater by stress

Present Class	Description	Present Status Category	Stress Index
I	Minimally used	A	≤0.05
		B	0.05 - 0.2
II	Moderately used	C	0.2 - 0.4
		D	0.4 - 0.65
III	Heavily used	E	0.65 - 0.95
		F	>0.95

2.2.3 Groundwater Levels

Groundwater level data is available from 233 DWS open stations (**Table 2-6)**. There are 17 stations with more than 40 years of record, 52 with more than 30 years of record and 113 with more than 20 years of record. This provides much valuable data for assessing water level trends. Their distribution is shown in **Figure 2-1.** The monitoring stations cover all of the catchments with high levels of abstraction except C31F near Schweizer Reneke and C32A.

Where no long term DWS monitoring data is available, data was sourced from the Tshiping Water Users Association Water Information Management System, which is a mine and municipality water information database system, offering water accounting with reporting. Although most of the data is of a relatively short period (post 2010 or thereabouts), some historic long-term data is contained. Tshiping only covers catchments C92A and C, D41JK, C33B, D42C, and D71 and D73 which are largely outside the lower Vaal.

Groundwater levels per Quaternary catchment are shown in Appendix 1. Groundwater level trends can be categorised according to **Table 2-7,** with catchments with a water level trend of Status 4 requiring the most urgent intervention. A status of 0 (no data), combined with a high stress index are also indicative of a need for urgent intervention.

Table 2-6 Available water level data

Station Number	Quaternary	Begin Date	Monitoring Frequency
C3N0030	C31B	1975/08/15	Quarterly
C3N0050	C32B	1980/10/03	Quarterly
C3N0054	C32B	1980/07/28	Quarterly
C3N0060	C32B	1982/11/07	Quarterly
C3N0062	C32B	1980/05/30	Quarterly
C3N0064	C32B	1981/10/31	Quarterly
C3N0069	C32B	1980/09/06	Quarterly
C3N0071	C32B	1979/09/01	Quarterly
C3N0072	C32B	1980/09/09	Quarterly
C3N0075	C32B	1981/10/17	Quarterly
C3N0078	C32B	1979/06/09	Quarterly
C3N0098	C32D	1985/02/21	Quarterly
C3N0099	C32D	1984/10/31	Quarterly
C3N0107	C31B	1987/04/01	Quarterly
C3N0500	C31C	1987/08/13	Quarterly
C3N0511	C32B	1958/05/12	Quarterly
C3N0527	C33A	1987/07/25	Quarterly
C3N0530	C33A	1987/01/22	Quarterly
C3N0553	C31A	1990/08/23	Quarterly
C3N0555	C33A	1992/12/22	Quarterly
C3N0556	C33A	1994/07/08	Quarterly
C3N0561	C32D	1995/03/15	Quarterly
C3N0605	C33A	2003/04/07	Quarterly
C3N0621	D41L	2002/09/25	Quarterly
C3N0655	C32A	2013/06/05	Quarterly
C3N0656	C32C	2013/06/05	Quarterly
C3N0657	C31C	2013/06/03	Quarterly
C3N0661	C31E	2013/06/05	Quarterly
C3N0662	C31E	2013/06/05	Quarterly
C3N0665	C33C	2013/09/17	Quarterly
C3N0666	C33C	2013/09/17	Quarterly
C3N0668	C31C	2017/08/21	Quarterly
C9N0549	C92A	2002/09/17	Quarterly
C9N0559	C91E	2006/12/18	Quarterly
C9N0616	C91E	2012/06/27	Quarterly
D3N0561	C32D	2002/04/15	Quarterly
D3N0562	C32D	2002/04/15	Quarterly
D3N0564	C32D	2002/04/15	Quarterly
D3N0565	C32D	2002/04/15	Quarterly
D3N0566	C32D	2002/04/15	Quarterly
D3N0569	C32D	2002/04/15	Quarterly
D4N0143	D41B	1977/02/11	Quarterly

Station Number	Quaternary	Begin Date	Monitoring Frequency
D4N0706	D41J	1981/11/23	Quarterly
D4N1533	D41L	1998/01/17	Quarterly
D4N1535	D41B	1997/08/27	Quarterly
D4N1536	D41B	1997/08/27	Quarterly
D4N1538	D41G	1997/03/04	Quarterly
D4N1539	D41L	2001/08/01	Quarterly
D4N1544	D41L	1973/01/23	Quarterly
D4N1546	C33C	1970/01/01	Quarterly
D4N1548	D41L	1985/12/05	Quarterly
D4N1550	D41L	1970/07/11	Quarterly
D4N1556	D41L	2001/01/24	Quarterly
D4N1557	C33C	1995/03/03	Quarterly
D4N1560	D41J	1996/09/04	Quarterly
D4N1564	D41J	1996/06/01	Quarterly
D4N1566	D41J	1996/06/01	Quarterly
D4N1568	D41J	1996/06/01	Quarterly
D4N1569	D41J	1998/07/27	Quarterly
D4N1572	D41J	1996/06/01	Quarterly
D4N1580	D41L	1987/11/24	Quarterly
D4N1581	D41L	1988/05/10	Quarterly
D4N1583	D41L	1992/12/31	Quarterly
D4N1585	D41L	1988/01/26	Quarterly
D4N1614	D41J	1996/06/01	Quarterly
D4N1616	D41J	1996/09/04	Quarterly
D4N1654	D41B	1998/12/14	Quarterly
D4N1660	D41E	1998/09/15	Quarterly
D4N1662	D41E	1997/10/30	Quarterly
D4N1665	D41E	1998/09/04	Quarterly
D4N1671	D41H	1985/08/20	Quarterly
D4N1685	C32D	1985/01/08	Quarterly
D4N1694	C32D	1987/09/01	Quarterly
D4N1700	D41E	1992/07/29	Quarterly
D4N1721	D41D	1985/01/11	Quarterly
D4N1789	D41L	1992/03/12	Quarterly
D4N1791	D41L	1992/03/12	Quarterly
D4N1792	D41L	1992/03/12	Quarterly
D4N1799	D41L	1994/06/07	Quarterly
D4N1861	D41K	2005/05/09	Quarterly
D4N1866	D41L	1991/05/01	Quarterly
D4N1867	D41L	1991/05/01	Quarterly
D4N1868	D41L	1994/09/28	Quarterly
D4N1869	D41L	1991/01/02	Quarterly
D4N1871	D41L	1991/01/02	Quarterly

Station Number	Quaternary	Begin Date	Monitoring Frequency
D4N1872	D41L	1991/01/02	Quarterly
D4N1876	D41L	1991/01/02	Quarterly
D4N1878	D41L	1995/03/03	Quarterly
D4N1882	D41L	2002/10/22	Quarterly
D4N1885	D41L	2006/05/26	Quarterly
D4N1894	D41L	2004/08/25	Quarterly
D4N1956	D41D	1998/04/01	Quarterly
D4N1977	C32D	1998/04/01	Quarterly
D4N1988	D41D	1998/04/01	Quarterly
D4N1989	C32D	1998/04/01	Quarterly
D4N1993	C32D	1998/04/01	Quarterly
D4N1998	C32B	1998/04/01	Quarterly
D4N2000	C32D	1998/04/01	Quarterly
D4N2009	D41D	1998/04/01	Quarterly
D4N2024	C32D	1998/04/01	Quarterly
D4N2031	C31E	2008/11/09	Quarterly
D4N2034	C31D	2010/03/25	Quarterly
D4N2038	C31D	2008/11/09	Quarterly
D4N2050	C31E	2011/11/01	Quarterly
D4N2051	C31E	2008/11/05	Quarterly
D4N2060	C31C	2008/11/04	Quarterly
D4N2068	C31C	2008/11/04	Quarterly
D4N2070	C31E	2008/11/05	Quarterly
D4N2082	C31C	2008/11/04	Quarterly
D4N2085	C31B	2008/11/04	Quarterly
D4N2097	C31D	2008/11/06	Quarterly
D4N2108	C31E	2008/11/04	Quarterly
D4N2113	C31E	2008/11/06	Quarterly
D4N2125	C31E	2008/11/07	Quarterly
D4N2143	C31E	2008/11/07	Quarterly
D4N2174	C31E	2008/11/06	Quarterly
D4N2175	C31D	2008/11/06	Quarterly
D4N2178	C31E	2008/11/07	Quarterly
D4N2186	C31E	2008/11/06	Quarterly
D4N2187	C31E	2011/11/04	Quarterly
D4N2225	C31E	2008/11/08	Quarterly
D4N2264	C32C	2008/11/07	Quarterly
D4N2274	C32D	2002/04/15	Quarterly
D4N2277	C32B	2001/04/15	Quarterly
D4N2279	C32D	2002/04/15	Quarterly
D4N2280	C32D	2002/04/15	Quarterly
D4N2281	C32D	2002/04/15	Quarterly
D4N2286	D41D	2003/09/23	Quarterly

Station Number	Quaternary	Begin Date	Monitoring Frequency
D4N2287	D41D	2003/09/16	Quarterly
D4N2288	D41D	2003/09/12	Quarterly
D4N2289	D41D	2003/10/23	Quarterly
D4N2290	D41D	2003/10/22	Quarterly
D4N2291	D41D	2004/03/29	Quarterly
D4N2296	D41D	1991/07/09	Quarterly
D4N2297	D41D	1991/06/14	Quarterly
D4N2298	D41C	2004/06/18	Quarterly
D4N2302	D41D	1991/06/27	Quarterly
D4N2305	D41D	1991/06/19	Quarterly
D4N2309	D41D	2001/04/01	Quarterly
D4N2310	D41D	2001/04/01	Quarterly
D4N2311	D41C	2004/09/02	Quarterly
D4N2314	D41D	1991/02/21	Quarterly
D4N2315	D41D	1991/02/27	Quarterly
D4N2316	D41D	1991/02/08	Quarterly
D4N2317	D41D	1991/02/08	Quarterly
D4N2320	D41D	1991/03/22	Quarterly
D4N2322	D41D	1991/03/15	Quarterly
D4N2323	D41D	1991/03/13	Quarterly
D4N2325	D41D	1991/02/16	Quarterly
D4N2326	D41D	1991/02/16	Quarterly
D4N2344	D41D	1991/02/26	Quarterly
D4N2370	D41J	2006/05/22	Quarterly
D4N2371	D41J	2006/08/16	Quarterly
D4N2373	D41J	2006/02/09	Quarterly
D4N2375	D41J	2006/02/09	Quarterly
D4N2377	D41J	2007/05/16	Quarterly
D4N2378	D41L	2006/09/07	Quarterly
D4N2382	D41K	2006/09/08	Quarterly
D4N2383	D41K	2006/09/08	Quarterly
D4N2384	D41K	2009/03/04	Quarterly
D4N2385	D41K	2006/05/25	Quarterly
D4N2386	D41K	2006/05/25	Quarterly
D4N2458	D41L	2006/05/23	Quarterly
D4N2459	D41K	2006/08/17	Quarterly
D4N2461	D41K	2008/05/20	Quarterly
D4N2463	D41K	2006/08/21	Quarterly
D4N2464	D41K	2006/12/11	Quarterly
D4N2466	D41K	2006/08/19	Quarterly
D4N2467	D41K	2006/08/19	Quarterly
D4N2470	D41J	2007/11/26	Quarterly
D4N2488	D41E	2002/08/21	Quarterly

Station Number	Quaternary	Begin Date	Monitoring Frequency
D4N2490	D41E	2002/08/22	Quarterly
D4N2498	D41B	2010/07/20	Quarterly
D4N2499	D41B	2013/06/19	Quarterly
D4N2503	D41B	2010/08/02	Quarterly
D4N2519	D41E	2011/06/21	Quarterly
D4N2523	D41M	2014/05/20	Quarterly
D4N2524	D41M	2014/05/20	Quarterly
D4N2525	D41K	2014/05/19	Quarterly
D4N2528	D41M	2014/05/20	Quarterly
D4N2529	D41M	2014/05/20	Quarterly
D4N2537	D41L	2006/05/23	Quarterly
D4N2539	C31E	2013/06/04	Quarterly
D4N2545	D41G	2006/05/22	Quarterly
D4N2548	D41J	2013/06/03	Quarterly
D4N2549	D41J	2013/06/03	Quarterly
D4N2558	D41K	2013/08/15	Quarterly
D4N2559	D41L	2014/05/21	Quarterly
D4N2560	D41L	2014/05/21	Quarterly
D4N2561	D41L	2014/05/21	Quarterly
D4N2563	D41G	2014/09/17	Quarterly
D4N2565	D41M	2014/09/12	Quarterly
D4N2567	D41K	2014/03/18	Quarterly
D4N2568	D41K	2014/03/18	Quarterly
D4N2573	D41E	2015/03/18	Quarterly
D4N2576	D41E	2015/03/20	Quarterly
D4N2578	D41E	2015/08/24	Quarterly
D4N2580	D41E	2015/03/20	Quarterly
D4N2582	D41D	2015/03/20	Quarterly
D4N2583	D41E	2015/03/20	Quarterly
D4N2592	D41D	2015/03/20	Quarterly
D4N2593	D41L	2015/03/20	Quarterly
D4N2603	D41D	2015/03/26	Quarterly
D4N2604	D41D	2015/03/26	Quarterly
D4N2605	D41C	2015/03/26	Quarterly
D4N2608	D41C	2015/03/26	Quarterly
D4N2609	D41C	2015/03/26	Quarterly
D4N2616	D41C	2015/03/26	Quarterly
D4N2617	D41C	2015/03/26	Quarterly
D4N2622	D41L	2006/05/25	Twice yearly
D4N2623	D41J	2015/03/04	Twice yearly
D4N2627	D41E	2010/06/08	Quarterly
D4N2636	D41B	2016/08/25	Quarterly
D4N2637	D41B	2016/12/03	Quarterly

Station Number	Quaternary	Begin Date	Monitoring Frequency
D4N2638	D41B	2016/11/03	Quarterly
D4N2639	D41B	2016/11/03	Quarterly
D4N2642	D41E	2015/08/25	Quarterly
D4N2643	C31D	2015/09/08	Quarterly
D4N2644	D41E	2015/08/24	Quarterly
D4N2649	D41J	2014/06/24	Quarterly
D6N0645	C91D	2012/03/22	Quarterly
D7N0525	D73A	2002/05/07	Quarterly
D7N0527	D73A	2002/05/07	Quarterly
D7N0531	D73A	2004/09/28	Quarterly
D7N0533	D73A	2004/09/28	Quarterly
D7N0534	D73A	2004/09/28	Quarterly
D7N0536	D73A	2004/09/28	Quarterly
D7N0537	D73A	2004/09/28	Quarterly
D7N0539	D73A	2004/09/28	Quarterly
D7N0540	D73A	2004/09/28	Quarterly
D7N0580	D73A	2007/10/08	Quarterly
D7N0723	D73A	2000/01/26	Quarterly
D7N0728	D73A	1994/12/01	Quarterly
Tshiping Data			
BES2	C33C	1997/05/27	Quarterly
PPC14	C92C	1986/01/20	Variable
502/01	C92C	1997/11/04	Variable
WT05	C92C	1970/10/01	Variable
LT11	D73C	1969/12/19	Variable

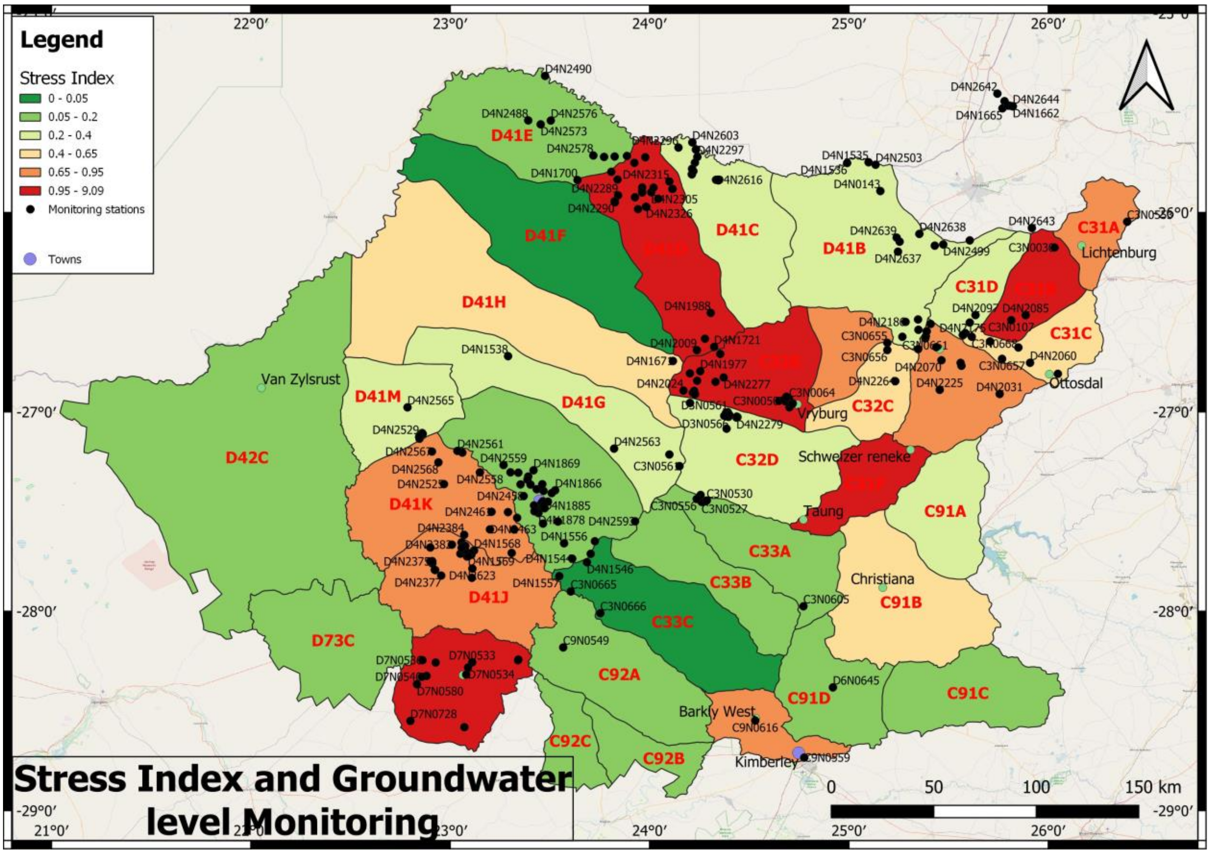


Figure 2-1 Groundwater level monitoring stations and stress index

Table 2-7 Groundwater level trends

Status	Groundwater Level
0	No data available
1	Groundwater level stable
2	Groundwater level shows a historic decline but is now stable
3	Groundwater level exhibits a gradual decline and intervention will be needed to protect groundwater
4	Ground exhibits a declining trend and protection is required

3 STUDY AREA

The study area has been described in the Water Resources Assessment Report and is only summarized here.

