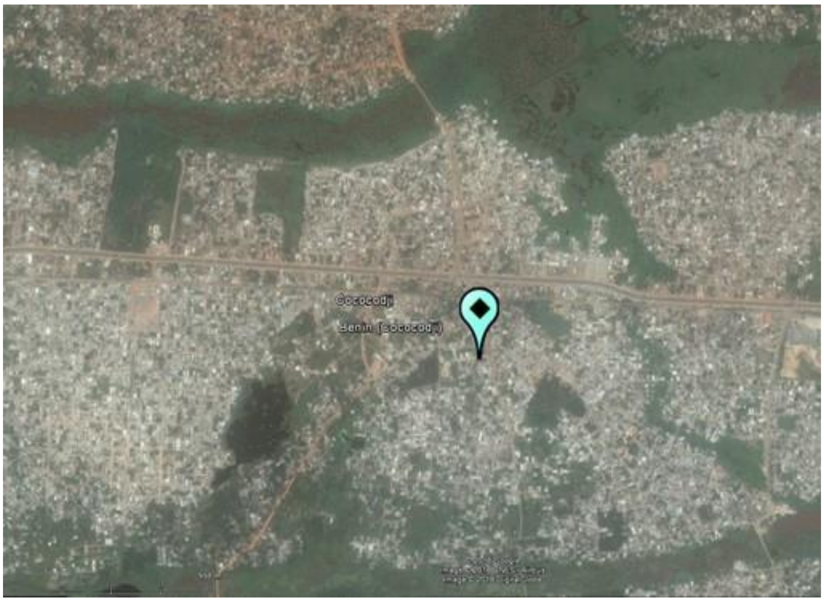
Supplementary Information Table 1. Metadata for 14 long-term groundwater-level time series across sub-Saharan Africa. Aridity index and mean annual PET (potential evapotranspiration) are computed from the CGIAR-CSI Global-Aridity and Global-PET Database (Zomer, Trabucco et al., 2008); mean annual precipitation derives from individual station records at each site; mamsl: metres above mean sea level; mbgl: metres below ground level.

Location:	**Benin, Cococodji (FR7-2)**
basin:	Coastal Sedimentary Basin
monitoring body:	Laboratory of Applied Hydrology, University of Abomey Calavi
aridity index, designation:	0.81, humid
mean annual precipitation (mm):	1208
hydrological year:	January to December
mean annual PET (mm):	1436
landcover:	mixed: urban/residential and lowland forest
aquifer environment:	unconsolidated Quaternary sediments
drainage boundary:	1km to coastal lagoon @ 5 mamsl
pumping influence:	remote from pumping
latitude, longitude (digital):	6.386N, 2.273E
elevation (mamsl):	9
piezometer depth (mbgl):	15
screen interval (mbgl):	6.8 to 12.8
analysed record interval:	7 March 1991 to 28 December 2017
frequency of observations:	weekly (mean frequency is 8 days)
mode of monitoring:	manual (dipper)
distance to rain gauge:	7.1 km
source of rainfall data:	International Institute of Tropical Agriculture (WMO station no. 6534403)
conceptual model:	Diffuse recharge occurs via monsoonal rainfall that infiltrates rapidly through permeable, coarse-grained surface soils to a shallow water table (1.7 to 6.4 mbgl) beneath a surface of low-relief. Forward modelling experiments applying the Water-Table Fluctuation method in which recharge is estimated as a scalar of daily rainfall (Kotchoni, Vouillamoz et al. 2019), indicate that recharge is biased to heavy rainfalls exceeding a threshold of 5 mm·day^{-1} and the time lag between rainfall and groundwater-level responses is less than 1 day (Nash-Sutcliffe Efficiency of 0.78). Seasonal recharge drains to a nearby (≤1 km) lagoon. Permeable surface soils possess high storage (specific yield = 16%±1%), promoting recharge capture from monsoonal rainfall.
notes on the analysis:	Recessions from seasonal groundwater-level rises resulting from direct (diffuse) recharge were estimated from declining trends observed during the dry-season. The location is remote from

intensive abstraction, and groundwater discharges to local lagoon. Recessions were estimated using an exponential term employing decay coefficients of head recession ranging from 1.53×10^{-3} to 2.35×10^{-3} day^{-1} and drainage base levels from 0 to -1 mamsl. To quantify recharge for comparative purposes, a specific yield of 16±1%, derived from Magnetic Resonance Sounding experiments as reported by Kotchoni, Vouillamoz et al. (2018), was applied.

wider data availability: This record, which is part of a network of ~40 piezometers in the Abomey-Calavi and Cotonou region of Benin, operated by Laboratory of Applied Hydrology at the University of Abomey Calavi and Direction Générale de l'Eau (DG-Eau), was selected for analysis on account of its continuity, duration and interpretability.

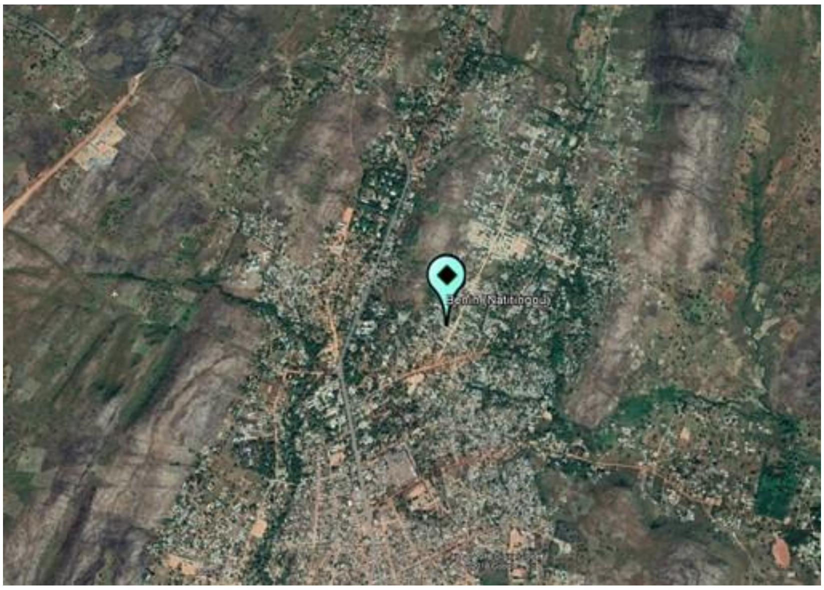
GoogleEarth:



Location:	**Benin, Natitingou (A1252)**
basin:	River Volta Basin
monitoring body:	Direction Générale de l'Eau (DG-Eau)
aridity index, designation:	0.64, sub-humid
mean annual precipitation (mm):	1190
hydrological year:	January to December
mean annual PET (mm):	1906
landcover:	acacia woodland and shrubland
aquifer environment:	weathered crystalline rock: fissured quartzite
drainage boundary:	~650 m laterally to a fault-controlled, seasonal wetland (fadama) @ 425 mamsl
pumping influence:	remote from pumping
latitude, longitude (digital):	10.317N, 1.383E
elevation (mamsl):	417
piezometer depth (mbgl):	74

screen interval (mbgl):	10 to 73.7
analysed record interval:	21 May 1997 to 29 December 2014
frequency of observations:	weekly (mean frequency is 9 days)
mode of monitoring:	manual (dipper)
distance to rain gauge:	3.8 km (DG-Eau)
source of rainfall data:	Meteo-Benin (station number BJ0020S)
conceptual model:	Diffuse recharge occurs via monsoonal rainfall that infiltrates rapidly via preferential pathways within a thin saprolite underlying a surface of low-relief. Forward modelling experiments applying the Water-Table Fluctuation method in which recharge is estimated as a scalar of daily rainfall (Kotchoni, Vouillamoz et al. 2019), suggest that recharge is biased to heavy rainfalls exceeding 15 mm·day^{-1} and the time lag between rainfall and groundwater-level responses is 2 days (Nash-Sutcliffe Efficiency of 0.66). Seasonal recharge drains to a wetland known by various terms such as *bas-fonds*, fadama, and dambo that characterise drainage in deeply weathered surfaces of low relief. Recharge is greatly restricted by the very low dynamic storage capacity of the fissured quartzite (specific yield = 0.4%).
notes on the analysis:	Recessions from seasonal groundwater-level rises resulting from diffuse recharge were estimated from declining trends observed during the dry-season. The location is remote from intensive abstraction and groundwater discharges to seasonal wetland (*i.e. bas fonds*). Maximum and minimum linear groundwater level recession end members of 3.88 x 10^{-2} and 4.13 x 10^{-2} m·day^{-1} were used to estimate the uncertainty bounds in computed recharge. To quantify recharge for comparative purposes, a specific yield of 0.4±0.1%, derived from Magnetic Resonance Sounding experiments as reported by Kotchoni, Vouillamoz et al. (2018), was applied.
wider data availability:	This record, which is part of a national network of ~40 piezometers operated by the DG-Eau, was selected for analysis on account of its continuity, duration and interpretability.

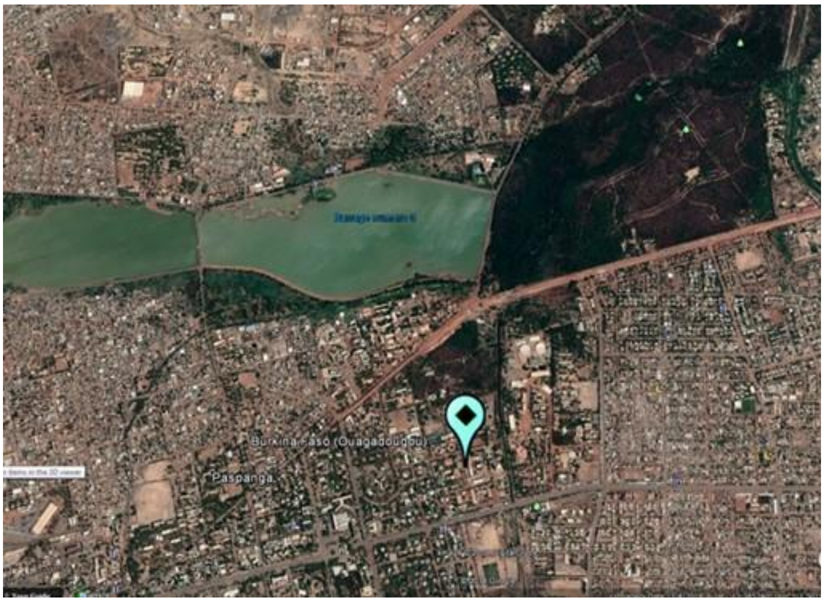
GoogleEarth:



Location:	**Burkina Faso, Ouagadougou (Nk_Ka_Ou/01)**
basin:	River Nakanbe Basin
monitoring body:	University of Ouagadougou and DGRE (Direction Générale des Ressources en Eaux)
aridity index, designation:	0.39, semi-arid
mean annual precipitation (mm):	750
hydrological year:	January to December
mean annual PET (mm):	2003
landcover:	mixed: urban and deep-rooted (phreatophytic) woodland
aquifer environment:	weathered (coarse saprolite) and fractured (saprock) granite
drainage boundary:	groundwater discharge occurs from phreatophytes locally and to the Bangr Weogo wetland regionally, 1.5 km to the northeast @ 286 mamsl
pumping influence:	this location is remote from intensive abstraction but may experience a low, seasonal influence from localised abstraction for urban gardening
latitude, longitude (digital):	12.373N, 1.502W
elevation (mamsl):	294.1
piezometer depth (mbgl):	20
screen interval (mbgl):	8 to 20
analysed record interval:	8 April 1978 to 31 December 2016
frequency of observations:	highly variable: monthly and biweekly to hourly (since 2015)
mode of monitoring:	manual (dipper) and automated datalogger
distance to rain gauge:	2.5 to 3.0 km (Ouagadougou Airport)

source of rainfall data:	National Meteorological Agency (NAMA), Burkina Faso
conceptual model:	Recharge processes at this location are the subject of active research. An early study (Thiéry, Diluca et al. 1993) applied a daily soil-moisture balance model (GARDENIA) to simulate the groundwater-level time series over a 13-year period from 1978 to 1992 that implicitly assumed recharge is diffuse, occurring from the direct infiltration of monsoonal rainfalls. More recent research (Mouhouyouddine, Yameogo et al. 2017) employing a 2D numerical model (MODFLOW) argues that contributions of focussed recharge via leakage from controlled barrages (e.g. no. 3, ~1 km to the north) are necessary to explain groundwater-level rises since the 1990s. In contrast, groundwater levels in suburban Ouagadougou (Silmissin), remote (~14 km) from the barrages and groundwater abstraction, show substantial declines since the 1990s. Further, newly compiled observations show further that water levels in the unlined barrage no. 3 are higher (~2.5 to ~3.5 m) than groundwater levels at this site (Nk_Ka_Ou/01) throughout the annual cycle. Consequently, focussed recharge is expected to be dominant pathway of groundwater recharge at this location, though diffuse recharge may also take place.
notes on the analysis:	The Water Table Fluctuation analysis was carried out on a seasonal basis and applied exponential recessions to estimate groundwater drainage with a co-efficient of head recession ranging from 0.009 to 0.011 month^{-1} and drainage base level of 270 mamsl. Where recharge was quantified for comparative purposes, an average specific yield of 10% was employed and a range of uncertainty between 8 and 12%; total porosity that is the sum of specific yield and specific retention in the shallowest zone of the saprolite (~5.9 to 6.9 mbgl) has been observed to range from 21 to 24% (Bazie, Dieng et al. 1995).
wider data availability:	This record is one of ~6 long-term (>10 years) records in Burkina Faso and was chosen on the basis of its duration, continuity and interpretability.

