The ZAMBEZI
Guidelines in modelling hydrology and hydropower based on case studies

Addendum A: A map database on the Aquaknow platform to support Hydrological modelling

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Introduction

The data made available in this database was intended to support modelling. From this database we can develop more products as the need arises. This database contains enough information to set up models like SPATSIM, SWAT, JAMS and many others. It can also be used in refining current models used in the Zambezi basin on a local sub-catchment scale.

The database include the following folders

1. Climate
    a. Rainfall
    b. Temperature
    c. Evapotranspiration
2. Covers (shapefiles)
    a. Catchment boundary
    b. Rivers
    c. Water flow measuring points
    d. Elevation model (SRTM90)
3. Landcover maps of the Zambezi
4. Observed flows
5. Reservoirs
6. Soils information
    a. Clay
    b. Course fragment content
    c. Rootzone depth
    d. Rootzone soil texture
    e. Sand content
    f. Soil Morphons
    g. Soter soil map
    h. Zambia soils.
7. WEAP model data

Table 1 provides a short description of the database content and the origin of the information.

Table 1: Database description

Category	Item	Description	Origin	Units	Format
Climate	Rainf_daily_WFDEI_CRU.zambezi.nc	Daily Rainfall: netCDF gridded file from 1979 to about 2018	Made available by http://www.acdi.uct.ac.za/acdi/centres/climate-system-analysis-group-csag	mm	Grid file *.nc
	TairMAX_WFDEI_UTC+2.zambezi.nc TairMIN_WFDEI_UTC+2.zambezi.nc	Maximum and minimum air temperature, as daily netCDF gridded file from 1979 to about 2018	Made available by http://www.acdi.uct.ac.za/acdi/centres/climate-system-analysis-group-csag	Celsius	Grid file *.nc
	Rainfall.zip	Monthly average rainfall: from1901 to 2015 as applied in SPATSIM as in Table 5	CRU data received from Rhodes University https://www.ru.ac.za/iwr/research/software/	mm	Text Files
	Evapotranspiration	Averaged monthly evapotranspiration See Table 8 (no data added to the database)	Averaged CRU as used by SPATSIM Rhodes University: https://www.ru.ac.za/iwr/research/software/	mm	Table 8
Covers	Catchment boundary	The file contains the catchment boundary of the whole Zambezi catchment	Derived from SRTM90	Geometry	Shapefile (polygons)
	Rivers	Rivers in the Zambezi catchment	Rhodes University: https://www.ru.ac.za/iwr/research/software/	Geometry	Shapefile (polylines)
	Water flow measuring points	All known water flow measurement points. See **Figure** 3 and **Table** 6	ZAMCOM and Rhodes University	Location	Shapefile (points)
	Elevation model (SRTM90)	Elevation model in raster format	USGS. The data can be downloaded directly but also from within QGIS USGS: https://earthexplorer.usgs.gov/	Meter above sea level	Raster (GeoTiff)
Landcover maps of the Zambezi	Land cover map	The land cover was mapped in 10 classes, the legend being in **Table** 2 A 20m resolution map is provided.	CCI Land Cover – S2 Prototype Land Cover 20m Map Of Africa 2016 http://2016africalandcover20m.esrin.esa.int/download.php	2500m (see link for the 20m product)	Geo Tiff