3.1 Location and Drainage

The Lower Vaal catchment (former WMA 10) lies in the north-eastern part of the Northern Cape Province, the western part of Northwest Province, and a part of the northern Free State Province (**Figure 3-1**). It contains the Molopo and Kuruman (D4), Harts (C3), and the Vaal (C9) (below Bloemhof dam and above Douglas Weir) catchments. These catchments include Tertiary catchments C31-C33, C91-92, D41, and Quaternary catchments D73A, D42C-D, D73B-E. They contain dolomite aquifers, where interaction with surface water can be significant. The water in the Lower Vaal region drains to the Lower Orange drainage region before reaching the Atlantic Ocean near the town of Alexander Bay in the western corner of the country.

The basins are located in a semi-arid to arid region of South Africa. Most of the surface water resources originate upstream of Bloemhof dam. Groundwater is an important water resource, especially in areas located away from surface water bodies. Groundwater use depletes the already meagre surface water resources by inducing losses from river channels or depleting flow from dolomitic eyes and as baseflow.

The Lower Vaal is located between the Middle Vaal drainage region and the Lower Orange drainage region, with the Upper Orange basin to the southeast, and Botswana to the north. The Lower Vaal has an area of approximately 136 146 km^2. It excludes the Riet-Modder River catchment) (C5), the Molopo River system above its confluence with the Nossob (parts of D42) and portions of the Vaal River catchment below the confluence with the Harts and Douglas weir (parts of C92B and C, and D71B). It is important to note that although the Riet-Modder Catchment forms part of the Vaal River Basin, it is included as part of the Upper Orange River sub-system, mainly due to the fact that there are several transfers from the Orange River to support water requirements in the Riet-Modder catchment. The only connection between the Vaal and Riet-Modder rivers is the spills from the Riet-Modder catchment into the Vaal River just upstream of Douglas Weir.

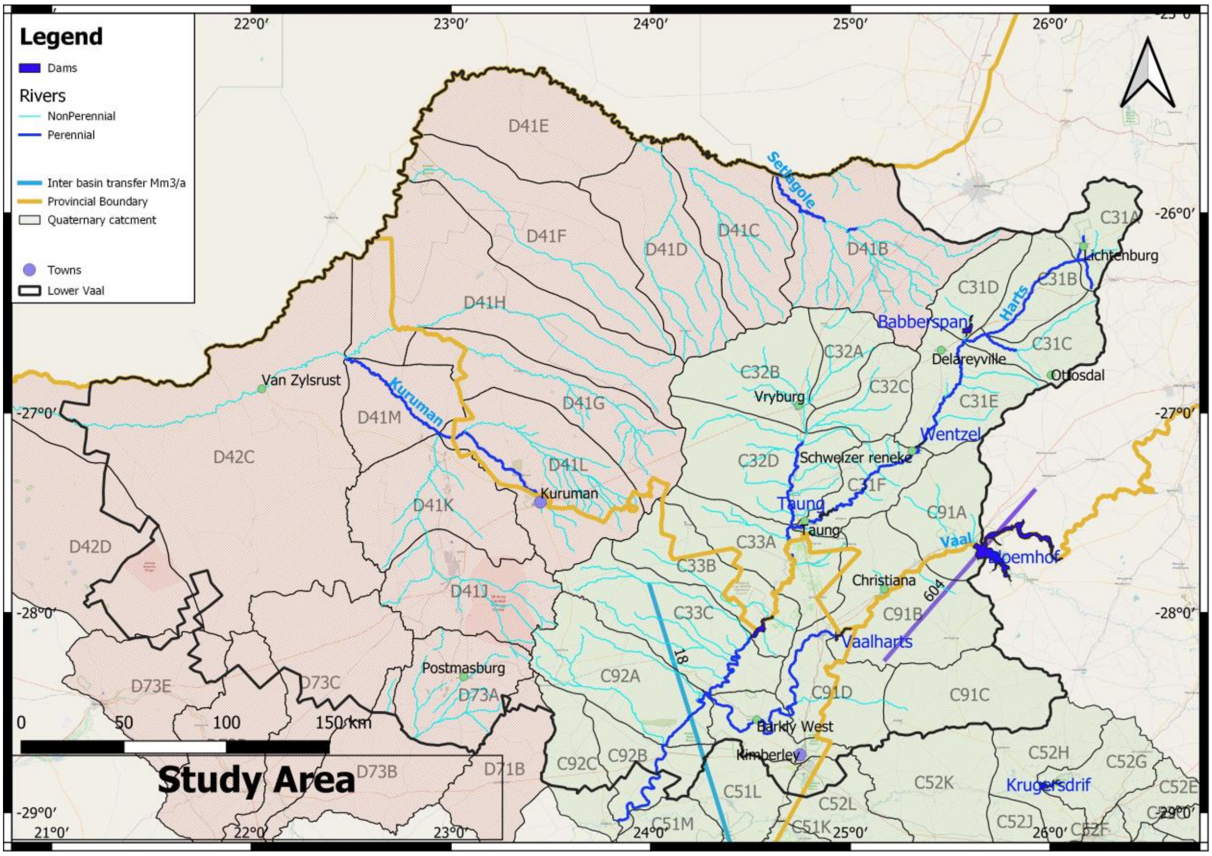


Figure 3-1 Lower Vaal drainage Region

The main rivers of the Lower Vaal catchment, the Vaal and Harts Rivers, are perennial and most of their tributaries are ephemeral. The main source of surface water is the Vaal River, which flows into the study area below Bloemhof Dam, before its confluence with the Orange River. The main dams are Wentzel, Taung, Spitskop, Vaalharts Weir, Douglas weir and Bloemhof. The largest pan is Babberspan, located in the Harts sub-catchment.

The Kuruman and Molopo Rivers, which drain the Kalahari and northern Lower Orange regions, do not make a meaningful contribution to the surface water resources of the Orange River, and interact with groundwater via evapotranspiration and losses of flow generated by upstream springs into dry river channels.

The dolomitic springs in the Harts and Molopo catchments form distinct groundwater ecosystems and are themselves a form of surface-groundwater interaction.

3.2 Climate

Climate plays a significant role in groundwater quality in terms of the aridity concentrating the load of salts, and evaporation concentrating salt loads. It also affects recharge and baseflow.

Minute by minute gridded rainfall shows that the MAP ranges from 150 to over 600 mm/a, with the highest rainfall in the northeast, declining to the west. (**Figure 3-2**).

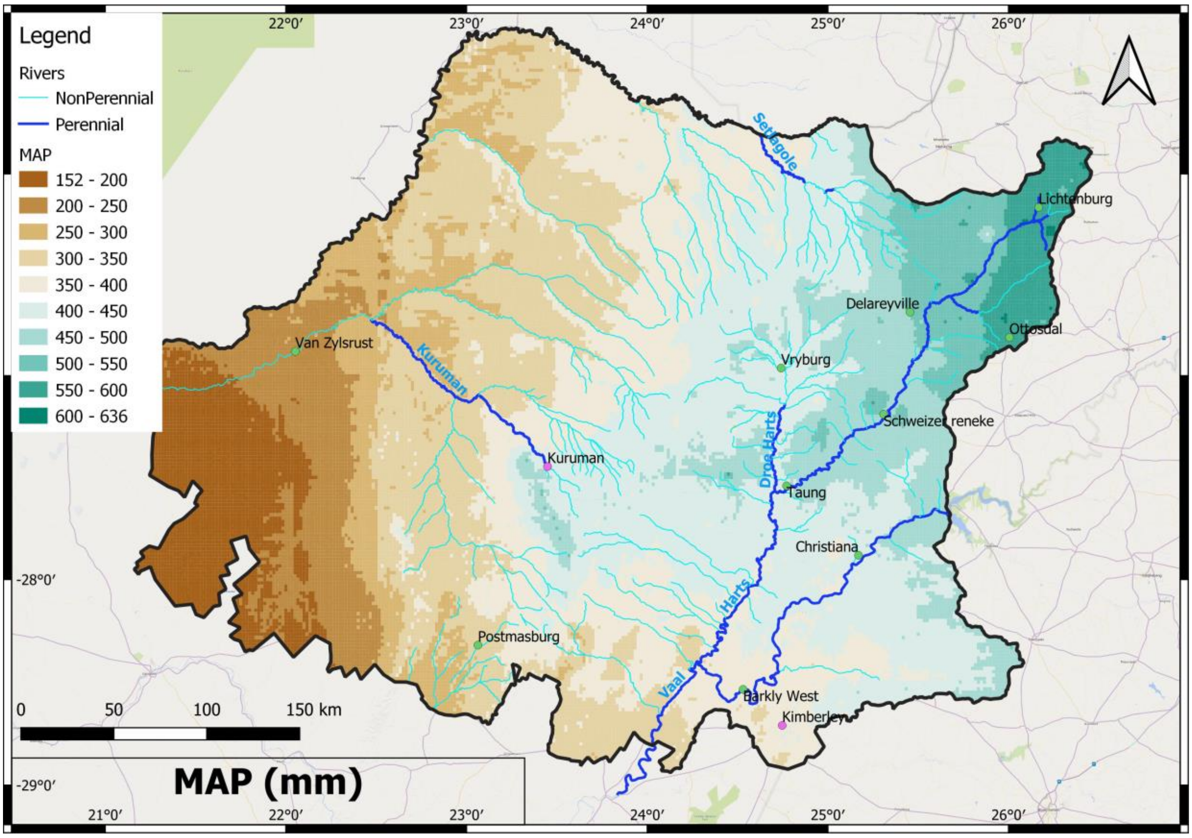


Figure 3-2 MAP in the lower Vaal

S-pan evaporation increases from 1800 mm/a in the east to 2690 mm/a in the west.

3.3 Geology

The Lower Vaal catchment area is underlain by diverse lithologies. Several broad lithostratigraphic units fall within the boundaries.

A large portion of the central and north-east corner of Lower Vaal is underlain by the Transvaal Supergroup (ANbr-Rvw), with much of it consisting of dolomite, chert, and subordinate limestone. The dolomitic area is characterised by a high potential for groundwater development, with relatively high recharge, storage and borehole yields. The groundwater level is between 8 to 20 metres below ground level on average. Water is found mainly in fractures; dissolution features are not prominent. Interactions occur where these compartments drain via dolomitic eyes.

Unlike the central dolomitic area, the geology of the western part of the catchment does not lend itself to significant groundwater resources. Boreholes tend to be less successful and much deeper, up to 125 metres below ground level. Water is also often saline. It is this very limited and unreliable groundwater resource that necessitated the implementation of the Kalahari East and West rural water supply schemes. There is no connection between surface and groundwater.

The Olifantshoek Supergroup (Orlm-Ecz) lies to the west of the study area in the vicinity of Van Zylsrust, Hotazel, Sishen and Postmasburg. Here the geology consists of very low-to-low grade metamorphic rocks of schist, quartzite, lava, sub greywacke and conglomerates. Dwyka Tillite with Ecca sandstone, mudstone, and shale (C-pd-Pt) is also found in the area (DWAF,2004).

The Ventersdorp Supergroup (ANkb-ANbo) lies to the east and north of the Transvaal Supergroup and is composed mainly of volcanic rocks, andesite, quartz porphyry, sedimentary rocks, conglomerate, and sandstone. This area also represents a low-grade metamorphism and water is found in weathered fractures. The probability of a successful borehole yielding >2l/s is 10-20% with the average groundwater level being between 8 to 20 metres below ground level.

Dolomitic compartments are a key aspect of groundwater protection in terms of their high borehole yields and recharge, being the prime source of baseflow, and their vulnerability to contamination. The dolomitic compartments present in the lower Vaal are shown in **Figure 3-3.**

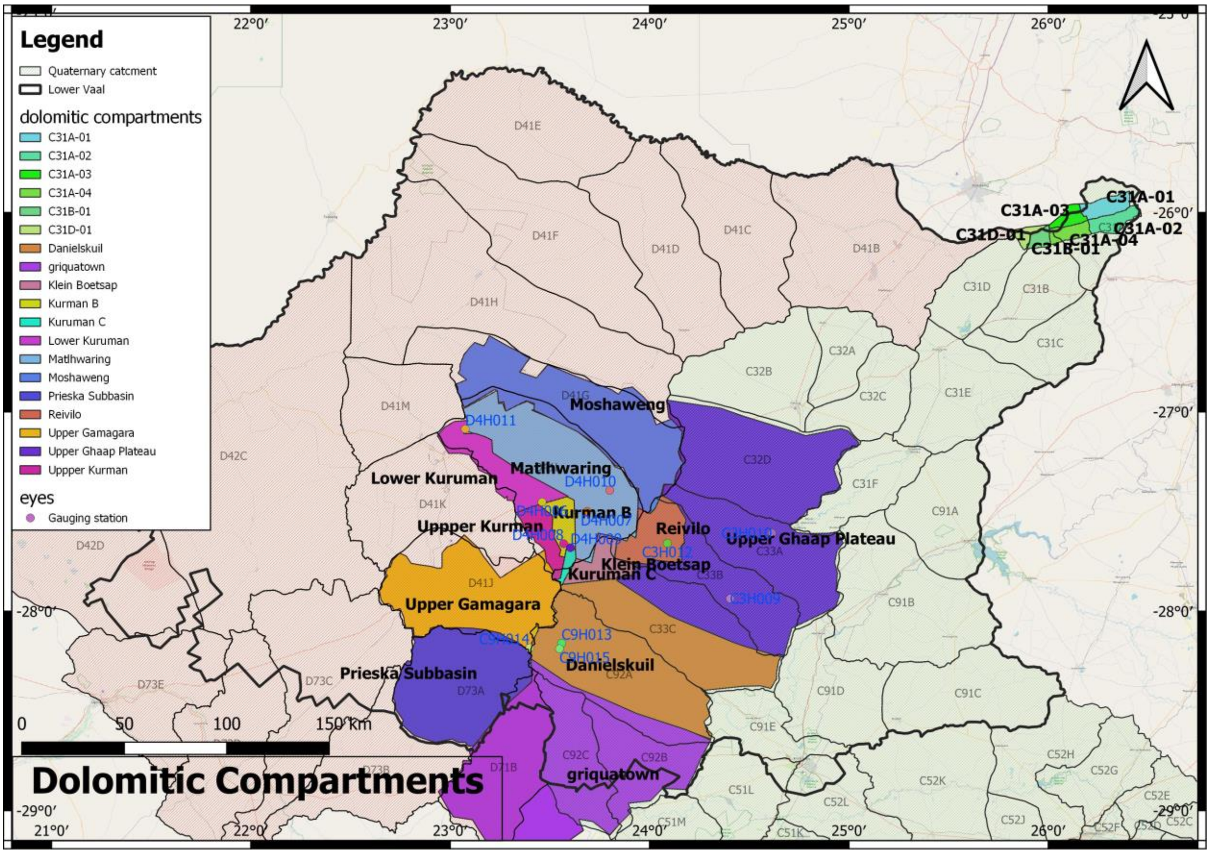


Figure 3-3 Dolomitic Compartments

3.4 Recharge and Baseflow

Recharge and baseflow per compartment and catchment were determined from WRSM Pitman Modelling in DWS (2023). These are integrated by Quaternary catchment and shown in **Figure 3-4 and 3-5.** Recharge declines from over 22 mm/a in the Lichtenburg dolomites to 1 mm/a in the west where extensive Kalahari cover exists.

Baseflow is generated largely from dolomites with 0 baseflow in the drier west (**Figure 3-5).** Of the 107.1 Mm^3/a of baseflow, 105.39 Mm^3/a is generated from dolomites.