GoogleEarth:

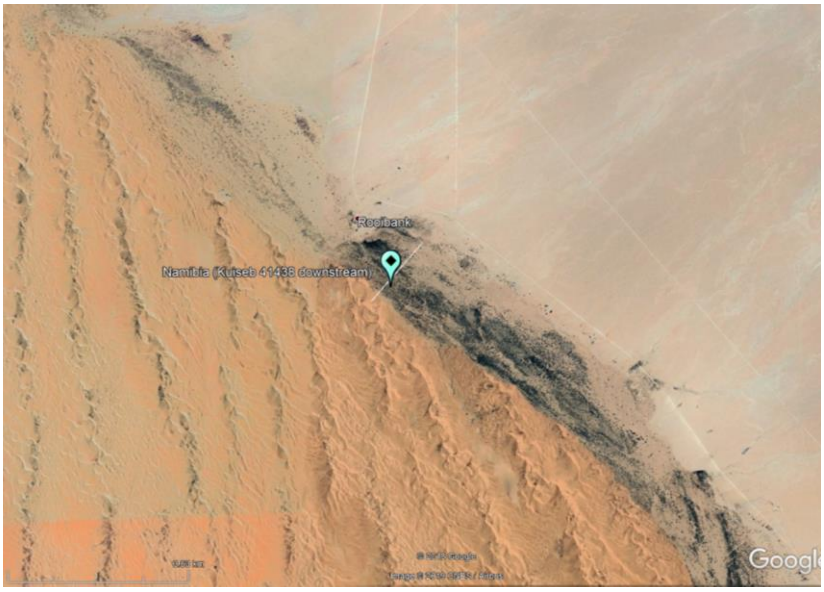


Location:	**Ghana, Accra**
basin:	Coastal Basin
monitoring body:	WRI (Water Research Institute)
aridity index, designation:	0.57, sub-humid
mean annual precipitation (mm):	948
hydrological year:	January to December
mean annual PET (mm):	1446
landcover:	semi-urban: widely spaced office buildings with mostly open land and garden, possible garden watering
aquifer environment:	weathered crystalline rock (phyllite, Togo series)
drainage boundary:	stream approx. 100 m north at 40 mamsl
pumping influence:	Unknown but unlikely within 100 m
latitude, longitude (digital):	5.596N, 0.184W
elevation (mamsl):	42
piezometer depth (mbgl):	<50
screen interval (mbgl):	*Unknown*
analysed record interval:	29 January 1976 to 15 December 1994
frequency of observations:	Monthly
mode of monitoring:	manual (dipper)
distance to rain gauge:	1.0 km (Accra Airport, WMO# 65472), 5.6N, 0.17 W @ 68m
source of rainfall data:	GPCC (Global Precipitation Climatology Centre)
conceptual model:	Diffuse recharge occurs in most years when direct rainfall infiltration overcomes evapotranspirative demand. Vegetation is sparse. During dry periods, recessions in groundwater levels are likely driven by evapotranspiration since the average water table is

	less than 1 m below ground level. Seasonal recharge in this sub-humid environment drains to a local stream.
notes on the analysis:	An exponential recession relationship was assumed with a groundwater level decay rate of 0.157 to 0.171 m·month^{-1} per m of head difference between the observed value and a base level of 1.7 mbgl. Where recharge was quantified for comparative purposes and in the absence of site specific data for this location (Dapaah-Siakwan and Gyau-Boakye 2000), a range of values for specific yield from 2% to 6% was assumed based on data compiled for saprolite in the literature (Taylor, Tindimugaya et al. 2010, Kotchoni, Vouillamoz et al. 2019).
wider data availability:	This record is the only long duration record known for Ghana but is no longer being monitored.
GoogleEarth:	

Location:	**Namibia, Rooibank (41348)**
basin:	Kuiseb
monitoring body:	Ministry of Agriculture, Water and Forestry (MAWF)
aridity index, designation:	0.01, hyper-arid
mean annual precipitation (mm):	12 (396 at Claratal rain gauge)
hydrological year:	September to August
mean annual PET (mm):	1373
landcover:	Sand desert with some trees & shrubs locally around the Kuiseb floodplain
aquifer environment:	Alluvial aquifer

drainage boundary:	Longitudinal drainage along Kuiseb channel alluvium and discharge by downstream transpiration or pumping; the extent of lateral drainage to adjacent formations is unknown.
pumping influence:	remote from pumping
latitude, longitude (digital):	23.188S, 14.656E
elevation (mamsl):	133
piezometer depth (mbgl):	*unknown*
screen interval (mbgl):	*unknown*
analysed record interval:	21 October 1998 to 14 November 2017
frequency of observations:	Approx. every 3 – 4 months
mode of monitoring:	manual (dipper)
distance to rain gauge:	~220 km to Claratal gauge located in the runoff-generation area of the ephemeral River Kuiseb
source of rainfall data:	Mr Freyer (farmer in Claratal, No. 0739/588) @ 22.80S, 16.833E. Contact the authors for advice on data access.
conceptual model:	Recharge occurs indirectly as focussed recharge via streambed transmission losses when ephemeral flows occur in the adjacent Kuiseb river that are driven by rainfall in the headwaters which extend more than 250 km east-northeast.
notes on the analysis:	Since the recessions of groundwater mounds caused by recharge events occur over multiple years, some mounding recession was not complete when the next event occurred. Hence, timescales of recharge mound recession were manually estimated for each event to reach background levels of the longitudinal recession which were estimated as 0.256 $m \cdot y^{-1}$. Maximum and minimum recession end members were used to estimate uncertainty bounds. A specific yield in the approximate range of 20% to 40% is likely as estimated further upstream by (Dahan, Tatarsky et al. 2008).
wider data availability:	This record is part of a network of approximately 40 monitoring wells in the Swartbank and Rooibank area of the lower Kuiseb River. This record was chosen as being representative of the typical hydrograph responses seen in the downstream section of the monitored area.