Category	Item	Description	Origin	Units	Format
				See **Table** 2	
Observed flows	Time series flow data per model node. Accumulated flow per indicated sub catchment	Measured time series flow data at the different SPATSIM flow nodes. See **Tables** 5, 6 and 7, and **Figure** 3. For example. In Table 5	Information was gathered from published information like thesis, personal contacts and river and water authorities in Countries. ZAMCOM is also acknowledged	Flow in m^3/month	Time series
	Basin_observed_monthly_flows.zip	Raw Flow data. Used to populate the SPATSIM model node data. Some File names are referenced in table 6 and 7. The rest is unknown at this stage.	SPATSIM data base Rhodes University: https://www.ru.ac.za/iwr/research/software/	Flow in m^3/month	Time series
Reservoirs	Gauge station reflecting water levels	Recorded water flow, levels and storage from different reservoir gauging stations	ZAMCOM See **Table** 5.	m per month	Time series
Soils information	Clay content of the topsoil	The map is a raster map that indicates the distribution of clay in the topsoil for the whole Zambezi Catchment. Done at a 250m resolution	https://data.isric.org/geonetwork/srv/eng/catalog.search#/home	Weight% Range 0 to 63%	Raster
	Course fragment content	The map is a raster map that indicates the distribution of course fragments in the topsoil for the whole Zambezi Catchment. Done at a 250m resolution	https://data.isric.org/geonetwork/srv/eng/catalog.search#/home. Volumetric coarse fragments content (v%) of the soil whole earth, aggregated over the Effective Root Zone Depth for Maize, mapped at 1km resolution	Percentage coarser than 2mm at a Volume Range 0 to 45%	Raster
	Root zone depth	The map is a raster map that indicates the soil depth distribution for the whole Zambezi Catchment. Done at a 250m resolution	https://data.isric.org/geonetwork/srv/eng/catalog.search#/home	desimeter Range 2 to 18 dm	Raster
	Root zone soil texture	The map is a raster map that indicates the total root zone soil texture for the whole Zambezi Catchment. Textural class (USDA) of the soil fine earth	https://data.isric.org/geonetwork/srv/eng/catalog.search#/home Soil Properties at 250 m Resolution. See Table 4.	12 Texture classes Range 1 to 12. Table 4.	Raster

Category	Item	Description	Origin	Units	Format
		fraction, aggregated over the Effective Root Zone Depth for Maize, mapped at 1km resolution			
	Sand content	The map is a raster map that indicates the distribution of sand in the topsoil for the whole Zambezi Catchment. Done at a 250m resolution	https://data.isric.org/geonetwork/srv/eng/catalog.search#/home	Weight % Range from 22 to 97%	Raster
	Soil Morphones	The map indicates the distribution of land forms for the whole Zambezi Catchment. See legend below in **Table** 3	wpdc@sun.ac.za information was derived from the SRTM90 Elevation data	Pixels	Raster Map
	SOTER soil map	This map excludes Zambia. The SOTER data was based on the South African land-type data base and may contribute to defining some sub-basins in the Zambezi catchment for modelling	https://www.isric.org/projects/soil-and-terrain-soter-database-programme	Blocks	Shape file
	Zambia soils	Soil classification map of Zambia. See **Table** 9 for description	Online soils archive https://www.wossac.com/ https://www.isric.org/projects/eudasm-european-digital-archive-soil-maps	Polygons	Jpg
WEAP model data	Model data for use in WEAP	Data derived from SPATSIM for use in the WEAP model. This can be used as a test set to refine WEAP modelling of the reservoirs	Prof Denis Hughes. https://www.ru.ac.za/iwr/research/software/	Various	Text files

Table 2. Legend for the Landcover map of the Zambezi

VALUE	LABEL
0	No data
1	Trees cover areas
2	Shrubs cover areas
3	Grassland
4	Cropland
5	Vegetation aquatic or regularly flooded
6	Lichen Mosses / Sparse vegetation
7	Bare areas
8	Built up areas
9	Snow and/or Ice
10	Open water

Table 3: Morphon map legend for the Zambezi Catchment

Value	**Label**
1	Flat
2	Summit
3	Ridge
4	Shoulder
5	Spur
6	Slope
7	Hollow
8	Footslope
9	Valley
10	Depression
11	Error