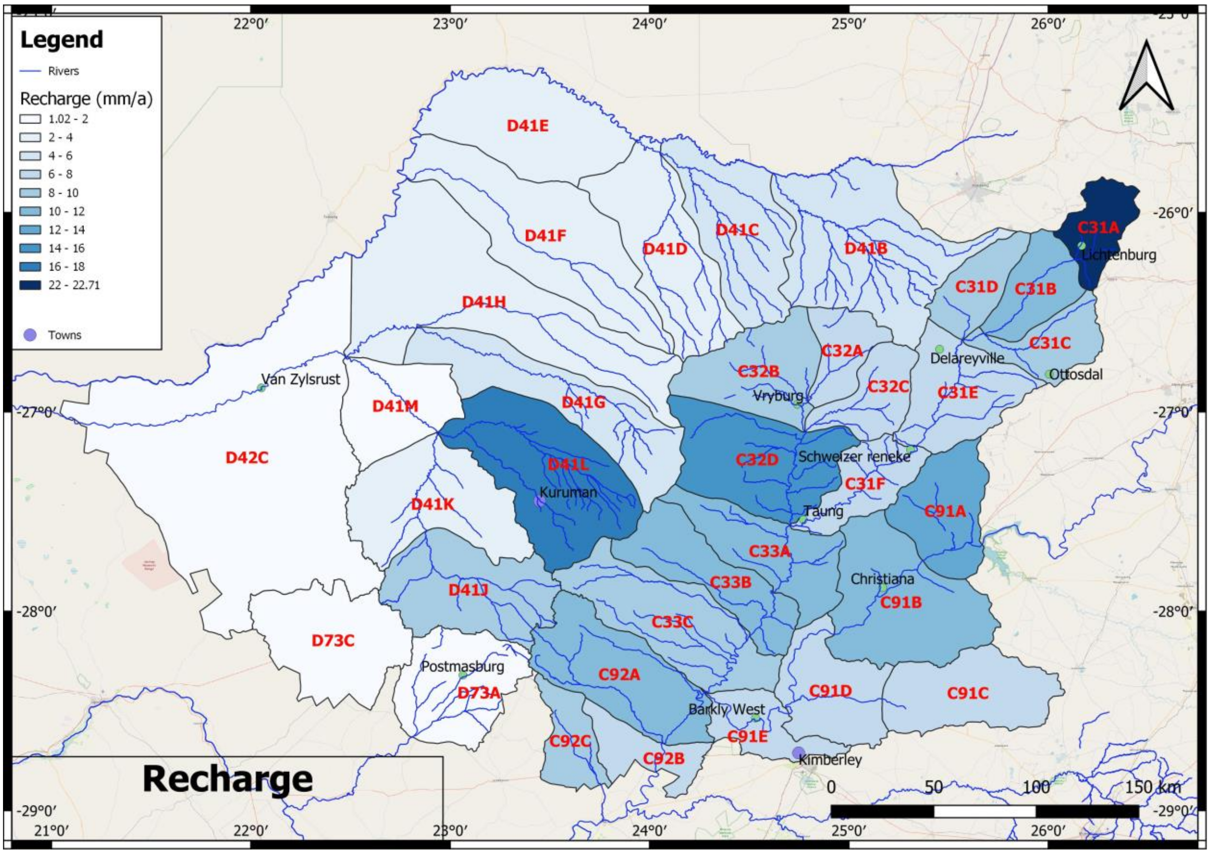


Figure 3-4 Recharge simulated with WRSM Pitman

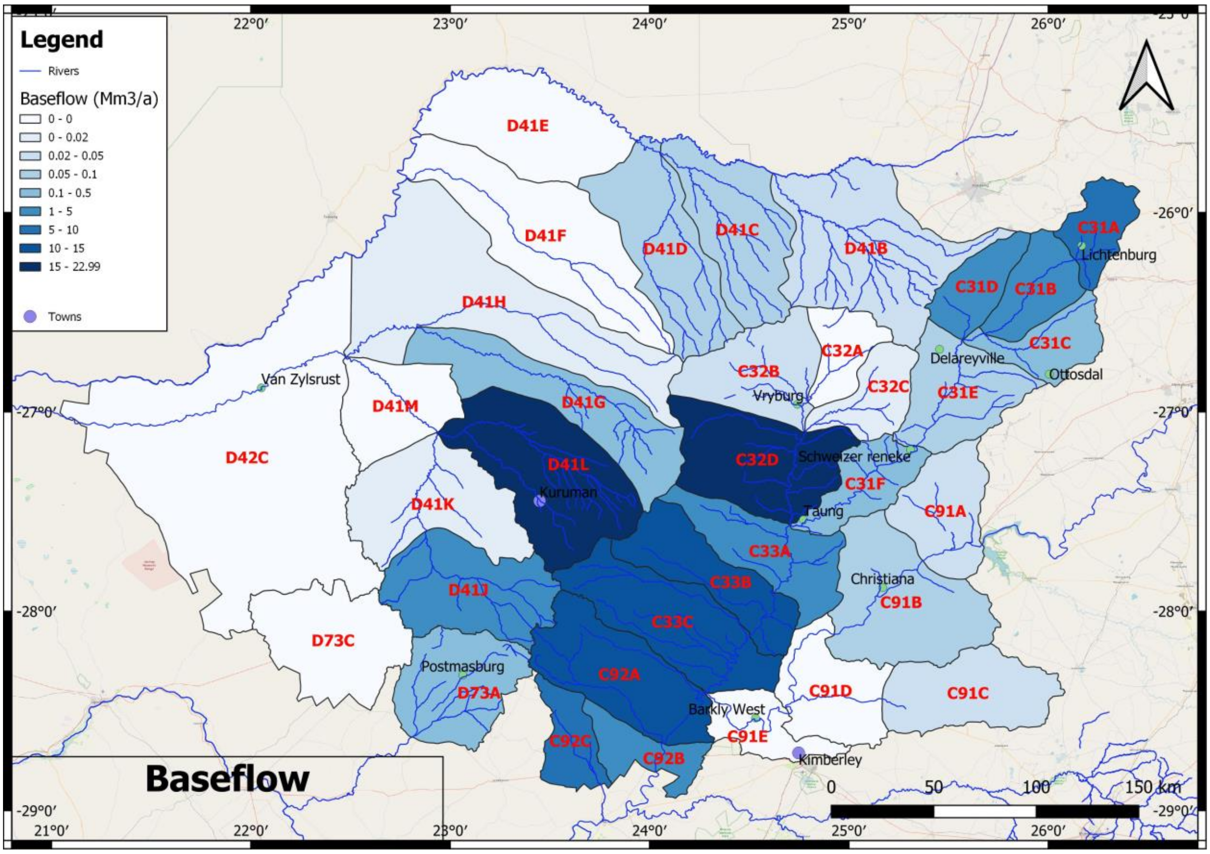


Figure 3-5 Baseflow generated by WRSM Pitman

3.5 Soils

Soils are important in determining groundwater recharge and aquifer vulnerability. Sandy soils are found in the extreme west, underlying D42 and D73. The Kalahari sands covering most of D41 consists of sands to loamy sands **(Figure 3-6)**. C31 is underlain by sandy clay loams and sandy clays. In general, soils get coarser towards the west.

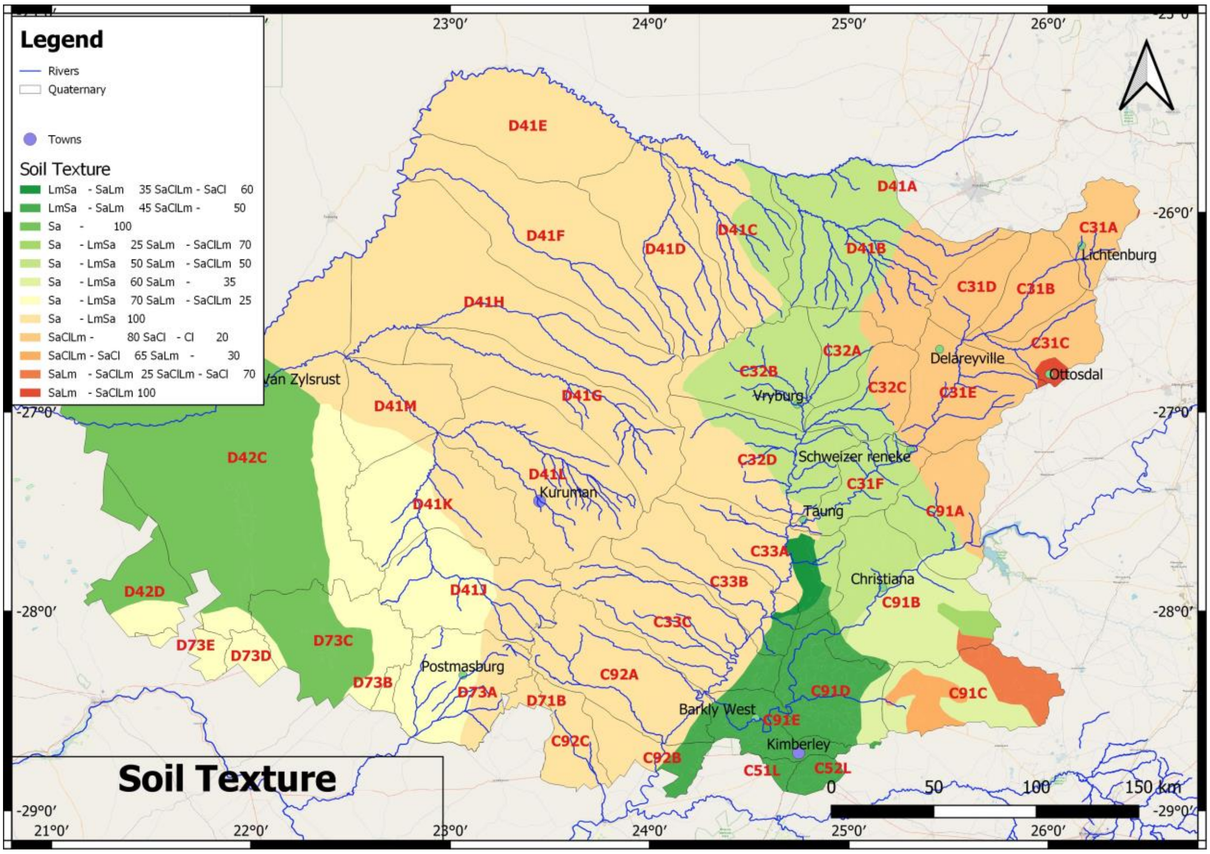


Figure 3-6 Soil texture

3.6 Groundwater Level

The depth to groundwater was derived from 17355 boreholes with water level data in the NGA (**Figure 3-7).** Depth to groundwater is less than 20 mbgl in C31-C33 and in C91. It increases rapid to the west in the Molopo River catchment reaching 140 mbgl. Shallow groundwater is found only in the vicinity of dolomitic eyes. The low hydraulic gradients in large variations on groundwater depth based on topography.

Groundwater flow follows the topography **(Figure 3-8),** with gradients being oriented to the SW in the Harts and Vaal catchments (C3 and C9), and to the west in the Molopo catchment (D4). Gradients are oriented towards the Vaal and Harts rivers, indicative of baseflow. In D41, gradients are not oriented towards the rivers.

The regional groundwater flow is to the west, with groundwater levels dropping from 1500 mamsl to 950 mamsl.

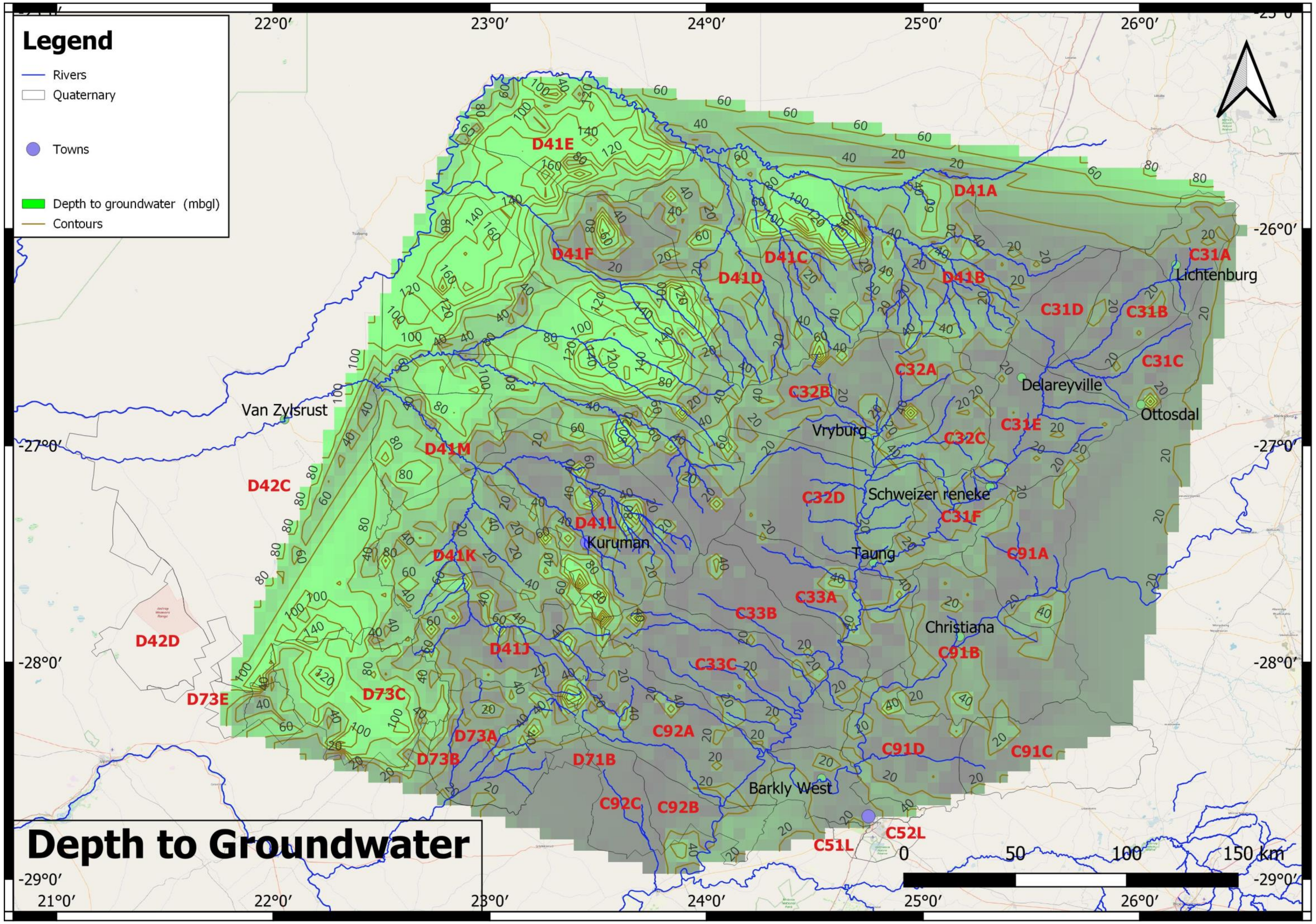


Figure 3-7 Depth to groundwater

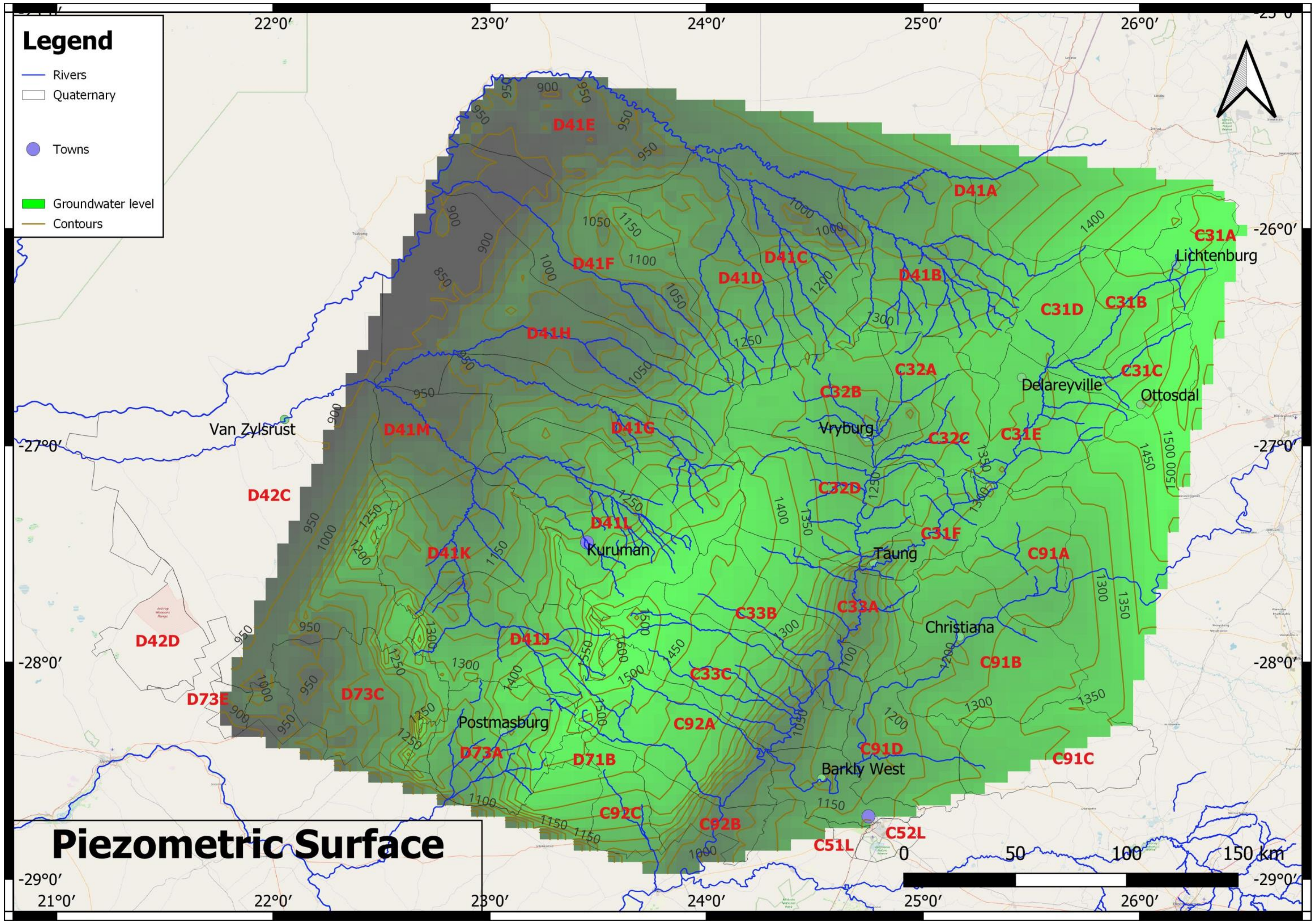


Figure 3-8 Piezometric Surface

4 PROTECTION ZONES

4.1 Local water supply borehole protection zones

Capture zones around registered water supply boreholes are shown in **Figure 4-1.** Large protection zones exist only around large-scale abstractions, especially those not on dolomite. The high recharge of dolomites reduces the size of capture zones. These can be observed at Kuruman, Vryburg and Taung. Many water supply schemes do not have their water supply registered, hence no protection zone can be determined.

4.2 Aquifer Vulnerability

Aquifer vulnerability is shown in **Figure 4-2.** Aquifer vulnerability is very high in the dolomitic areas of C32, C33, D41B and L and C92. It is also very high or high in areas of shallow water table, or limestones overlain by sands, such as in D41B, C31 and C91.

4.3 Baseflow Vulnerability

Catchments where baseflow is vulnerable to groundwater abstraction are shown in **Figure 4-3.** Baseflow is moderately vulnerable in C31A, C32D, C33B and C, D41L and C92A and B, with baseflow being 20-40% of recharge. These are dolomitic catchments. D41L and C92A potentially have the largest impact from baseflow reduction, since baseflow is over 70% of the total runoff generated.

4.4 Groundwater Stress and Water Level Code

The groundwater stress index and the water level code are shown in **Figure 4-4.** Rapidly declining water levels are evident in C32B, D41C and D41J and intervention is rapidly required. D41C only has a moderate stress index, suggesting that abstraction is most likely significantly higher than documented.

No data is available for C31F, yet the stress index indicates the catchment is stressed and requires monitoring.

C31A, B and D, D41B, D and E show a gradual decline in water level and intervention will be required. D41B and C31D also have a low stress index, suggesting significant undocumented abstraction accounting for water level declines.