GoogleEarth:	

Location:	**Namibia, Swartbank (20174)**
basin:	Kuiseb
monitoring body:	Ministry of Agriculture, Water and Forestry (MAWF), Division
aridity index, designation:	0.01, hyper-arid
mean annual precipitation (mm):	14 (396 at Claratal rain gauge)
hydrological year:	September to August
mean annual PET (mm):	1487
landcover:	Sand desert with trees & shrubs around the Kuiseb floodplain
aquifer environment:	Alluvial aquifer
drainage boundary:	Longitudinal drainage along Kuiseb channel alluvium and discharge by downstream transpiration or pumping; the extent of lateral drainage to adjacent formations is unknown.
pumping influence:	remote from pumping
latitude, longitude (digital):	23.322S, 14.767E
elevation (mamsl):	231.9
piezometer depth (mbgl):	37.4
screen interval (mbgl):	*unknown*
analysed record interval:	12 June 1975 (one observation), 10 September 1992 to 24 November 2016
frequency of observations:	approximately every 3 to 4 months
mode of monitoring:	manual (dipper)
distance to rain gauge:	Approx. 220 km to Claratal gauge located in the runoff-generation area of the ephemeral River Kuiseb
source of rainfall data:	Mr Freyer (farmer in Claratal, No. 0739/588) @ 22.80S, 16.833E. Contact the authors for advice on data access.
conceptual model:	Recharge occurs indirectly as focussed recharge via streambed transmission losses when ephemeral flows occur in the adjacent

	Kuiseb river that are driven by rainfall in the headwaters which extend more than 250 km to the east-northeast (Dahan, Tatarsky et al. 2008, Morin, Grodek et al. 2009).
notes on the analysis:	Since the recessions of groundwater mounds caused by recharge events occur over multiple years, some mounding recession was not complete when the next event occurred. Hence, timescales of recharge mound recession were manually estimated for each event to reach background levels of the longitudinal recession which were estimated as 0.292 $m \cdot y^{-1}$. Maximum and minimum recession end members were used to estimate uncertainty bounds. A specific yield in the approximate range of 20% to 40% is likely as estimated further upstream by (Dahan, Tatarsky et al. 2008).
wider data availability:	This record is part of a network of approximately 40 monitoring wells in the Swartbank and Rooibank area of the lower Kuiseb River. This record was chosen as being representative of the typical hydrograph responses seen in the upstream section of the monitored area.
GoogleEarth:	

Location:	**Niger, Banizoumbou**
basin:	River Niger
monitoring body:	Ministry of Hydraulics and Sanitation, Niger with support from AMMA-Catch (African Monsoon Multidisciplinary Analysis - Coupling the Tropical Atmosphere and the Hydrological Cycle)
aridity index, designation:	0.21, semi-arid
mean annual precipitation (mm):	460

hydrological year:	January to December
mean annual PET (mm):	2100
landcover:	millet and fallow agricultural landcover
aquifer environment:	Tertiary loosely cemented, clayey sandstone with scattered clay lenses
drainage boundary:	The groundwater recession in this location is controlled by a large piezometric depression inherited from pre-1960 conditions before the clearance of woody savannah landcover occurred and changed the hydrological regime. Currently there is no groundwater drainage boundary for tens of kilometres.
pumping influence:	Remote from intensive pumping, bucket and rope water collection occurs on site
latitude, longitude (digital):	13.533N, 2.662E
elevation (mamsl):	207
piezometer depth (mbgl):	45 to 55 (range of 2 piezometers), 1 large-diameter well is 400 m
screen interval (mbgl):	24 to 47 (range of 2 piezometers), 1 large-diameter well is 400 m
analysed record interval:	3 January 1996 to 1 March 2016
frequency of observations:	3-hourly and approximately monthly
mode of monitoring:	manual (dipper) and automatic (three-hourly)
distance to rain gauge:	~200 m (13.533S, 2.660E) @ 209 mamsl
source(s) of rainfall data:	AMMA-Catch (Galle, Grippa et al. 2018)
conceptual model:	Recharge is considered to occur predominantly via focussed recharge through ephemeral streams and ponds flowing through the valley in which the monitoring well is situated (Leduc, Favreau et al. 2001, Massuel, Cappelaere et al. 2011). Due to the combination of re-equilibration of the inherited pre-1960 (pre tree clearance) piezometry, and increased recharge due to focussed recharge along the valley, the groundwater hydrograph shows slow linear recessions in the driest parts of the year with superimposed rises and recessions due to groundwater mounds near the valley during and after surface water flow and ponding events.
notes on the analysis:	Water table fluctuation analysis was carried out on a seasonal basis using linear long term groundwater level recessions of 0.43 to 0.55 m·year^{-1} based on the observed dry period hydrograph. Where recharge was quantified for comparative purposes, a specific yield of 3.7±0.5% derived from Magnetic Resonance Sounding experiments and pumping tests (Boucher, Favreau et al. 2009, Boucher, Favreau et al. 2012), was applied.

wider data availability: This groundwater-level record is part of a network of monitoring wells in the area. This record was chosen on the basis of its long duration and continuity.

GoogleEarth:

Location: Niger, Berkiawel

basin: River Niger

monitoring body: Ministry of Hydraulics and Sanitation, Niger with support from AMMA Catch (African Monsoon Multidisciplinary Analysis - Coupling the Tropical Atmosphere and the Hydrological Cycle)

aridity index, designation: 0.22, semi-arid

mean annual precipitation (mm): 497

hydrological year: January to December

mean annual PET (mm): 2114

landcover: millet and fallow agricultural landcover

aquifer environment: Tertiary loosely cemented, clayey sandstone with scattered clay

drainage boundary: The groundwater recession in this location is controlled by piezometry inherited from pre-1960 conditions before the clearance of woody savannah landcover occurred and changed the hydrological regime. Currently the nearest groundwater drainage boundary is the River Niger approximately 20 km to the southwest.

pumping influence: Remote from intensive pumping, bucket and rope abstraction for domestic purposes from this large-diameter well

latitude, longitude (digital): 13.545N, 2.309E

elevation (mamsl): 228

piezometer depth (mbgl): 33 to 39 (range of 2 large-diameter wells)

screen interval (mbgl): 27 to 29 (range of 2 large-diameter wells)

analysed record interval: 14 August 1994 to 25 October 2016

frequency of observations: Approximately weekly to monthly *mode of monitoring:* manual (dipper)

distance to rain gauge: 0.5 km (13.511N, 2.308E) @ 224 mamsl

source(s) of rainfall data: AMMA-Catch (Galle, Grippa et al. 2018)

conceptual model: Recharge is thought to occur predominantly via focussed recharge through ephemeral streams and ponds flowing through the valley in which the monitoring well is situated (Leduc, Favreau et al. 2001, Massuel, Cappelaere et al. 2011). Due to the combination of re-equilibration of the inherited pre-1960 (pre tree clearance) piezometry, and increased recharge due to focussed recharge along the valley, the groundwater hydrograph shows slow linear recessions in the driest parts of the year with superimposed rises and recessions due to groundwater mounds near the valley during and after surface water flow and ponding events.

notes on the analysis: Water Table Fluctuation analysis was carried out on a seasonal basis using linear long term groundwater level recessions of 1.22 to 1.70 m·year^{-1} based on the observed dry-period hydrograph. Where recharge was quantified for comparative purposes, a specific yield of 2.0±0.7% derived from Magnetic Resonance Sounding experiments (Boucher, Favreau et al. 2009, Boucher, Favreau et al. 2012), was applied.

wider data availability: This groundwater-level time series is part of a network of monitoring wells in the area. This record was chosen on the basis of its long duration and continuity.