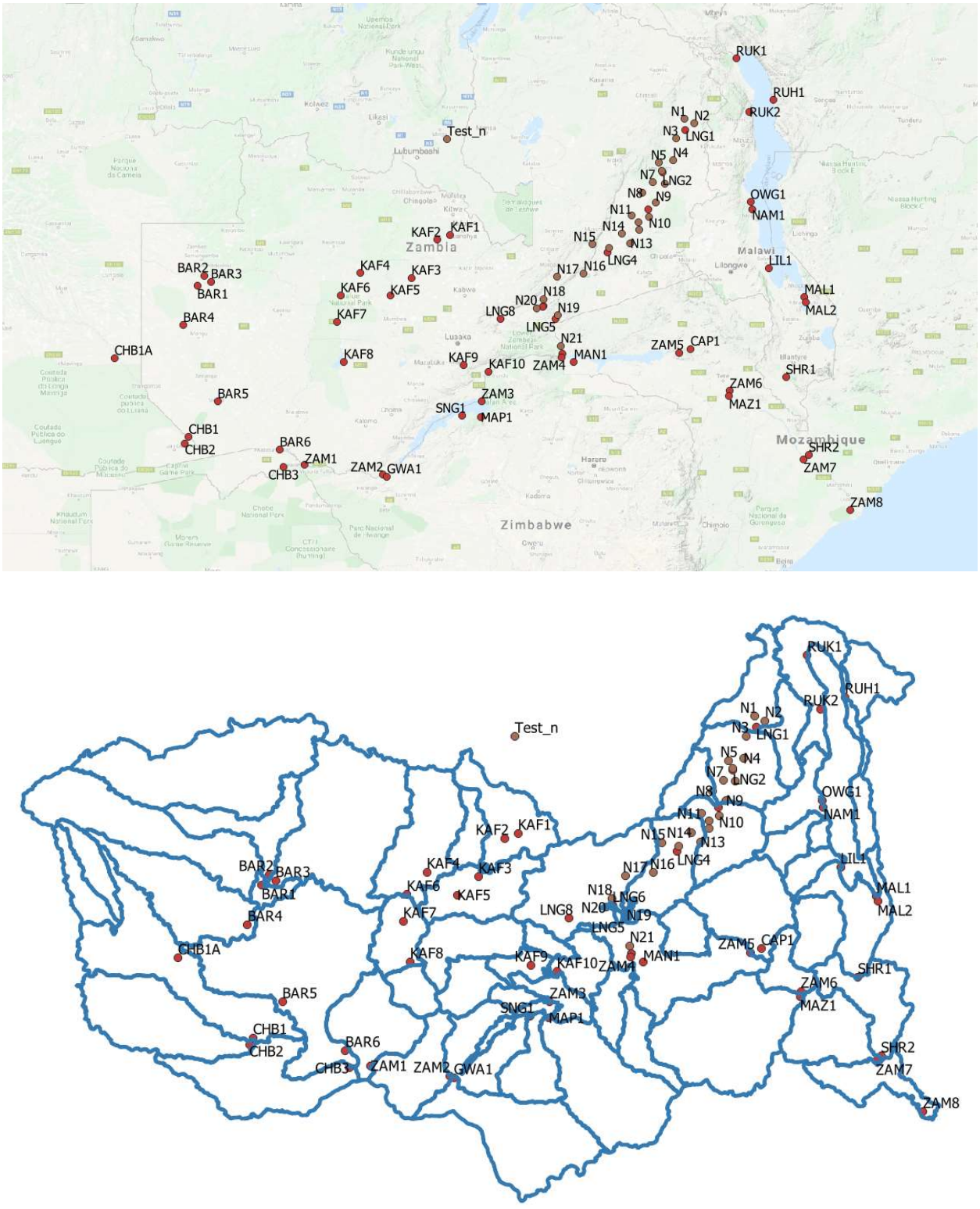

Figure 1. All flow nodes in the Zambezi Catchment accessible in SPATSIM. For all these nodes, CRU climate data was used. (Important to note that these node names, same as the station IDs in table 5, was used as file names for rainfall data and flow data in the SPATSIM setup.)

Table 4 Rootzone Soil texture indication for the Zambezi Catchment

Map number	Name of soil separate	Diameter limits (mm) (USDA classification)	Diameter limits (mm) (WRB classification)
1	Clay	less than 0.002	less than 0.002
3	Silt	0.002 – 0.05	0.002 – 0.063
4	Very fine sand	0.05 – 0.10	0.063 – 0.125
6	Fine sand	0.10 – 0.25	0.125 – 0.20
7	Medium sand	0.25 – 0.50	0.20 – 0.63
9	Coarse sand	0.50 – 1.00	0.63 – 1.25
11	Very coarse sand	1.00 – 2.00	1.25 – 2.00
12	Rocky	2.00 >	2.00 >

Table 5 Model node information. Empty year information indicate no flow data for the specific station. Please note that the station IDs were used for climate data from the CRU records.