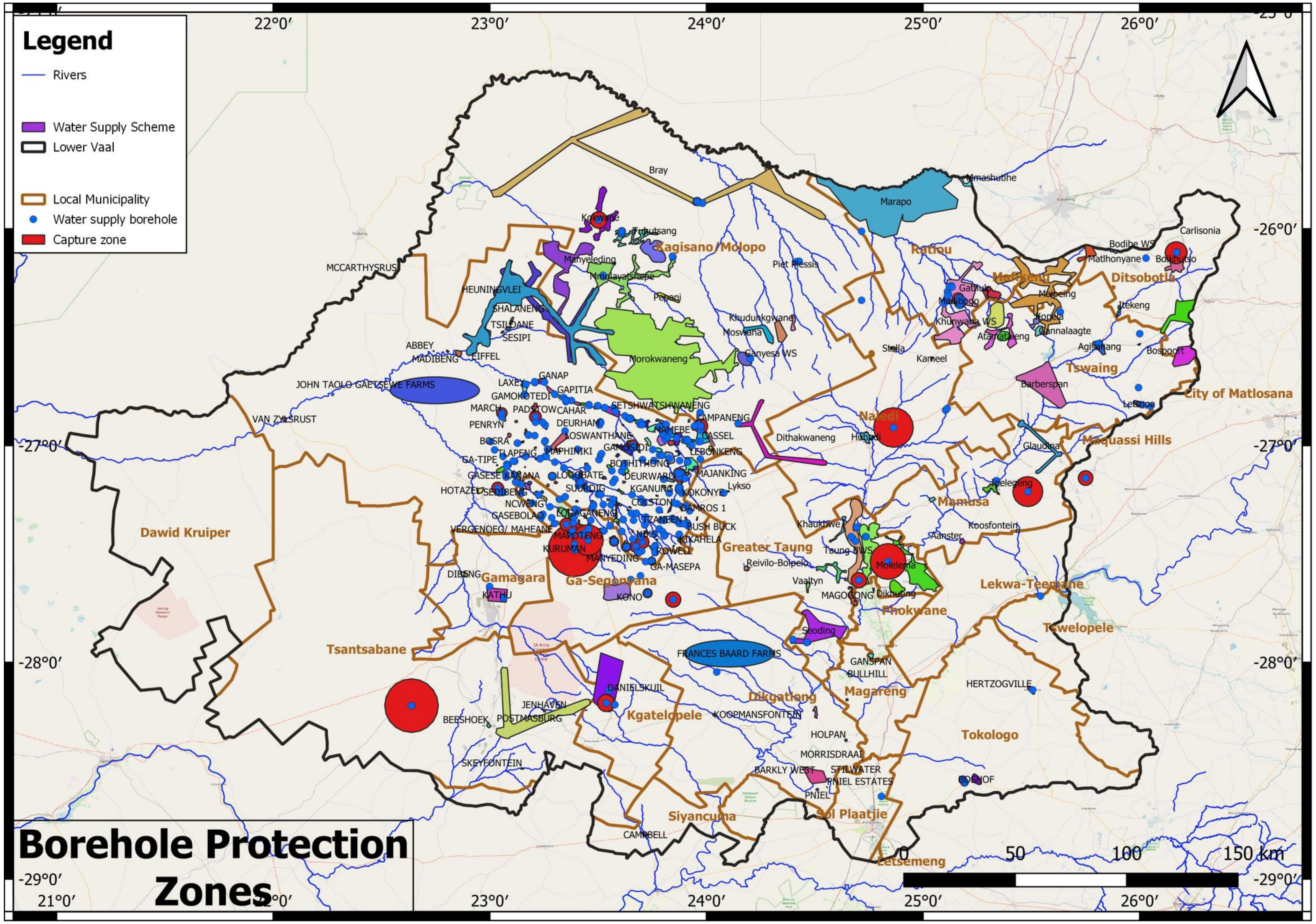


Figure 4-1 Borehole protection zones

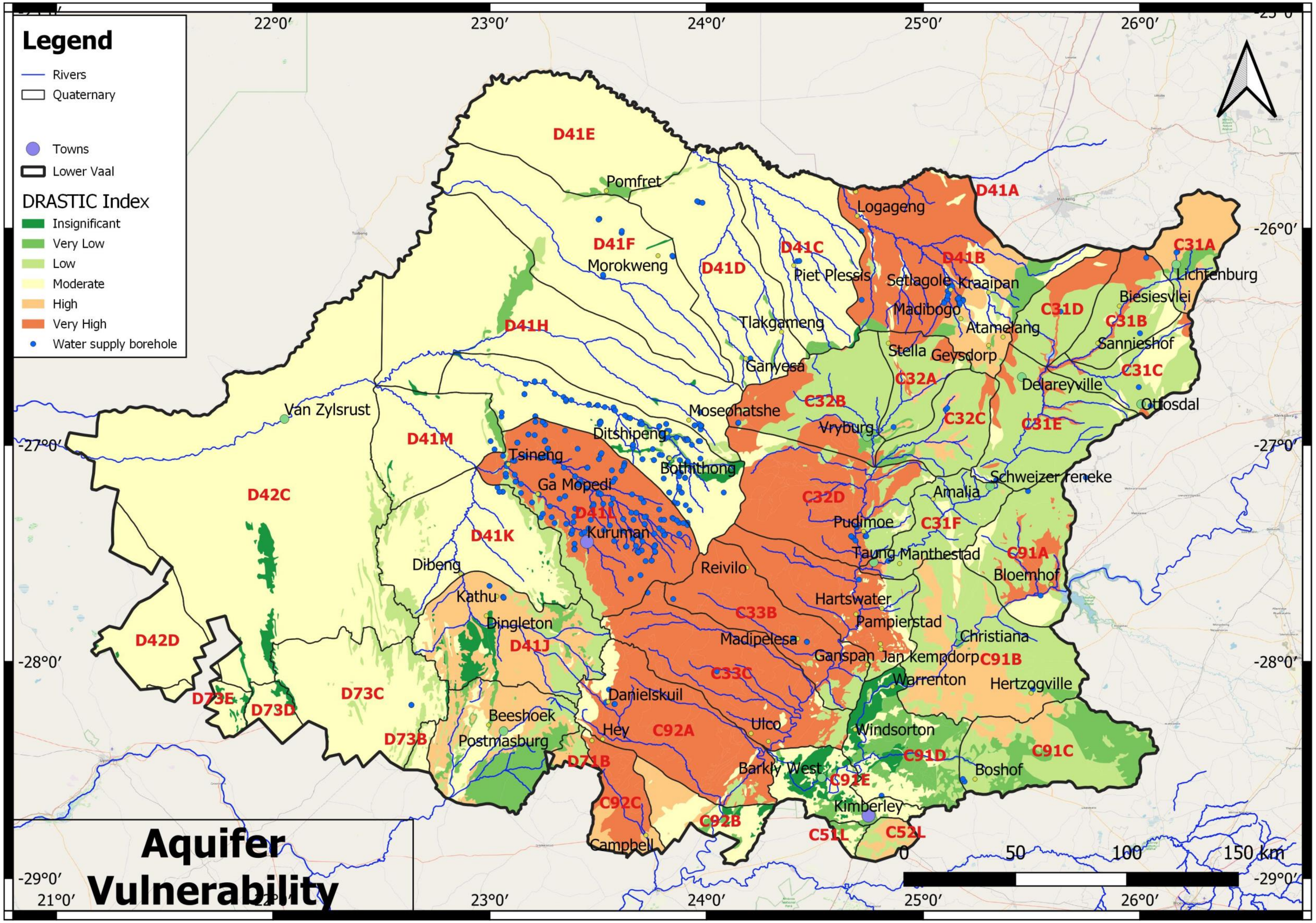


Figure 4-2 Aquifer vulnerability

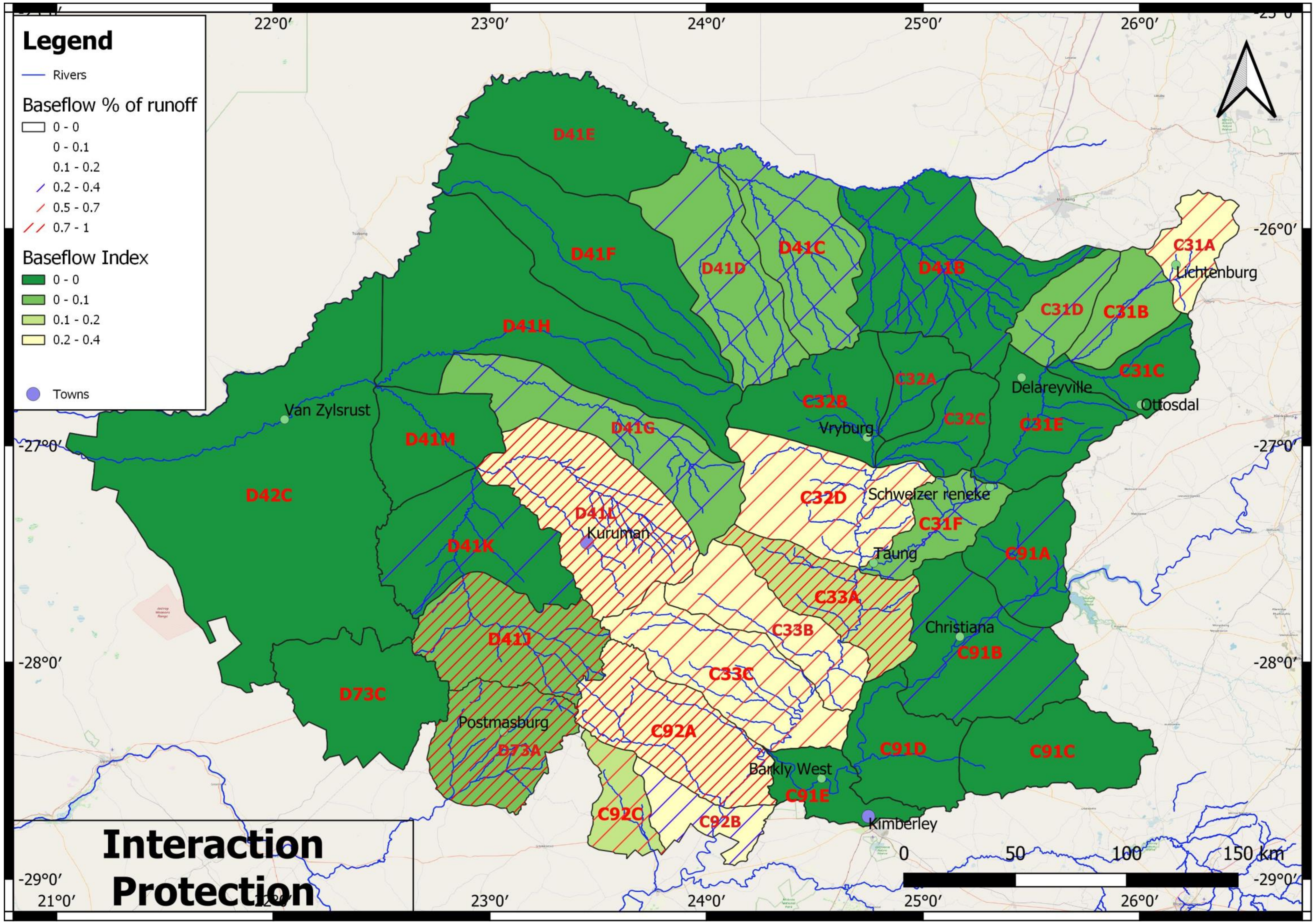


Figure 4-3 Baseflow index

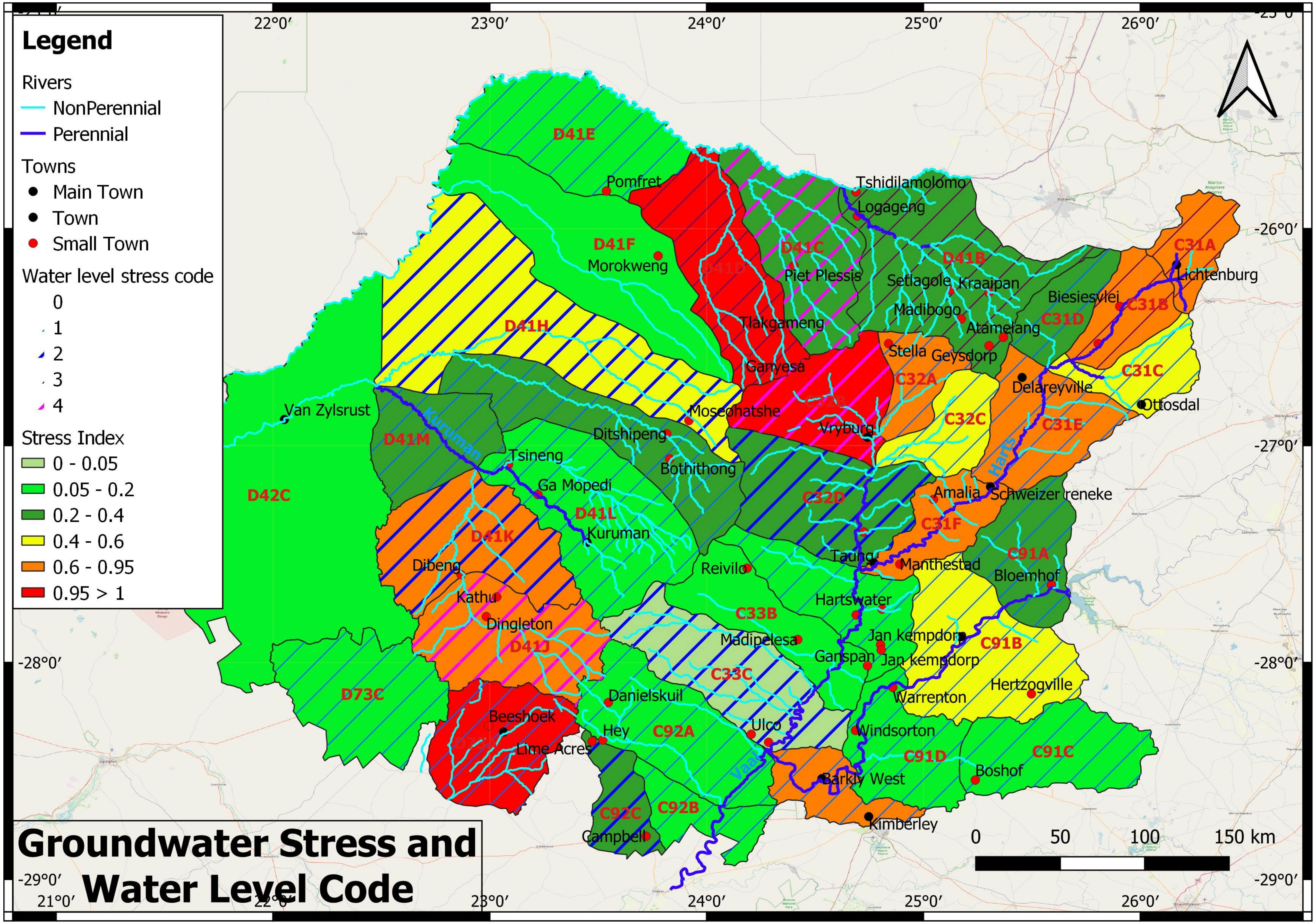


Figure 4-4 Stress Index and groundwater levels

5 SUMMARY AND CONCLUSIONS

The protection of groundwater requires the protection against:

- Degradation of water quality in vulnerable aquifers, which requires an assessment of impacts of land use within the capture zone of boreholes.
- Over abstraction and the decline of water levels which impacts groundwater users and groundwater dependent ecosystems, requiring the curtailing of abstraction or preventing further abstraction.
- Reduction of baseflow resulting from abstraction, which impacts downstream users and ecosystems which depend on groundwater. This requires minimizing abstraction near the vicinity of discharge points.

Catchments where protection and interventions are required are identified in **Table 5-1.** High priority catchments are in Red.

Table 5-1 Protection and interventions required

Quat	Protection Required			
	Groundwater Quality	Groundwater Quantity		Baseflow Protection
		Water level	Stress Index	
C31A	High aquifer vulnerability to contamination	Water levels declining. No further allocations possible. Some use may be undocumented	0.8	Abstraction can have a significant impact on baseflow and abstraction near a river or eye needs to be restricted
C31B	Very high aquifer vulnerability to contamination	Water levels declining. No further allocations possible	0.98	
C31C	No intervention required			
C31D	Very high aquifer vulnerability to contamination	Water levels declining. No further allocations possible. Some use may be undocumented	0.3	
C31E	No intervention required			
C31F		High stress but no water level data. Monitoring required	1	

C32A		High groundwater stress but no decline in water level is noted	0.93	
C32B	Very high aquifer vulnerability to contamination	Significant water level decline and high stress. High priority intervention required	1..35	
C32C	No intervention required			
C32D	Very high aquifer vulnerability to contamination			Abstraction can have a significant impact on baseflow and abstraction near a river needs to be restricted
C33A	Very high aquifer vulnerability to contamination			
C33B	Very high aquifer vulnerability to contamination			Abstraction can have a significant impact on baseflow and abstraction near a river needs to be restricted
C33C	Very high aquifer vulnerability to contamination			Abstraction can have a significant impact on baseflow and abstraction near a river needs to be restricted
C91A	Very high aquifer vulnerability to contamination			
C91B	High aquifer vulnerability to contamination			
C91C	No intervention required			
C91D	No intervention required			
C91E	No intervention required			
C92A	Very high aquifer vulnerability to contamination			Abstraction can have a significant impact on baseflow and abstraction near a river needs to be restricted
C92B	High aquifer vulnerability to contamination			Abstraction can have a significant impact on baseflow and abstraction near a river needs to be restricted
C92C	Very high aquifer vulnerability to contamination			
D41B	High aquifer vulnerability to contamination	Water levels declining but low stress index. Verification of use required	0.32	
D41C		Water levels declining but low stress index. Verification of use required	0.27	

D41D		High stress and water level decline	0.99	
D41E		Water levels declining but low stress index. Verification of use required	0.09	
D41F	No intervention required			
D41G	No intervention required			
D41H	No intervention required			
D41J	High aquifer vulnerability to contamination	Water level decline. Over abstraction. Abstraction likely not all documented	0.75	
D41K	No intervention required			
D41L	Very high aquifer vulnerability to contamination			Abstraction can have a significant impact on baseflow and abstraction near a river needs to be restricted.
D41M	No intervention required			
D42C	No intervention required			
D73A	High aquifer vulnerability to contamination	High stress index but water levels stable. Allocation may not be utilised	1.41	
D73C	No intervention required			