Location:	**South Africa, Modderfontein (B5N0013)**
basin:	Limpopo Basin
monitoring body:	Department of Water and Sanitation, Polokwane
aridity index, designation:	0.35, semi-arid
mean annual precipitation (mm):	604
hydrological year:	September to August
mean annual PET (mm):	1555
landcover:	woodland and open bushland
aquifer environment:	Dolomite
drainage boundary:	The fractured nature of the limestone in this location leads to complex groundwater recession behaviour; the apparent control on the groundwater level at approximately 36 mbgl is likely due to a permeable fracture which facilitates rapid drainage towards the stream located approximately 1 km to the south east of the site.
pumping influence:	Groundwater is widely used for irrigation but precise pumping rates are not available and thus the pumping influence is unknown. However, the monitoring well is approximately 3 km from the nearest known major irrigation abstraction.
latitude, longitude (digital):	24.296S, 29.212E
elevation (mamsl):	1208
piezometer depth (mbgl):	85
screen interval (mbgl):	*Unknown*
analysed record interval:	27 February 1976 to 16 March 2015
frequency of observations:	Monthly
mode of monitoring:	manual (dipper)
distance to rain gauge:	~43 km at Doorndraai Dam (Doorndraai A6E001, 24.2688S 28.7863E); despite being relatively distant from the monitoring well, the altitude of the rainguage is similar, at ~1170 mamsl.
source of rainfall data:	Department of Water and Sanitation, South Africa
conceptual model:	Recharge processes in the area are poorly constrained; diffuse recharge is possible through thin soils and fractures in the Malmani limestone whereas focussed recharge is expected via the base of small streams when runoff is generated in the steep terrain to the north of the site; focused recharge is likely to dominate, based on field and modelling studies from analogous limestone terrains (Hartmann, Gleeson et al. 2017).

notes on the analysis:	The hydrograph has a complex form typical of dolomite and thus presented challenges for the applied water table fluctuation methodology. In particular, very different modes of behaviour observed above and below ~36 mbgl are likely due to strong variations in specific yield and permeability (or a combination of both) at this level. As a result, recharge was only calculated during periods of water table rise when groundwater level recession rates were varied between two end members (0.06 to 0.08 $m \cdot d^{-1}$). Consequently, derived recharge values should be considered to be consistently underestimated. A specific yield of between 2% and 4% was used as the most commonly reported range for dolomite aquifers in South Africa (Cobbing 2018).
wider data availability:	This groundwater-level time series is part of a large network of monitoring wells in the area; this specific record was chosen on the basis of its long duration and good continuity, and via a cluster analysis, as being representative of one of two 'types' of hydrograph in the area; the other being represented by Sterkloop.
GoogleEarth:	

Location:	**South Africa, Sterkloop (A7N0561)**
basin:	Limpopo Basin
monitoring body:	Department of Water and Sanitation, Polokwane
aridity index, designation:	0.38, semi-arid
mean annual precipitation (mm):	463
hydrological year:	September to August
mean annual PET (mm):	1468
landcover:	woodland and open bushland
aquifer environment:	gneiss (Hout River)

drainage boundary:	The monitoring well is adjacent to an intermittent stream which flows to the NE and is likely to form the groundwater discharge boundary several kilometres downstream.
pumping influence:	The aquifer is widely abstracted for irrigation but precise pumping rates are not available and thus the pumping influence is unknown. However, the monitoring well is several km from the nearest known major irrigation abstraction.
latitude, longitude (digital):	23.901S, 29.435E
elevation (mamsl):	1238
piezometer depth (mbgl):	20
screen interval (mbgl):	*unknown*
analysed record interval:	12 November 1973 to 11 July 2016
frequency of observations:	Approx. every 5 days before 1989 and daily thereafter.
mode of monitoring:	Manual (dipper)
distance to rain gauge:	~5 km in Pietersberg (A7E003, 23.85S, 29.45E)
source of rainfall data:	Department of Water and Sanitation, South Africa
conceptual model:	Focussed recharge is thought to occur via streambed transmission losses when stream flow occurs in the ephemeral channel situated approximately 700 m west of the monitoring well. A diffuse component of recharge may also occur but focussed recharge appears to dominate, based on the co-incident timing of stream flow events and observed water table rises, and the style of the groundwater recessions described below.
notes on the analysis:	Steep rises in groundwater levels indicative of major recharge events are followed by decaying recessions which track back towards consistent long-term steady rates of groundwater-level decline. This behaviour is indicative of focused recharge consistent with the proximity of the monitoring well to the ephemeral stream nearby. Water Table Fluctuation analysis was carried out on a seasonal basis using linear long-term groundwater level recessions of 2.5 to 3.5 $mm \cdot d^{-1}$ based on the observed dry period hydrograph. A specific yield in the range of 1% to 5% was applied, consistent with that employed by (Ebrahim, Villholth et al. 2019) in the adjacent catchment.
wider data availability:	This record is part of a large network of monitoring wells in the area; this specific record was chosen on the basis of its long duration and good continuity, and via a cluster analysis, as being representative of one of two 'types' of hydrograph in the area (the other being represented by Modderfontein).

GoogleEarth:

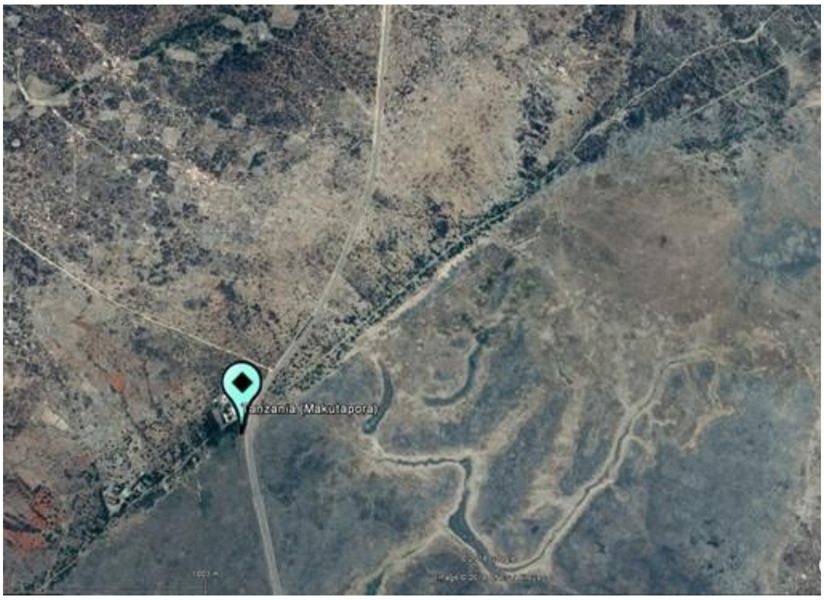
Location:	**Tanzania, Makutapora**
basin:	River Wami
monitoring body:	WamiRuvu Basin Water Board, Ministry of Water and Irrigation
aridity index, designation:	0.35, semi-arid
mean annual precipitation (mm):	564
hydrological year:	July to June
mean annual PET (mm):	1797
landcover:	acacia shrublands
aquifer environment:	weathered and fractured granite with alluvium
drainage boundary:	Controls on groundwater drainage beyond abstraction (below) are unresolved but are expected to include Lake Hombolo (reservoir) downstream of the River (Little Kinyasungwe)
pumping influence:	Intensively pumped for water supply of Dodoma City
latitude, longitude (digital):	5.957S, 35.737E (pump house)
elevation (mamsl):	1082 (pump house)
piezometer depth (mbgl):	35 to 140 (multiple co-located monitoring wells)
screen interval (mbgl):	20 to 130 (multiple co-located monitoring wells)
analysed record interval:	1 July 1955 to 30 June 2016
frequency of observations:	daily to weekly with hourly monitoring since 2013
mode of monitoring:	manual (dipper) and automatic (hourly)
distance to rain gauge:	adjacent to pump house / 21 km (Dodoma Airport)
sources of rainfall data:	WamiRuvu Basin Water Board (Makutapora, ID 09535007) / Tanzanian Meteorological Agency (Dodoma Airport WMO station
conceptual model:	Focussed recharge via leakage from ephemeral streamflow is inferred at this location from: (1) the decay of groundwater-level mounds observed laterally from an ephemeral stream channel, and

(2) strong correlations (R^2 = 0.85) observed between duration from ephemeral streamflow and groundwater recharge (Seddon 2019). Correlation of daily rainfall and groundwater-level records indicates an apparent rainfall threshold exceeding 70 mm over a 9-day period is required to generate recharge; this evidence does not preclude the occurrence of diffuse recharge but suggests that focussed recharge is the dominant recharge pathway.

notes on the analysis: Water Table Fluctuation analysis was carried out on a seasonal basis using groundwater-level recessions modelled in MIKE-SHE to account for the impact of intensive abstraction (Seddon 2019). Where recharge was quantified for comparative purposes, an average specific yield of 5.5% was used and a range of uncertainty between 4% and 7%, consistent with that estimated by (Taylor, Todd et al. 2013).

wider data availability: This groundwater-level time series is a composite of 8 time series of groundwater-level records from different wells in the same wellfield over a 60-year period. This record was chosen on the basis of its long duration and good continuity.

GoogleEarth:



Location: Uganda, Apac (S/N 48)

basin: Upper Nile Basin

monitoring body: Directorate of Water Resources Management (DWRM)

aridity index, designation: 0.72, humid

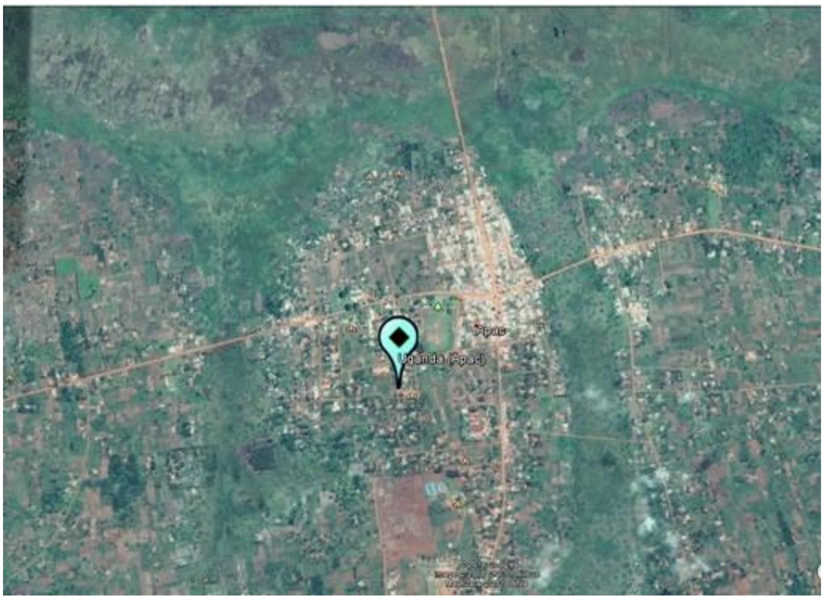
mean annual precipitation (mm): 1484

hydrological year: January to December

mean annual PET (mm): 1816

landcover: mixed: acacia/shrubland and urban

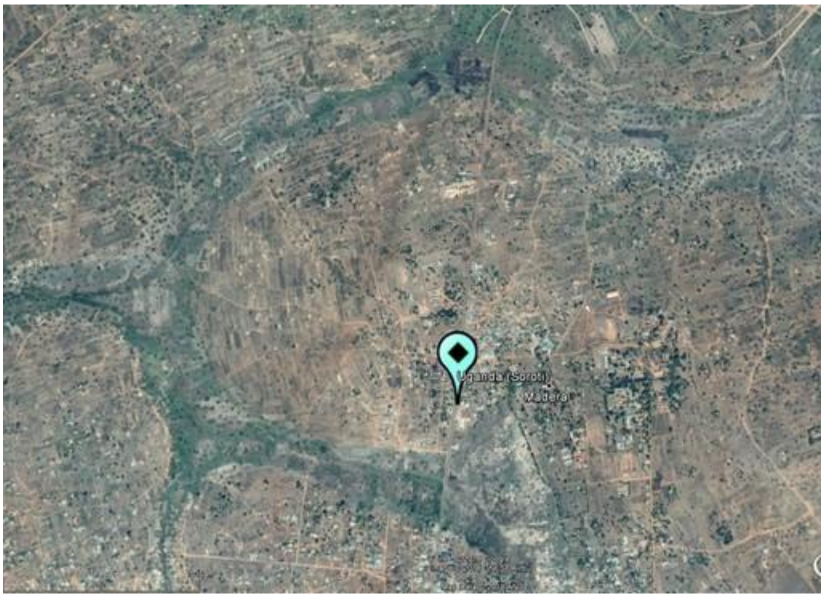
aquifer environment:	weathered crystalline rock (gneiss)
drainage boundary:	Aroca wetland (mubga, *bas-fonds*, fadama) between 0.7 and 1.1 km away @ 1040 to 1043 mamsl
pumping influence:	remote from pumping
latitude, longitude (digital):	1.982N, 32.530E
elevation (mamsl):	1053
piezometer depth (mbgl):	15
screen interval (mbgl):	8 to 14
analysed record interval:	1 January 1999 to 31 October 2015
frequency of observations:	daily
mode of monitoring:	manual (dipper)
distance to rain gauge:	2 m (DWRM), gaps infilled with data from meteorology station in Apac Town (~0.5 km away) operated by Uganda National Meteorological Authority (UNMA)
sources of rainfall data:	DWRM, UNMA
conceptual model:	Diffuse recharge occurs via bimodal rainfall that infiltrates the deeply weathered surface of low-relief; the reduced duration of the June-July-August dry season is thought to enhance September-October-November recharge relative to March-April-May rainy season. Correlations between daily rainfall and groundwater-level rises (i.e. inferred recharge) indicate a bias in groundwater recharge to daily rainfall exceeding 10 $mm \cdot day^{-1}$ and short time lags (<2 weeks) indicative of preferential pathways through the saprolite (Taylor and Howard 1999, Owor, Taylor et al. 2009). Seasonal groundwater recharge drains to a local wetland, also known as a dambo (Aroca).
notes on the analysis:	Recessions from seasonal groundwater-level rises resulting from direct (diffuse) recharge were estimated from declining trends observed during the dry-season. The location is remote from abstraction and groundwater discharges to local wetlands (dambos). Maximum and minimum linear groundwater level recession end members of 5.4×10^{-3} and 6.2×10^{-3} $m \cdot day^{-1}$ were used to estimate the uncertainty bounds in computed recharge. Where recharge was quantified for comparative purposes, a range of values for specific yield from 2% to 6%, consistent with analyses for saprolite derived from Precambrian basements rocks in East Africa (Taylor, Tindimugaya et al. 2010, Taylor, Todd et al. 2013) but sensibly much less than that proposed much earlier by (Taylor and Howard 1996).