STATION_ID/ Sparsim model node	SPATSIM ID	Description	LAT	LONG	Year start	Year end
LNG1	1		-11.136	32.858		
LNG2	2		-11.979	32.395		
LNG3	3		-12.713	32.109		
LNG4	4		-13.568	31.301		
LNG5	5		-14.894	30.264		
LNG6	6		-14.644	30.024		
LNG7	7		-14.651	30.013		
LNG8	8		-14.898	29.160		
LNG9	9		-15.583	30.399	1930	1990
KAF1	10		-13.222	28.162	1952	1985
KAF2	11		-13.324	27.895	1962	1996
KAF3	12		-14.079	27.386	1969	2000
KAF4	13		-13.986	26.363	1959	2004
KAF5	14		-14.435	26.965	1952	2004
KAF6	15		-14.427	25.971		
KAF7	16		-14.957	25.898		
KAF8	17	DAM: Maridiba	-15.753	26.036		
KAF9	18		-15.818	28.421	1971	2000
KAF10	19	DAM: Ruaha confluence	-15.947	28.930		
BAR1	20		-14.240	23.108		
BAR2	21		-14.034	23.253		
BAR3	22		-14.154	23.381		
BAR4	23		-15.022	22.830	1958	1981
BAR5	24		-16.541	23.515		
BAR6	25		-17.501	24.758	1947	2014
CHB1	26		-17.248	22.938		
CHB2	27		-17.382	22.866	1980	2002
CHB3	28		-17.843	24.831		
ZAM1	29		-17.797	25.256	1924	
ZAM2	30		-18.002	26.819	1926	
GWA1	31		-18.037	26.898		
MAP1	32		-16.855	28.771		
SNG1	33		-16.827	28.397		
ZAM3	34	DAM: Kariba	-16.543	28.786	1963	
ZAM4	35		-15.661	30.377		
MAN1	36		-15.761	30.631		
ZAM5	37	DAM: Cahorra Bassa	-15.569	32.737	1976	
CAP1	38		-15.493	32.959		
ZAM6	39		-16.335	33.740	1951	2008
MAZ1	40		-16.433	33.724	1968	
ZAM7	41		-17.700	35.218		
RUK1	42		-9.712	33.867		
RUK2	43		-10.775	34.134		
RUH1	44		-10.539	34.606		
OWG1	45		-12.571	34.154		
NAM1	46		-12.710	34.185	1992	2001
LIL1	47		-13.886	34.519	1974	
MAL1	48		-14.466	35.232	1962	
SHR1	49		-16.057	34.863	1962	
SHR2	50		-17.607	35.320		
ZAM8	51		-18.705	36.146		
CHB1A	52		-15.678	21.458		
MAL2	53		-14.564	35.252		

Table 6 Flow gauge info for the Kafue

ID NAME	NUMBER	FLOW ID	LATY	LONGX	NAME	DATE BEGIN	DATE END	FLOW_
K9	4669	13	-14.9333	25.9167	Kafue at Hook Bridge	1973	2001	1
K7	4450	12	-14.5667	26.4500	Kafue at Lubungu	1951	2001	2
L2	4560	11	-13.9833	26.3500	Lunga at Chifumpa	1953	2001	3
L1	4550	10	-13.7000	26.3333	Lunga at Kelongwa	1963	2001	4
K5	4280	8	-13.6500	27.6167	Kafue at Machiya	1962	1999	5
K4	4260	7	-13.4000	27.8164	Kafue at Ndubeni	1962	1999	6
KA1	4205	6	-13.3333	28.4500	Kafulafuta at Ibenga	1969	2001	7
K3	4150	4	-12.8333	28.2000	Kafue at Wusakile	1958	2001	8
M1	4120	3	-12.7000	28.1500	Mwambashi at Mwambashi	1959	2001	9
K2	4090	2	-12.6333	28.1667	Kafue at Kafironda	1958	2001	10
K1	4050	1	-12.4167	27.7333	Kafue at Raglan farm	1959	2001	11
K4	4200	5	-13.2500	28.1333	Kafue at Mpatamato	1950	1987	12
K5	4350	9	-14.1000	27.4167	Kafue at Chilenga	1962	2001	13
L01	1	14	-12.9167	26.5333	Chipembele (UNGAUGED)	0	0	14
LUF1	2	15	-14.4000	26.0333	Ntemwa Camp (UNGAUGED)	0	0	15
LUS1	4340	16	-13.8333	27.3667	Luswishi at Kangondi	1971	1996	16
K9	4307	22	-14.5833	27.0000	Kafue at Mswebi	1951	1980	17
K10	460995	26	-15.7500	26.0167	Itezhi-tezhi reservoir	1977	2001	18
K11	470800	30	-15.8500	28.4667	Kafue gorge reservoir	1971	2001	19