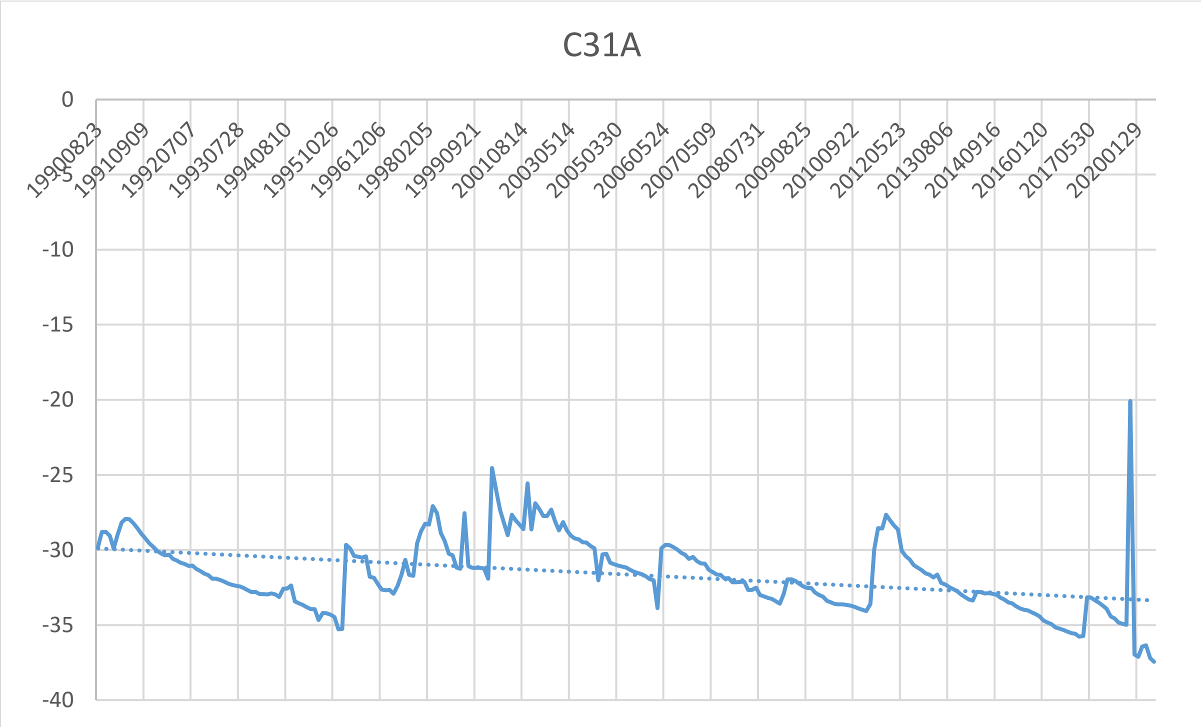
6 REFERENCES

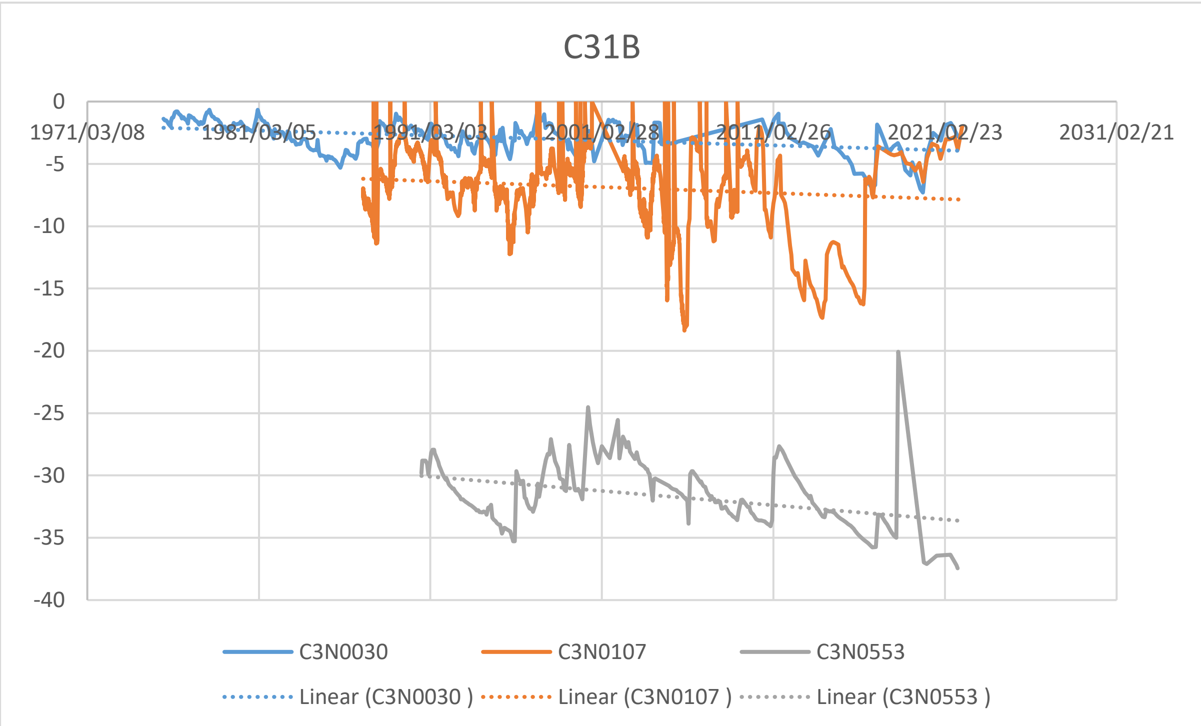
Department of Water and Sanitation (DWS), South Africa. 2023. Investigation of Groundwater and Surface Water Interaction for the Protection of Water Resources in the Lower Vaal Catchment: Recharge and Baseflow Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0123

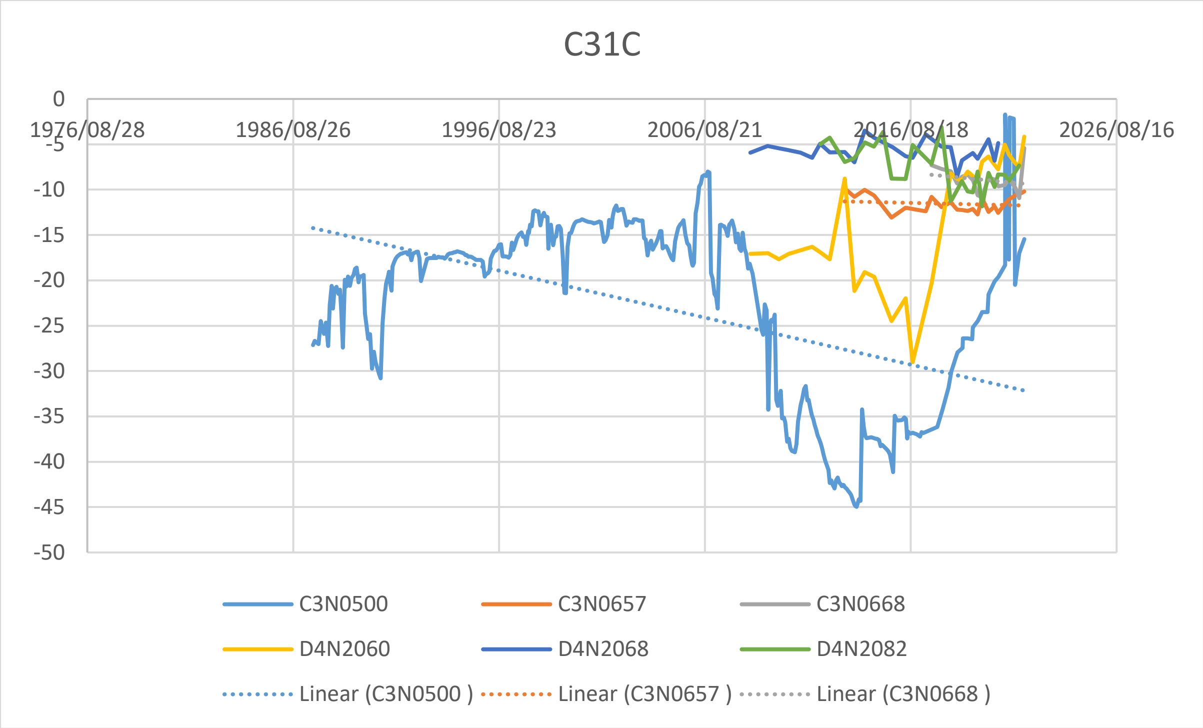
Lynch, S.D., Reynders, A.G. and Schulze, R.E. (1997). A DRASTIC approach to groundwater vulnerability in South Africa. South African Journal of Science, vol.93, February 1997.

Department of Water and Sanitation (DWS), South Africa. 2022. Investigation of Groundwater and Surface Water Interaction for the Protection of Water Resources in the Lower Vaal Catchment: Hydrocensus Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0422

7 APPENDIX 1 GROUNDWATER LEVELS






C31C
0
-5
-10
-15
-20
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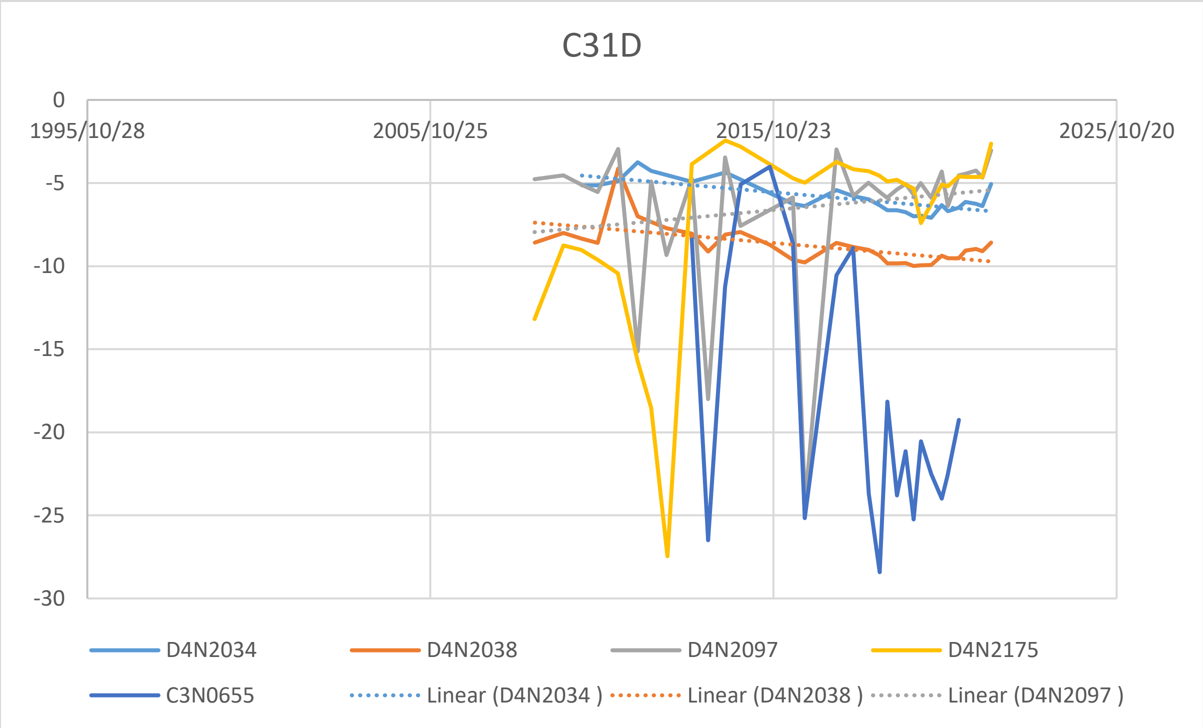
-30
-35
-40
-45
-50
1976/08/28
1986/08/26
1996/08/23
2006/08/21
2016/08/18
2026/08/16
C3N0500
C3N0657
C3N0668
D4N2060
D4N2068
D4N2082
Linear (C3N0500)
Linear (C3N0657)
Linear (C3N0668)


C31D
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1995/10/28
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2015/10/23
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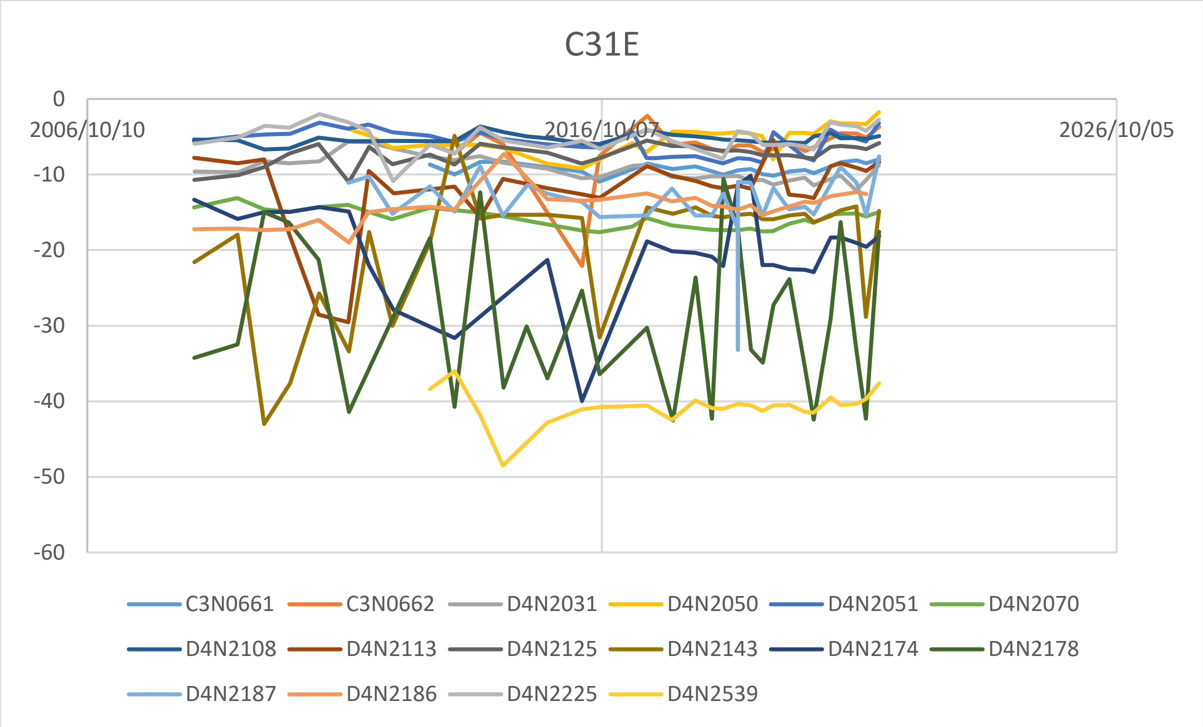
D4N2034
D4N2038
D4N2097
D4N2175
C3N0655
Linear (D4N2034)
Linear (D4N2038)
Linear (D4N2097)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2016/10/07
2026/10/05
C3N0661
C3N0662
D4N2031
D4N2050
D4N2051
D4N2070
D4N2108
D4N2113
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D4N2174
D4N2178
D4N2187
D4N2186
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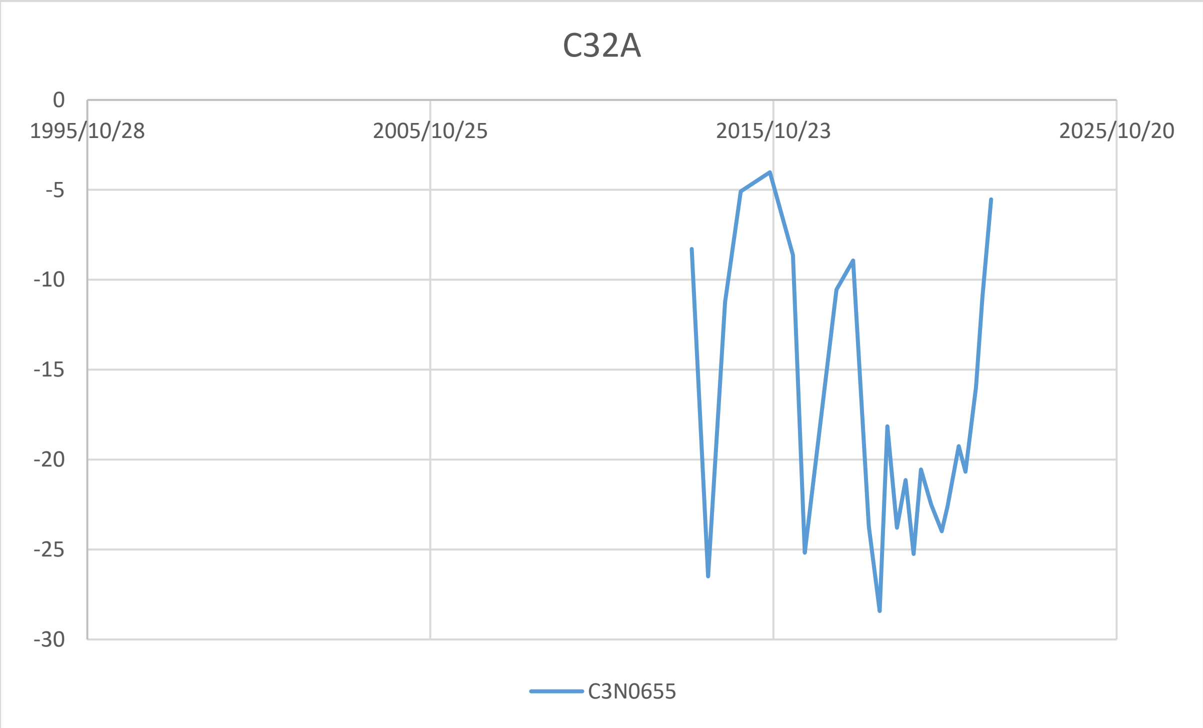
D4N2539


C32A
0
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1995/10/28
2005/10/25
2015/10/23
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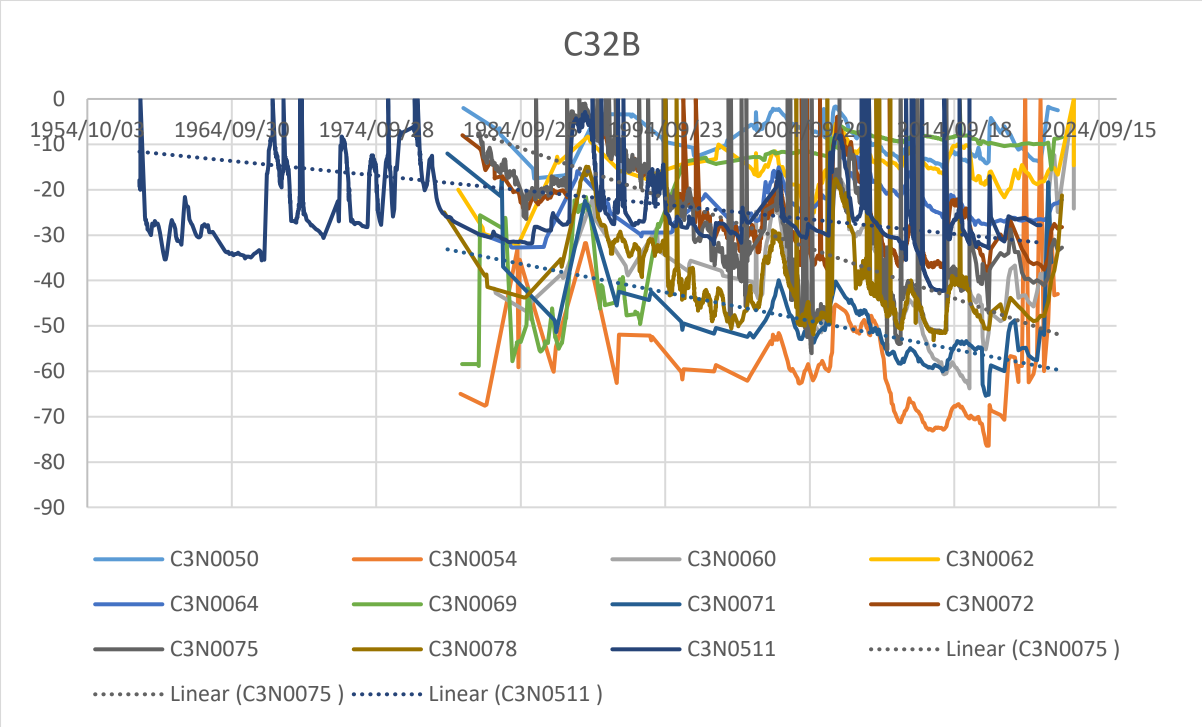
C3N0655