wider data availability:	This record is part of a national network of ~30 monitoring (17 by telemetry) operated by the DWRM and was selected for analysis on account of its continuity, duration and interpretability.
GoogleEarth:	

Location:	**Uganda, Soroti (S/N 25)**
basin:	Upper Nile Basin
monitoring body:	Directorate of Water Resources Management (DWRM) Ministry of Water and Environment
aridity index, designation:	0.74, humid
mean annual precipitation (mm):	1308
hydrological year:	January to December
mean annual PET (mm):	1836
landcover:	mixed: acacia/shrubland and urban
aquifer environment:	weathered crystalline rock (gneiss)
drainage boundary:	River Mpologama, 430 m away, headwater of the Lake Kyoga wetland (dambo, *bas-fonds*, fadama) swamp @ 1098 mamsl
pumping influence:	proximate to handpump abstraction
latitude, longitude (digital):	1.744N, 33.616E
elevation (mamsl):	1112
piezometer depth (mbgl):	66
screen interval (mbgl):	*Unknown*
analysed record interval:	25 March 1999 to 31 May 2017
frequency of observations:	daily
mode of monitoring:	manual (dipper)

distance to rain gauge:	2 m (DWRM), gaps infilled with records from 2.3 km away at Soroti Airport (1.721N, 33.620E) operated by Uganda National Meteorological Authority (UNMA)
sources of rainfall data:	DWRM, UNMA
conceptual model:	Diffuse recharge occurs via bimodal rainfall that infiltrates the deeply weathered surface of low relief (Cuthbert and Tindimugaya 2010); the reduced duration of the June-July-August dry season is thought to enhance September-October-November recharge relative to March-April-May rainy season.
notes on the analysis:	Recessions from seasonal groundwater-level rises resulting from direct (diffuse) recharge were estimated from declining trends observed during the dry-season. Preferential flow at a local scale is thought to occur enabling rapid groundwater-level responses to rainfall even in the presence of soil moisture deficits (Cuthbert and Tindimugaya 2010). The location is remote from intensive abstraction but there is potential influence of low-intensity, handpump abstraction ~100 m away. Groundwater discharges to local wetlands (dambos) that are part of the River Mpologoma, a headwater catchment of Lake Kyoga to the west. Linear (1.42×10^{-2} $m \cdot day^{-1}$ head recession) and exponential recessions were used to estimate recessions and range in uncertainty of computed recharge; the applied exponential recession employed a co-efficient of head recession of 1.71×10^{-3} day^{-1} and drainage base level of 1030.8 mamsl. Where recharge was quantified for comparative purposes, a range of values for specific yield from 2% to 6%, consistent with analyses for saprolite derived from Precambrian basements rocks in East Africa (Cuthbert and Tindimugaya 2010, Taylor, Tindimugaya et al. 2010, Taylor, Todd et al. 2013), was applied.
wider data availability:	This record is part of a national network of ~30 monitoring (17 by telemetry) operated by the DWRM and was selected for analysis on account of its continuity, duration and interpretability.

GoogleEarth:



Location:	**Zimbabwe, Khami (4-UMGU-088)**
basin:	Gwayi River, Zambezi Basin
monitoring body:	Zimbabwe National Water Authority (ZINWA)
aridity index, designation:	0.34, semi-arid
mean annual precipitation (mm):	550
hydrological year:	August to July
mean annual PET (mm):	1636 (Bulawayo Goetz Metrological Station @ 20.90S, 28.37E)
landcover:	Savannah grassland and savannah bush forest
aquifer environment:	Part of the Nyamandhlovu aquifer area comprising recent alluvium and Pleistocene Kalahari sands covering Tertiary Karoo Basalt, Triassic Forest Sandstone and deeper Pre-Cambrian Basement Complex; the water table at the monitoring location is within the Karoo Basalt.
drainage boundary:	The area is crossed by ephemeral streams which drain NW towards the Zambezi River approximately 300 km away. Groundwater flows in northern and north-western directions but the nearest points of natural groundwater discharge are unknown; the River Zambezi is the nearest known perennial watercourse to the monitoring location.
pumping influence:	The aquifer is widely abstracted for domestic use and irrigation but precise pumping rates are not available and thus the pumping influence is unknown; the monitoring well is located at least several km away from the nearest known major abstraction.
latitude, longitude (digital):	19.885S, 28.216E
elevation (mamsl):	1161.39
piezometer depth (mbgl):	60

screen interval (mbgl): 5 to 60

analysed record interval: 25 July 1989 to 9 April 2015

frequency of observations: monthly

mode of monitoring: manual (dipper) and datalogger (2001 – 2002)

distance to rain gauge: ~6 km (Nyamandhlovu village @ 19.860S, 28.268E)

source(s) of rainfall data: Bulawayo Goetz Metrological Station

conceptual model: Focussed recharge occurs via streambed transmission losses when ephemeral flows occur in the Khami river (Sibanda and Chikomwe 2001) as well as via 'windows' in the Karoo basalt where it is sufficiently fractured and weathered.

notes on the analysis: Steep rises in groundwater levels indicative of major recharge events are followed by decaying recessions which track back towards consistent long term steady rates of groundwater level decline. This behaviour is indicative of focussed recharge consistent with the proximity of the monitoring well to the ephemeral Khami river which flows after heavy rain. Water Table Fluctuation analysis was carried out on a seasonal basis using linear long term recessions of 2.0 to 2.5 $mm \cdot d^{-1}$ based on the observed dry period hydrograph. A specific yield in the range of 2% to 8% was applied and derived from pumping testsdata (Sibanda and Chikomwe 2001, Sibanda, Nonner et al. 2009).

wider data availability: This record is part of a network of approximately 90 monitoring wells in the Nyamandhlovu area. This record has been chosen for analysis based on its duration, continuity and interpretability.