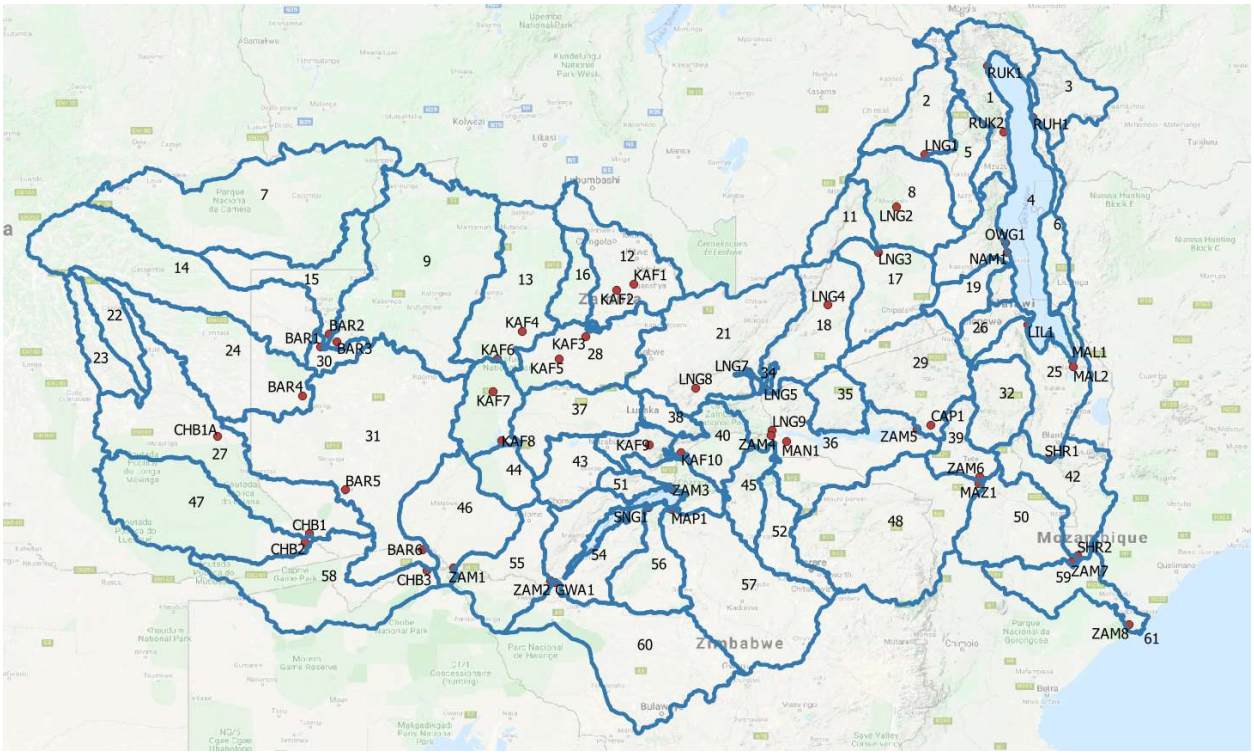

Figure 2 SPATSIM sub-basin Number and Model-Node ID (As also used in SPATIM).