C32B
0
-10
-20
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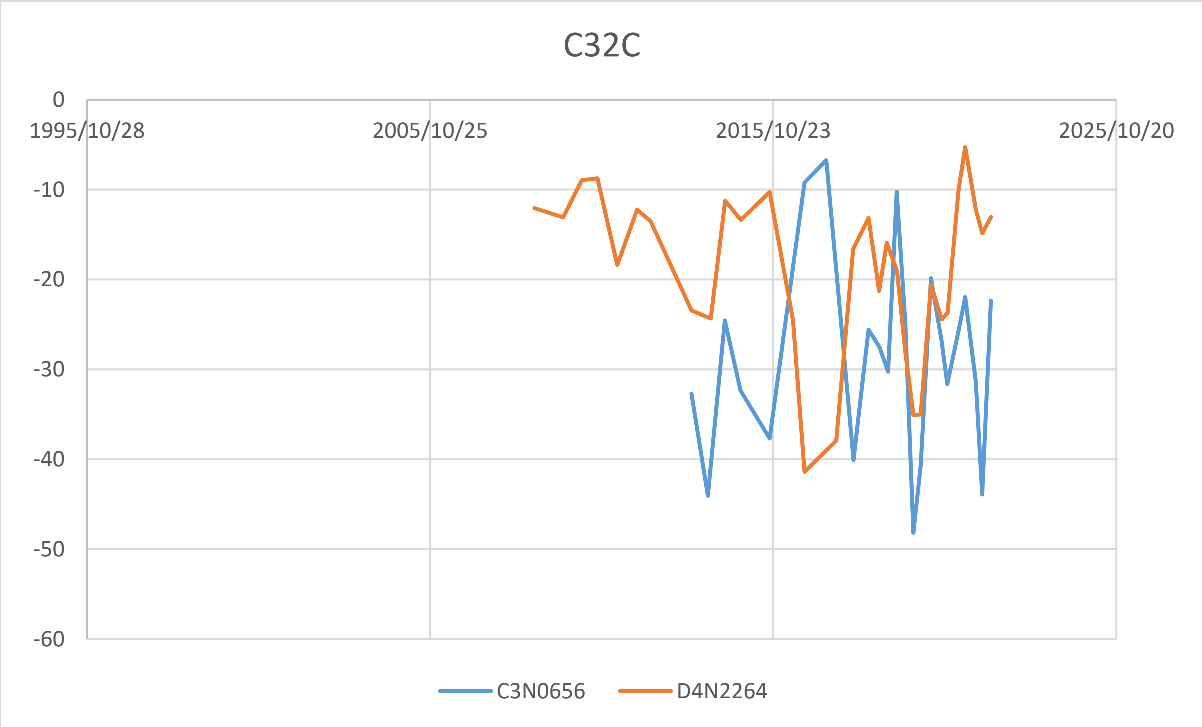
-40
-50
-60
-70
-80
-90
1954/10/03
1964/09/30
1974/09/28
1984/09/25
1994/09/23
2004/09/20
2014/09/18
2024/09/15
C3N0050
C3N0054
C3N0060
C3N0062
C3N0064
C3N0069
C3N0071
C3N0072
C3N0075
C3N0078
C3N0511
Linear (C3N0075)
Linear (C3N0075)
Linear (C3N0511)


C32C
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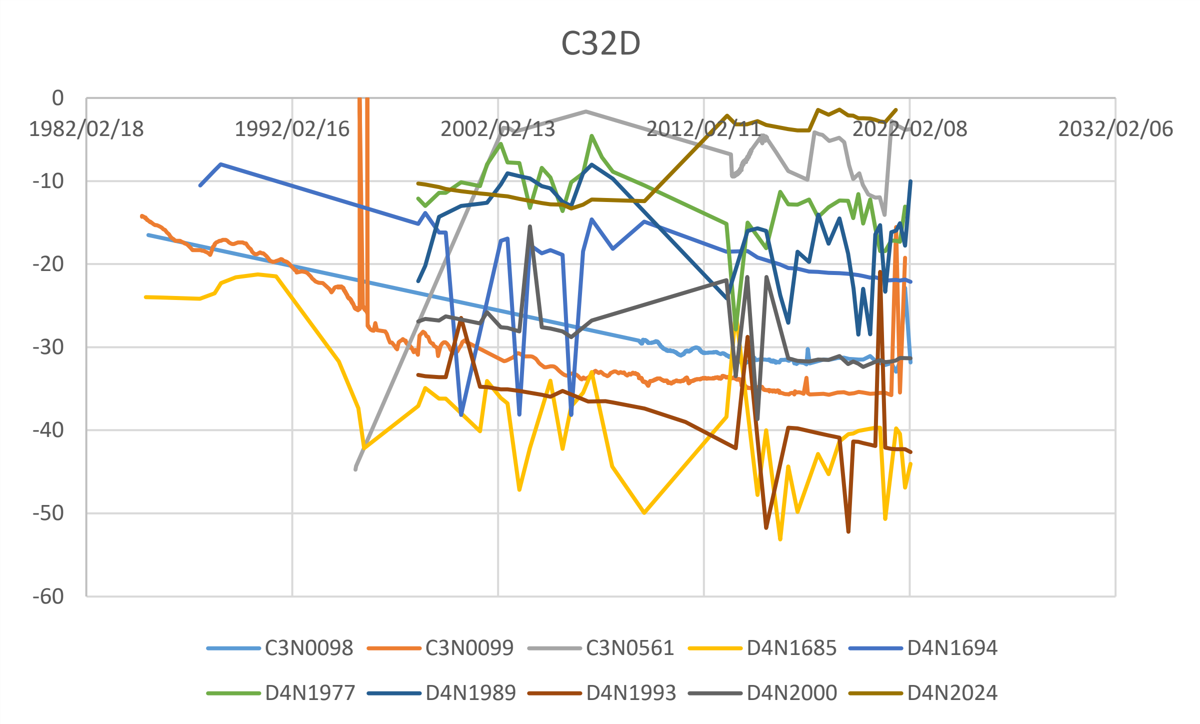
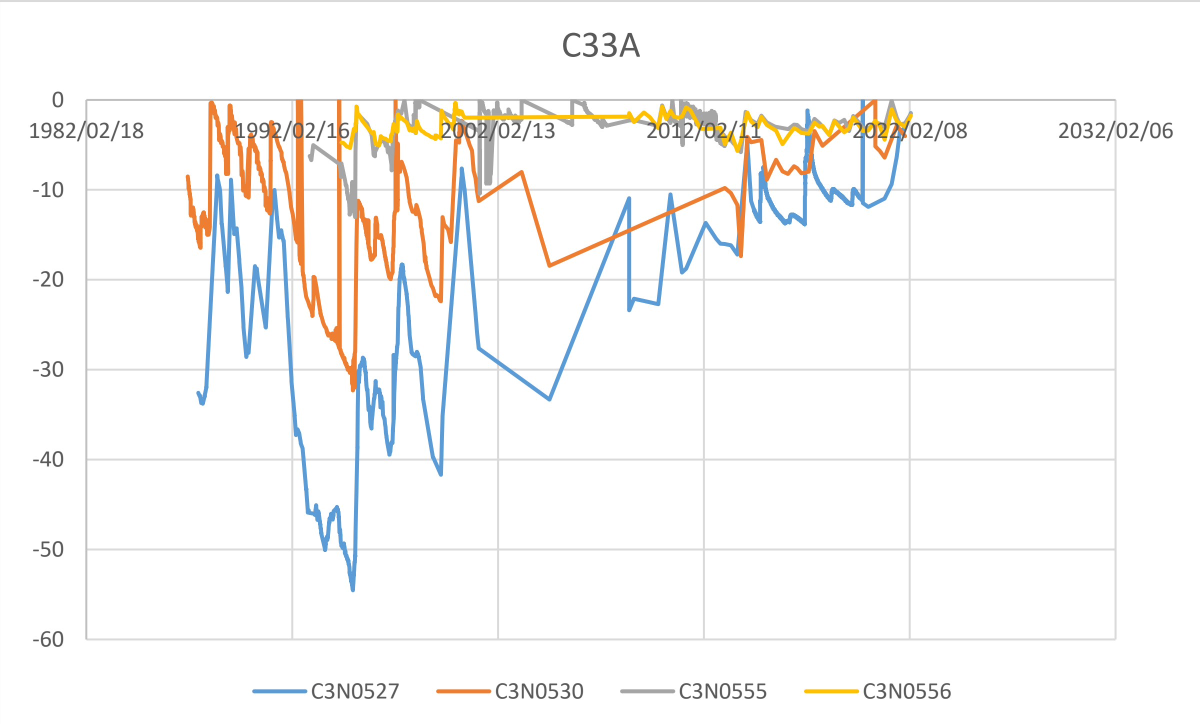
1995/10/28
2005/10/25
2015/10/23
2025/10/20
C3N0656
D4N2264


C32D
0
-10
-20
-30
-40
-50
-60
1982/02/18
1992/02/16
2002/02/13
2012/02/11
2022/02/08
2032/02/06
C3N0098
C3N0099
C3N0561
D4N1685
D4N1694
D4N1977
D4N1989
D4N1993
D4N2000
D4N2024


C33A
0
-10
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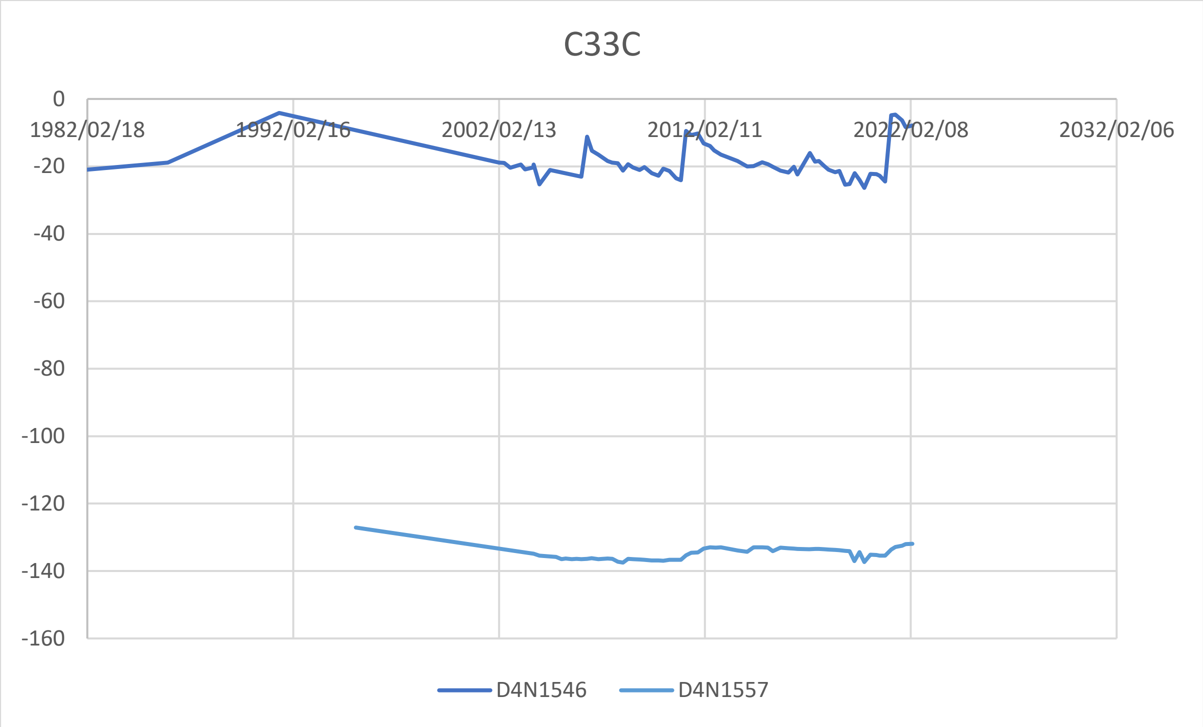
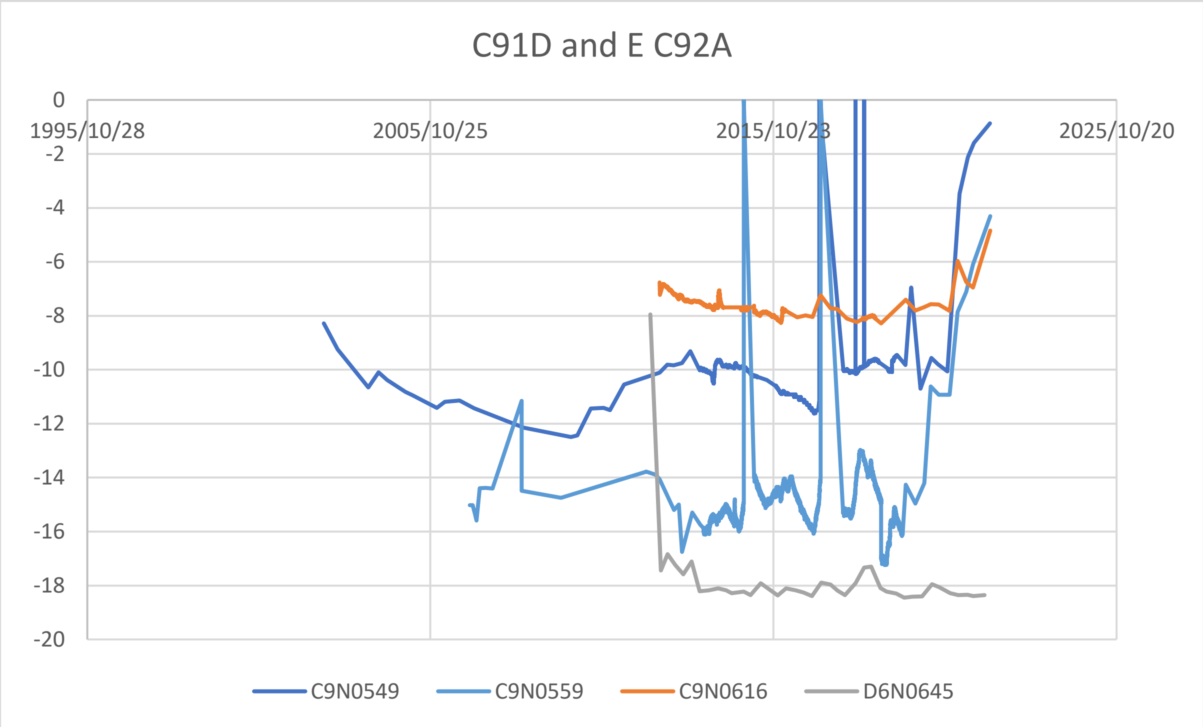
-40
-50
-60
1982/02/18
1992/02/16
2002/02/13
2012/02/11
2022/02/08
2032/02/06
C3N0527
C3N0530
C3N0555
C3N0556


C33C
0
-20
-40
-60
-80
-100
-120
-140
-160
1982/02/18
1992/02/16
2002/02/13
2012/02/11
2022/02/08
2032/02/06
D4N1546
D4N1557


C91D and E C92A
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
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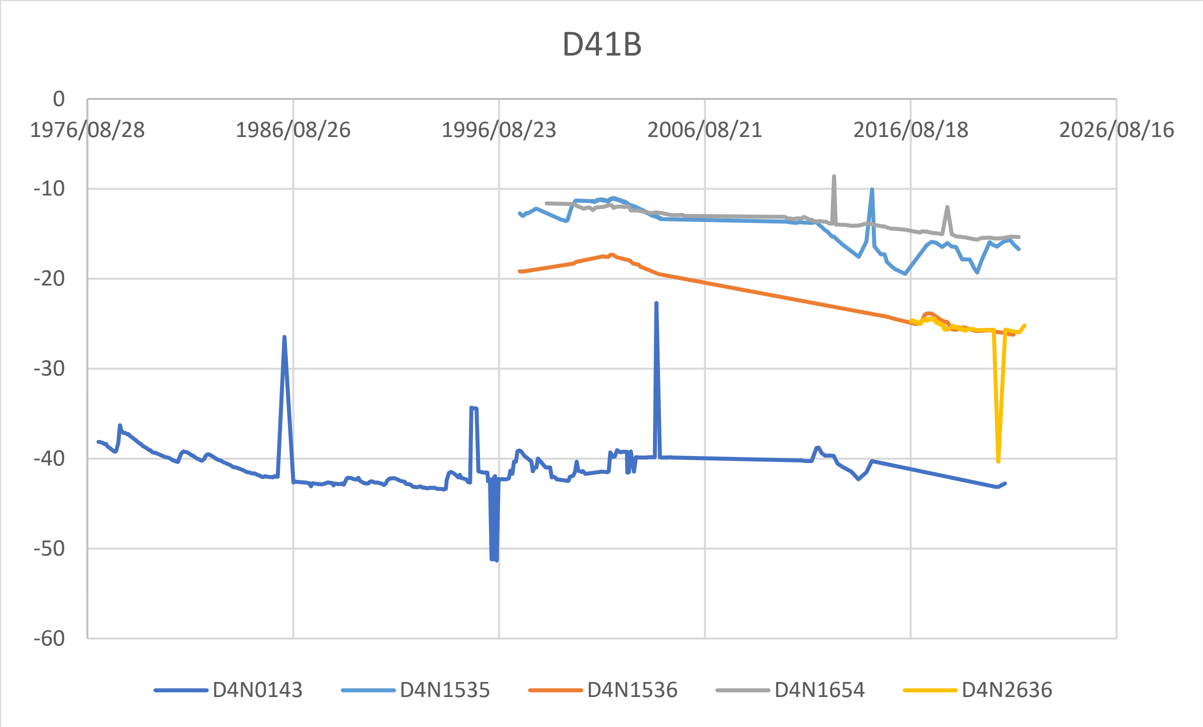
1995/10/28
2005/10/25
2015/10/23
2025/10/20
C9N0549
C9N0559
C9N0616
D6N0645