GoogleEarth:

References

Bazie, P., B. Dieng and P. Ackerer (1995). "Water balance in unsaturated soil under a Sudano-Sahelian climate: estimation of the groundwater recharge." Rev. Sci Eau (RSE) **8**: 237-260.

Boucher, M., G. Favreau, Y. Nazoumou, B. Cappelaere, S. Massuel and A. Legchenko (2012). "Constraining groundwater modeling with magnetic resonance soundings." Groundwater **50**(5): 775-784.

Boucher, M., G. Favreau, J.-M. Vouillamoz, Y. Nazoumou and A. Legchenko (2009). "Estimating specific yield and transmissivity with magnetic resonance sounding in an unconfined sandstone aquifer (Niger)." Hydrogeology Journal **17**(7): 1805.

Cobbing, J. (2018). "An updated water balance for the Grootfontein aquifer near Mahikeng." Water SA **44**(1): 54-64.

Cuthbert, M. and C. Tindimugaya (2010). "The importance of preferential flow in controlling groundwater recharge in tropical Africa and implications for modelling the impact of climate change on groundwater resources." Journal of Water and Climate Change **1**(4): 234-245.

Dahan, O., B. Tatarsky, Y. Enzel, C. Kulls, M. Seely and G. Benito (2008). "Dynamics of flood water infiltration and ground water recharge in hyperarid desert." Groundwater **46**(3): 450-461.

Dapaah-Siakwan, S. and P. Gyau-Boakye (2000). "Hydrogeologic framework and borehole yields in Ghana." Hydrogeology Journal **8**(4): 405-416.

Ebrahim, G. Y., K. G. Villholth and M. Boulos (2019). "Supporting sustainable agricultural groundwater use in a hard rock catchment, Hout, Limpopo Province, South Africa: application of an integrated hydrogeological model." Hydrogeology Journal.

Galle, S., M. Grippa, C. Peugeot, I. B. Moussa, B. Cappelaere, J. Demarty, E. Mougin, G. Panthou, P. Adjomayi and E. Agbossou (2018). "AMMA-CATCH, a Critical Zone Observatory in West Africa Monitoring a Region in Transition." Vadose Zone Journal **17**(1).

Hartmann, A., T. Gleeson, Y. Wada and T. Wagener (2017). "Enhanced groundwater recharge rates and altered recharge sensitivity to climate variability through subsurface heterogeneity." Proceedings of the National Academy of Sciences **114**(11): 2842-2847.

Kotchoni, D. V., J.-M. Vouillamoz, F. M. Lawson, P. Adjomayi, M. Boukari and R. G. Taylor (2019). "Relationships between rainfall and groundwater recharge in seasonally humid Benin: a comparative analysis of long-term hydrographs in sedimentary and crystalline aquifers." Hydrogeology Journal **27**: 447.

Leduc, C., G. Favreau and P. Schroeter (2001). "Long-term rise in a Sahelian water-table: The Continental Terminal in south-west Niger." Journal of hydrology **243**(1-2): 43-54.

Massuel, S., B. Cappelaere, G. Favreau, C. Leduc, T. Lebel and T. Vischel (2011). "Integrated surface water–groundwater modelling in the context of increasing water reserves of a regional Sahelian aquifer." Hydrological Sciences Journal **56**(7): 1242-1264.

Morin, E., T. Grodek, O. Dahan, G. Benito, C. Kulls, Y. Jacoby, G. Van Langenhove, M. Seely and Y. Enzel (2009). "Flood routing and alluvial aquifer recharge along the ephemeral arid Kuiseb River, Namibia." Journal of Hydrology **368**(1-4): 262-275.

Mouhouyouddine, A. H., S. Yameogo, P. Genthon, J. E. Paturel and M. Guilliod (2017). "Groundwater Level Changes since 1978 in an African City on Basement Rocks: The Case of the CIEH Borehole in Ouagadougou (Burkina Faso)." Journal of Water Resource and Protection **9**(10): 1097.

Owor, M., R. Taylor, C. Tindimugaya and D. Mwesigwa (2009). "Rainfall intensity and groundwater recharge: empirical evidence from the Upper Nile Basin." Environmental Research Letters **4**(3): 035009.

Seddon, D. (2019). The Climate Controls and Process of Groundwater Recharge in a Semi-Arid Tropical Environment: Evidence from the Makutapora Basin, Tanzania. PhD, University College London.

Sibanda, T. and S. Chikomwe (2001). Analysis of Groundwater Level Fluctuations in the Nyamandhlovu Aquifer, Zimbabwe National Water Authority Groundwater Unit

Sibanda, T., J. C. Nonner and S. Uhlenbrook (2009). "Comparison of groundwater recharge estimation methods for the semi-arid Nyamandhlovu area, Zimbabwe." Hydrogeology Journal **17**(6): 1427-1441.

Taylor, R. G. and K. Howard (1999). "The influence of tectonic setting on the hydrological characteristics of deeply weathered terrains: evidence from Uganda." Journal of Hydrology **218**(1-2): 44-71.

Taylor, R. G. and K. W. Howard (1996). "Groundwater recharge in the Victoria Nile basin of east Africa: support for the soil moisture balance approach using stable isotope tracers and flow modelling." Journal of Hydrology **180**(1-4): 31-53.

Taylor, R. G., C. Tindimugaya, J. Barker, D. Macdonald and R. Kulabako (2010). "Convergent radial tracing of viral and solute transport in gneiss saprolite." Groundwater **48**(2): 284-294.

Taylor, R. G., M. C. Todd, L. Kongola, L. Maurice, E. Nahozya, H. Sanga and A. M. MacDonald (2013). "Evidence of the dependence of groundwater resources on extreme rainfall in East Africa." Nature Climate Change **3**(4): 374.

Thiéry, D., C. Diluca and B. Diagana (1993). Modelling the aquifer recovery after a long duration drought in Burkina Faso. Extreme Hydrological Events: Precipitation, Floods and Droughts-Yokohama (Japon) 213, pp 43-50., IAHS Publication. hal 01062478.

Zomer, R. J., Trabucco, A., Bossio, D. A. & Verchot, L. V. (2008). “Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation.” Agriculture, Ecosystems & Environment **126**: 67-80.