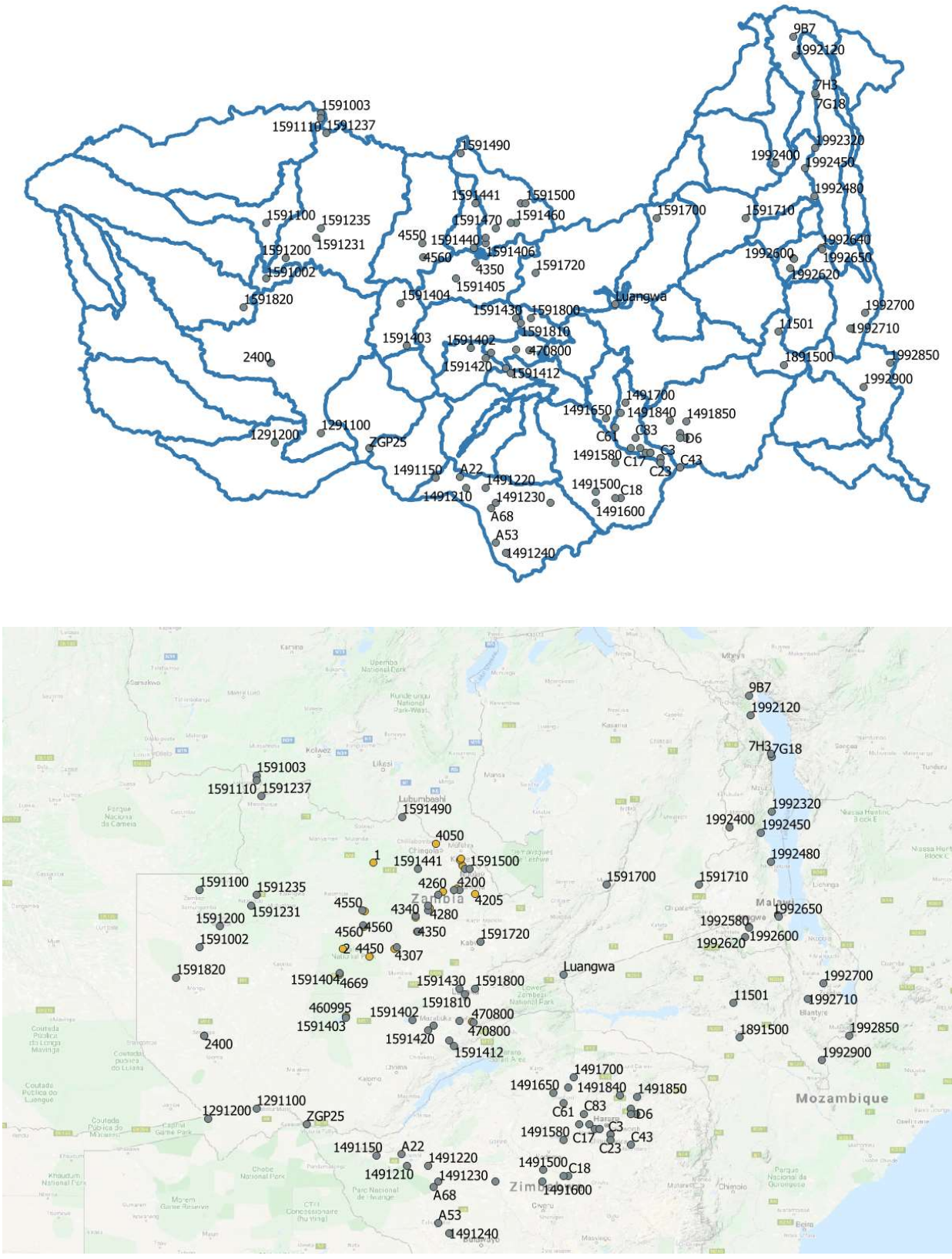

Figure 3. Zambezi flow gauge positions and reference (not all data is available)

Table 7: Zambezi flow gauge ID and SPATSIM ID number, with locations coordinates.