D41B
0
-10
-20
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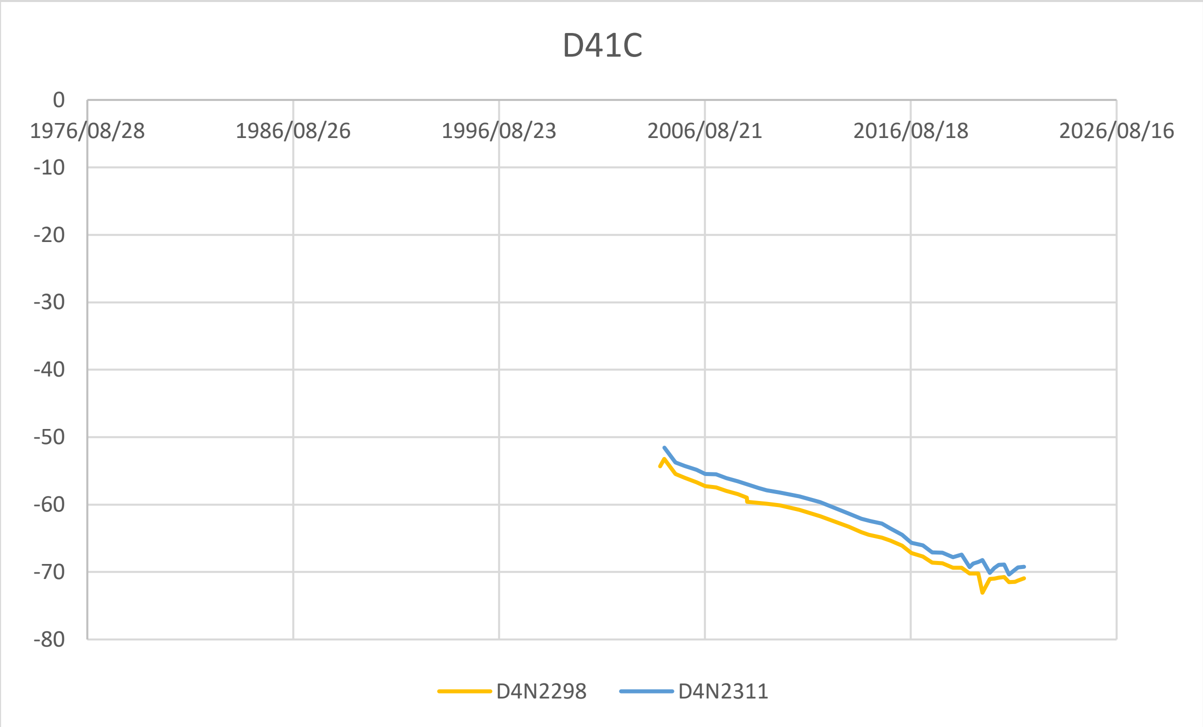
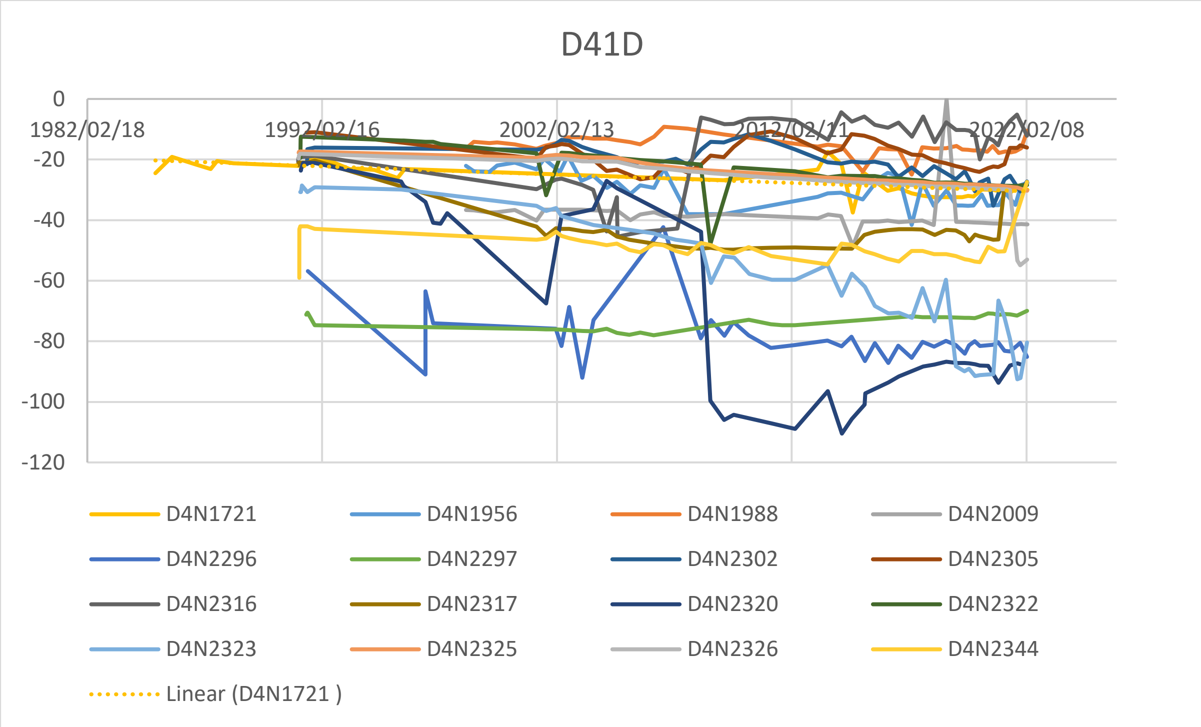
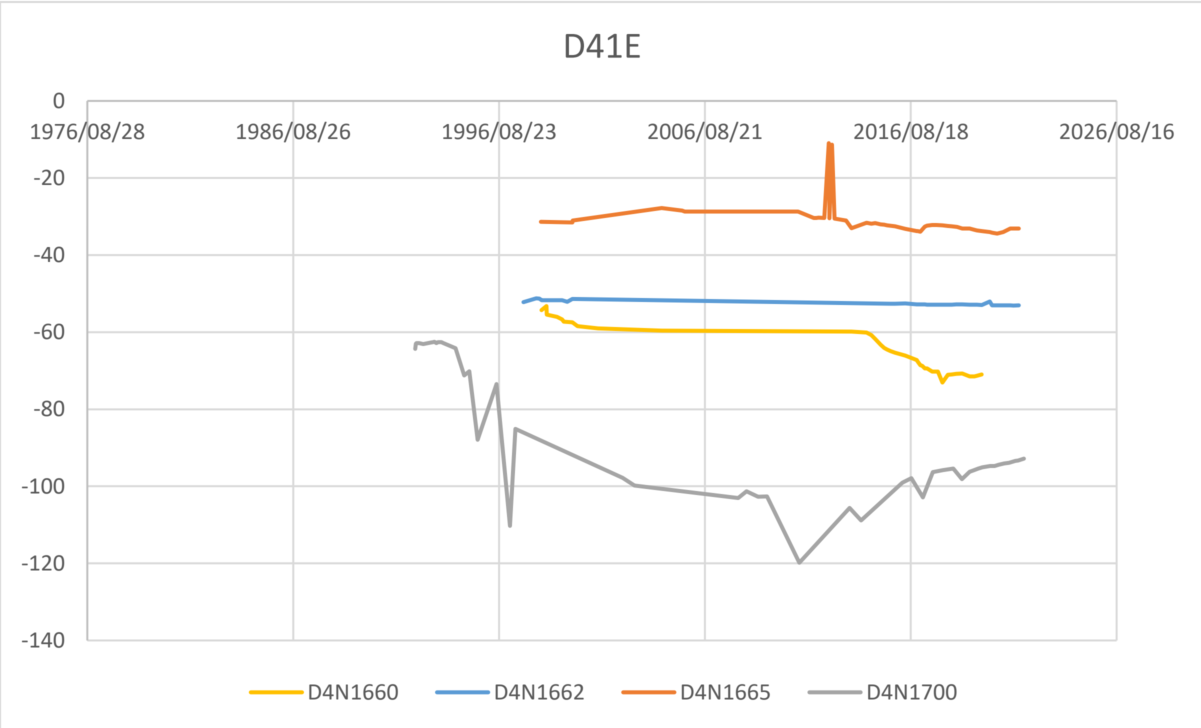
-40
-50
-60
1976/08/28
1986/08/26
1996/08/23
2006/08/21
2016/08/18
2026/08/16
D4N0143
D4N1535
D4N1536
D4N1654
D4N2636


D41C
0
-10
-20
-30
-40
-50
-60
-70
-80
1976/08/28
1986/08/26
1996/08/23
2006/08/21
2016/08/18
2026/08/16
D4N2298
D4N2311


D41D
0
-20
-40
-60
-80
-100
-120
1982/02/18
1992/02/16
2002/02/13
2012/02/11
2022/02/08
D4N1721
D4N1956
D4N1988
D4N2009
D4N2296
D4N2297
D4N2302
D4N2305
D4N2316
D4N2317
D4N2320
D4N2322
D4N2323
D4N2325
D4N2326
D4N2344
Linear (D4N1721)


D41E
0
-20
-40
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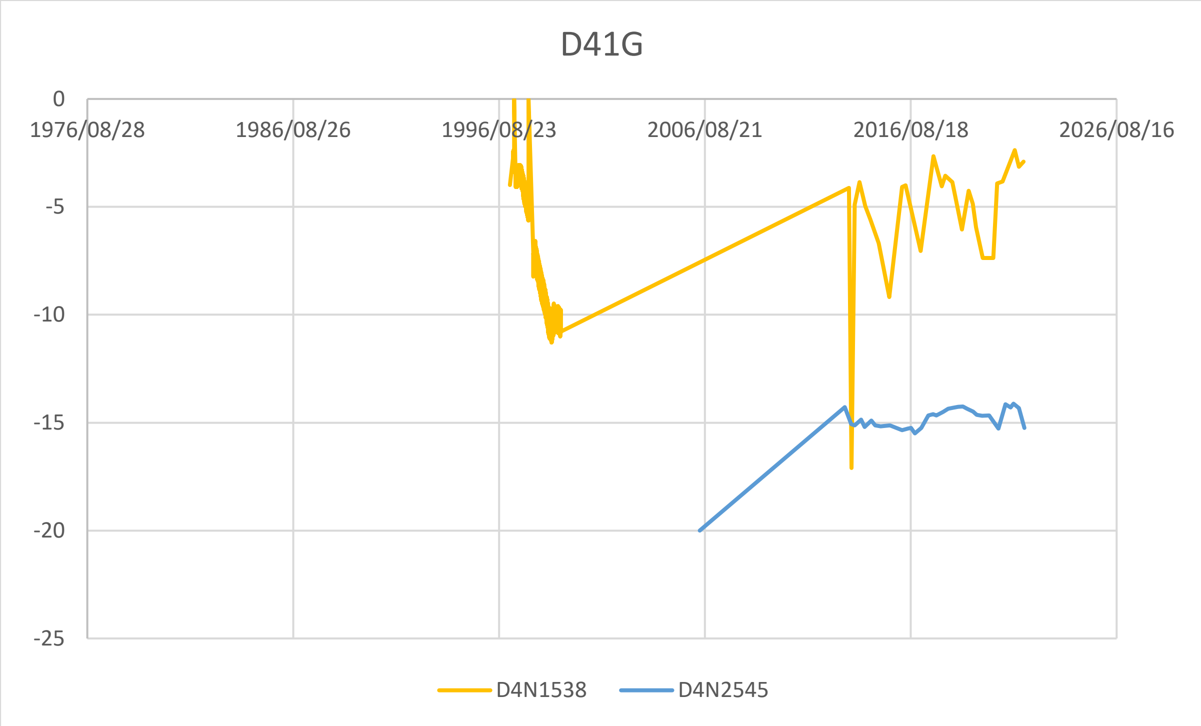
-120
-140
1976/08/28
1986/08/26
1996/08/23
2006/08/21
2016/08/18
2026/08/16
D4N1660
D4N1662
D4N1665
D4N1700


D41G
0
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-10
-15
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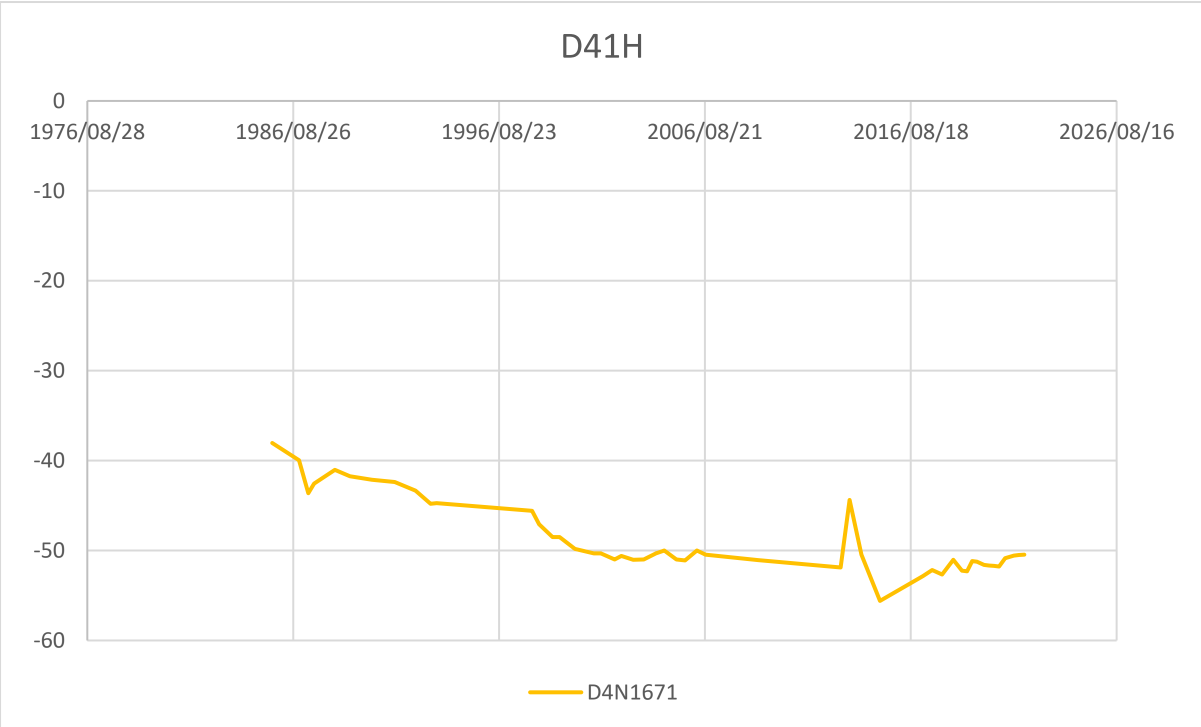
1976/08/28
1986/08/26
1996/08/23
2006/08/21
2016/08/18
2026/08/16
D4N1538
D4N2545


D41H
0
-10
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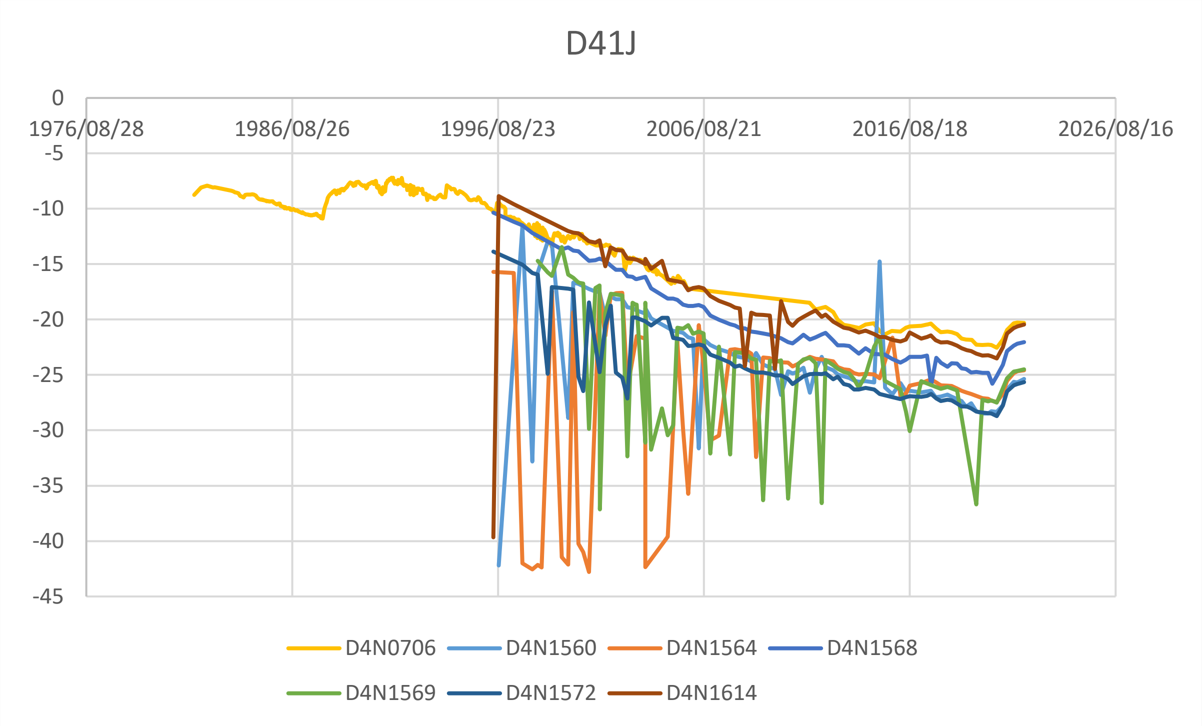
1976/08/28
1986/08/26
1996/08/23
2006/08/21
2016/08/18
2026/08/16
D4N1671


D41J
0
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-15
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1976/08/28
1986/08/26
1996/08/23
2006/08/21
2016/08/18
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D4N0706
D4N1560
D4N1564
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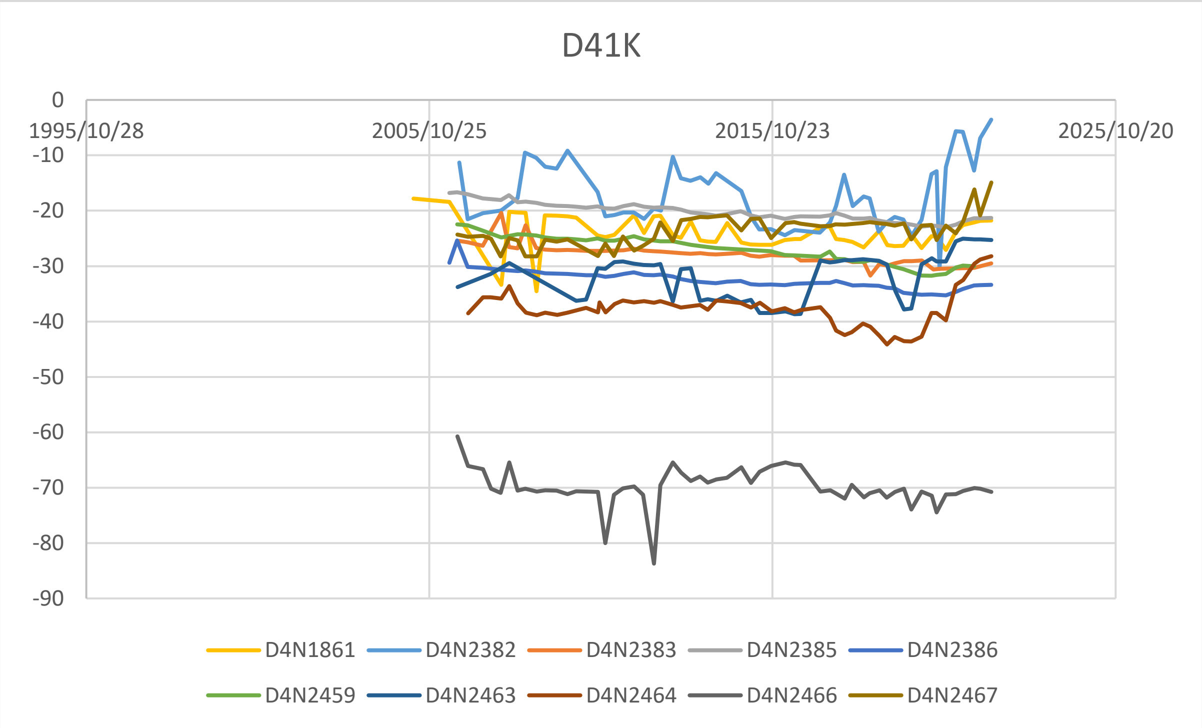
D4N1569
D4N1572
D4N1614


D41K
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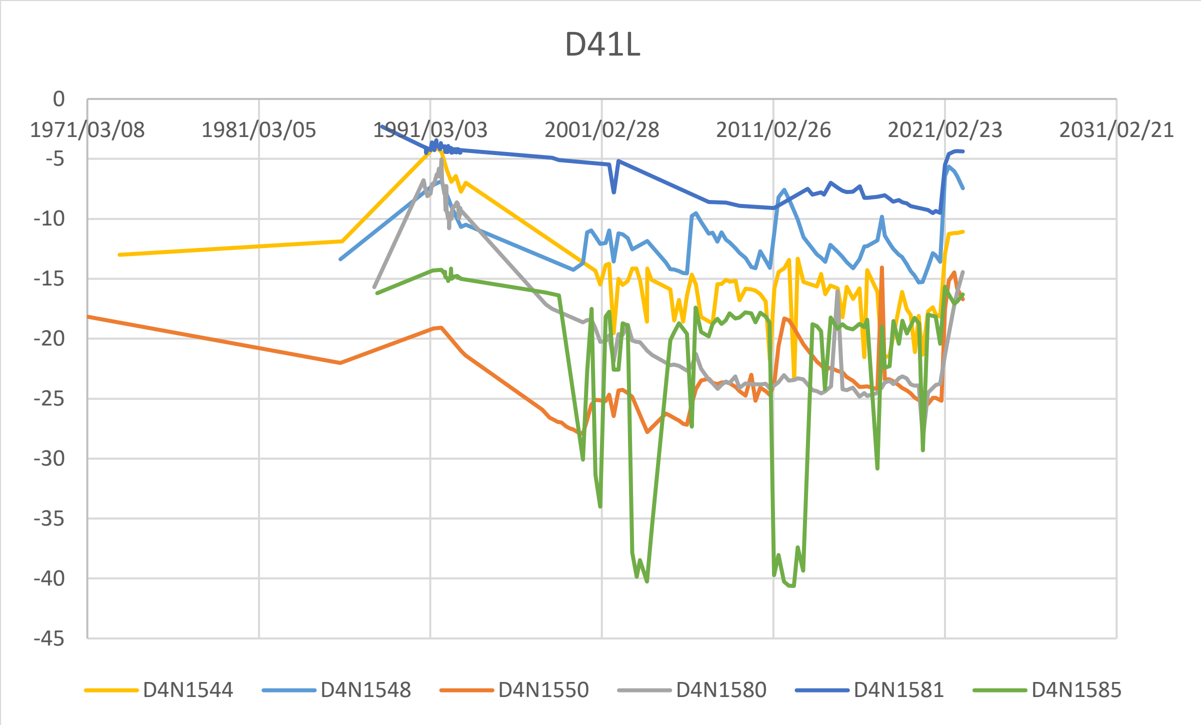
-90
1995/10/28
2005/10/25
2015/10/23
2025/10/20
D4N1861
D4N2382
D4N2383
D4N2385
D4N2386
D4N2459
D4N2463
D4N2464
D4N2466
D4N2467


D41L
0
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-10
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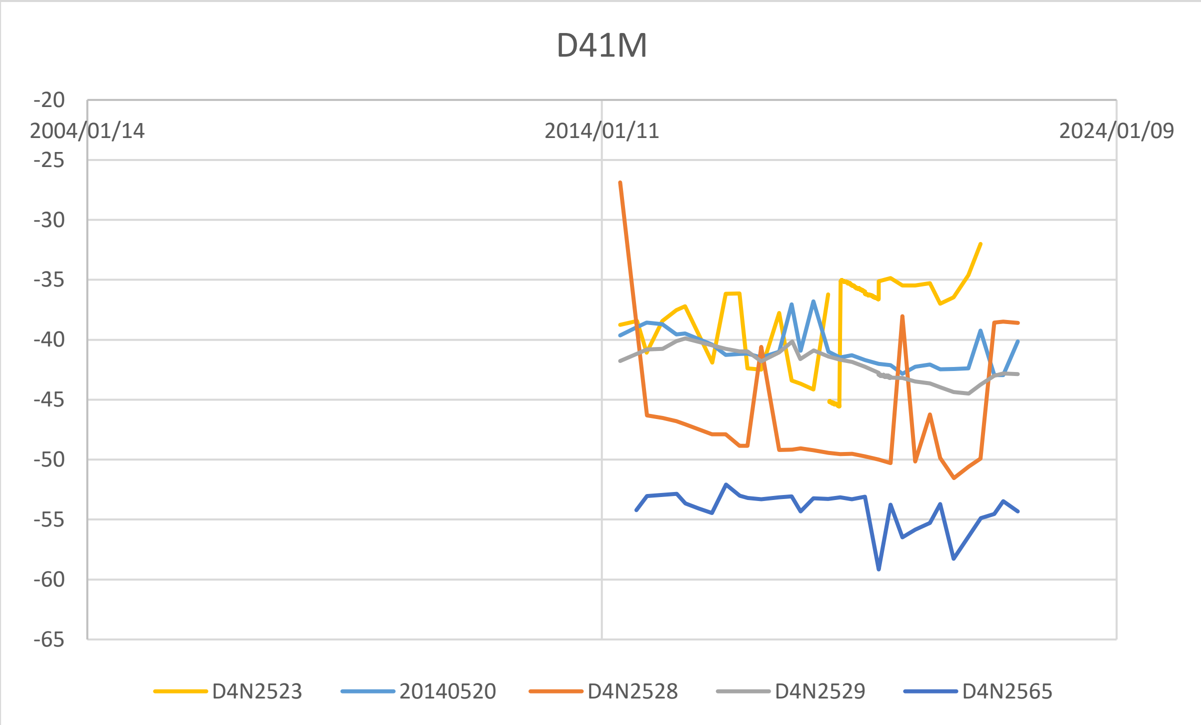
-45
1971/03/08
1981/03/05
1991/03/03
2001/02/28
2011/02/26
2021/02/23
2031/02/21
D4N1544
D4N1548
D4N1550
D4N1580
D4N1581
D4N1585


D41M
-20
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-50
-55
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2014/01/11
2024/01/09
D4N2523
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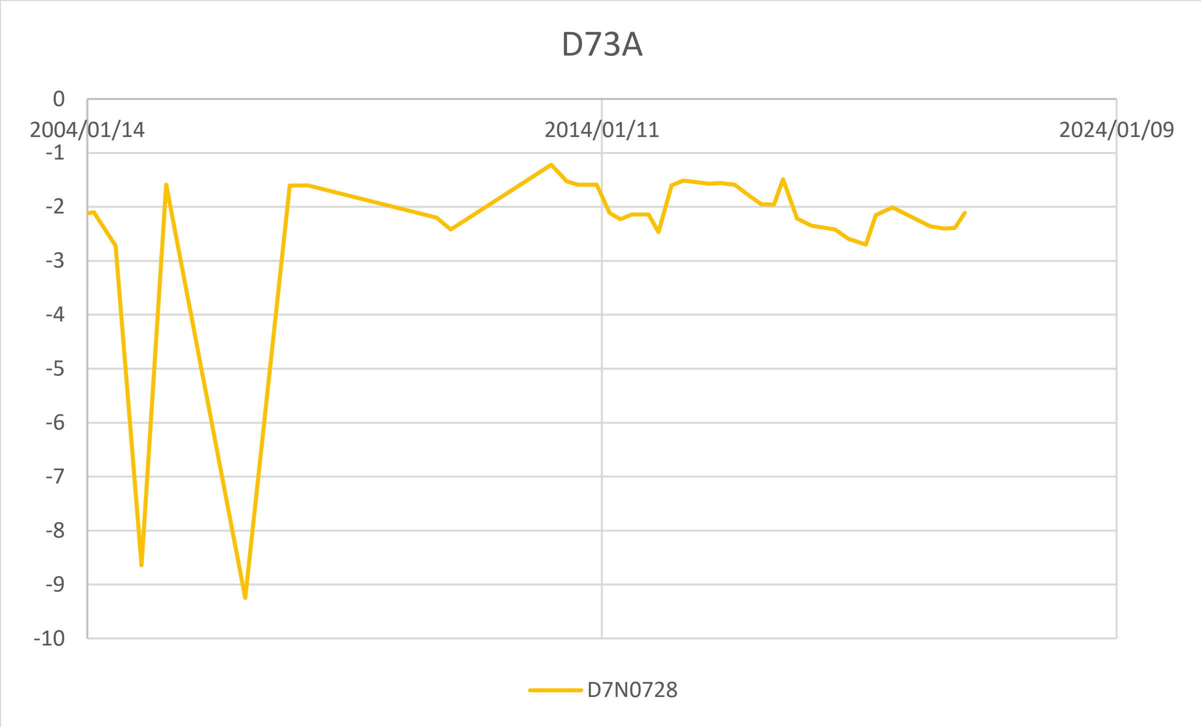
D4N2528
D4N2529
D4N2565


D73A
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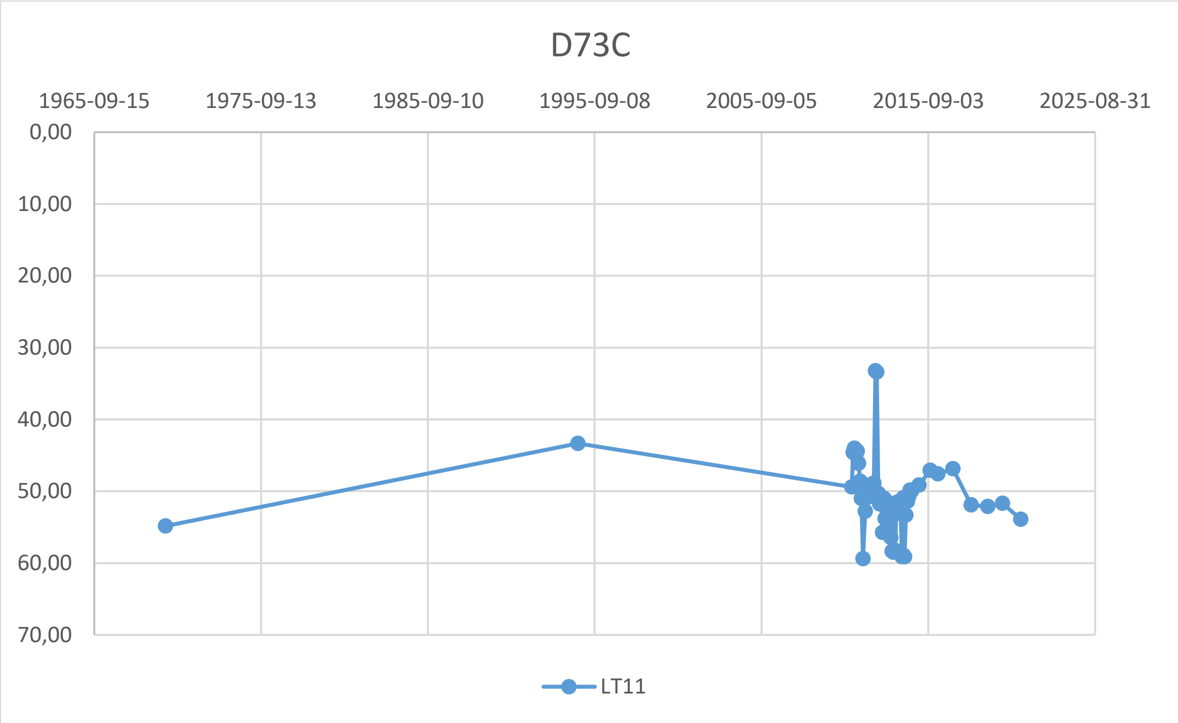
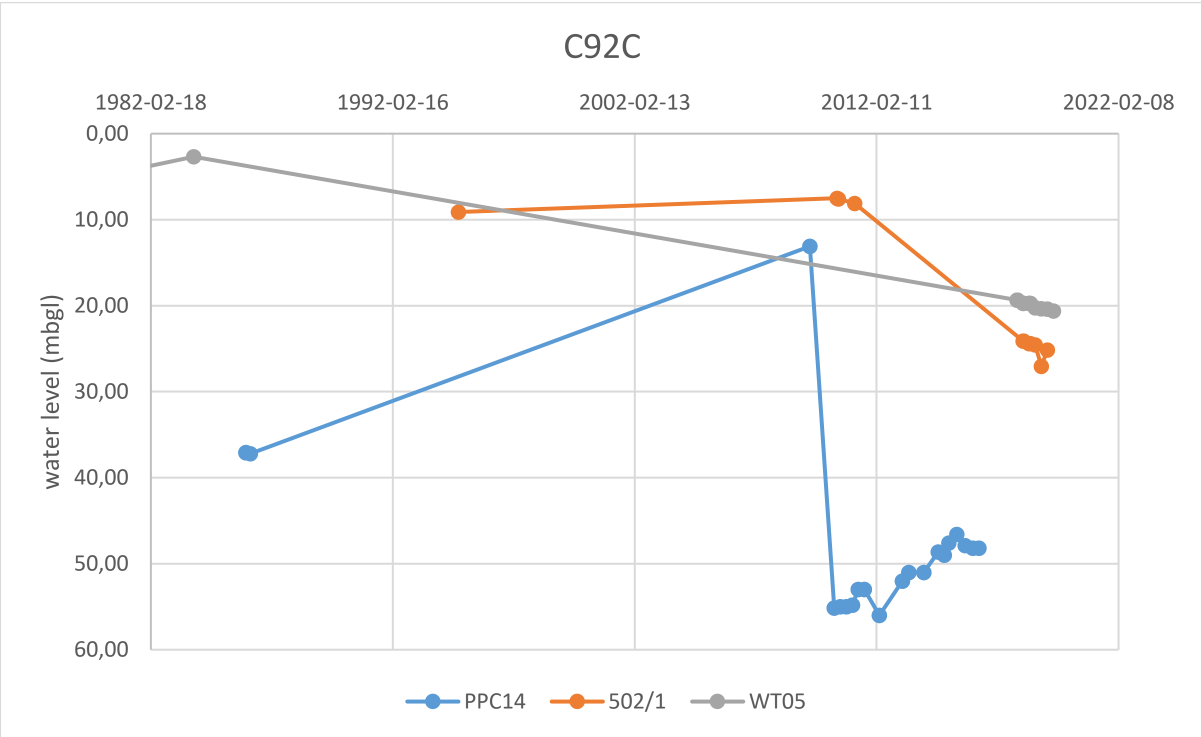
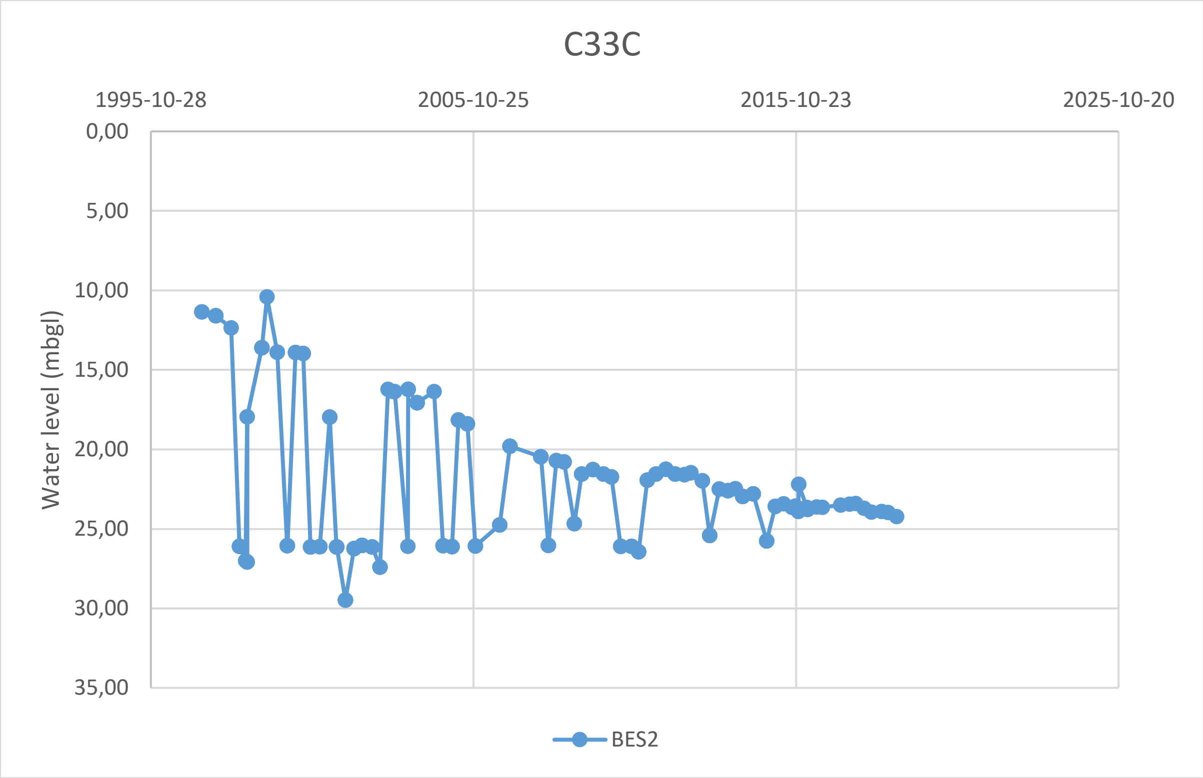
2004/01/14
2014/01/11
2024/01/09
D7N0728

TSHIPING WATER LEVEL DATA






C33C
1995-10-28
2005-10-25
2015-10-23
2025-10-20
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30,00
35,00
Water level (mbgl)
BES2