STATION_CODE	ID	LATITUDE	LONGITUDE
1291100	1	-17.5000	24.3000
1891500	2	-16.1000	33.6000
1491580	3	-18.1000	30.2000
1491600	4	-18.9000	29.8000
1491650	5	-17.2000	30.0000
1491670	6	-17.1000	30.3000
1491820	7	-17.5000	31.5000
1491840	8	-17.3000	31.3000
1491850	9	-17.3000	31.6000
1491760	10	-18.0000	31.1000
1491210	11	-18.6000	27.2000
1491220	12	-18.6000	27.6000
1491240	13	-19.9000	28.0000
1491250	14	-18.9000	28.9000
1491230	15	-18.9000	27.8000
1491150	16	-18.4000	26.6000
1491700	17	-16.9000	30.4000
1491500	18	-18.7000	29.8000
1992120	19	-10.0000	33.8000
1992320	20	-11.8000	34.2000
1992400	21	-12.1000	33.4000
1992450	22	-12.2000	34.0000
1992480	23	-12.8000	34.2000
1992580	24	-14.0000	33.8000
1992600	25	-14.0000	33.8000
1992620	26	-14.2000	33.7000
1992640	27	-13.8000	34.3000
1992650	28	-13.8000	34.4000
1992700	29	-15.1000	35.2000
1992710	30	-15.4000	34.9000
1992850	31	-16.1000	35.7000
1992900	32	-16.6000	35.1000
1591001	33	-16.1000	23.3000
1591002	34	-14.4000	23.2000
1591003	35	-11.1000	24.3000
1591100	36	-13.3000	23.2000
1591110	37	-11.2000	24.3000
1591200	38	-14.0000	23.6000
1591231	39	-13.6000	24.2000

1591235	40	-13.4000	24.3000
1591237	41	-11.5000	24.4000
1591401	42	-15.8000	28.2000
1591402	43	-15.8000	27.3000
1591403	44	-15.8000	26.0000
1591404	45	-14.9000	25.9000
1591405	46	-14.4000	27.0000
1591406	47	-13.7000	27.6000
1591410	48	-16.2000	28.0000
1591411	49	-15.9000	27.7000
1591412	50	-16.3000	28.1000
1591420	51	-16.0000	27.6000
1591430	52	-15.2000	28.2000
1591440	53	-13.8000	27.4000
1591441	54	-12.9000	27.4000
1591460	55	-13.3000	28.2000
1591470	56	-13.4000	27.8000
1591471	57	-13.3000	28.1000
1591474	58	-13.6000	27.6000
1591480	59	-12.9000	28.3000
1591490	60	-11.9000	27.1000
1591500	61	-12.9000	28.4000
1591700	62	-13.2000	31.0000
1591710	63	-13.2000	32.8000
1591720	64	-14.3000	28.6000
1591800	65	-15.2000	28.5000
1591810	66	-15.3000	28.3000
1591820	67	-15.0000	22.7000
1291200	68	-17.7000	23.3000
A22	69	-18.4000	27.0000
A53	70	-19.7000	27.8000
A68	71	-19.0000	27.7000
C3	72	-18.0000	31.1000
C17	73	-17.9000	30.8000
C18	74	-18.8000	30.3000
C22	75	-17.9000	30.9000
C23	76	-18.1000	31.1000
C24	77	-17.9000	30.9000
C30	78	-18.8000	30.2000
C43	79	-18.2000	31.5000
C61	80	-17.4000	30.2000
C79	81	-17.8000	30.7000
C83	82	-17.6000	30.6000

C89	83	-17.8000	30.5000
D6	84	-17.6000	31.6000
D7	85	-17.6000	31.5000
4560	86	-13.9833	26.3500
4550	87	-13.7000	26.3333
470800	88	-15.8500	28.4667
4350	89	-14.1000	27.4000
2400	90	-16.1000	23.3000
ZGP25	91	-17.8000	25.9500
7G18	92	0.0000	0.0000
7H3	93	0.0000	0.0000
9B7	94	0.0000	0.0000
11501	95	0.0000	0.0000
Luangwa	96	0.0000	0.0000

Table 8 Evaporation distribution data per Model Node used in SPATSIM

Model Node	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
LNG1	12.35	10	7.55	6.85	6.35	7.3	7.15	7.2	6.9	7.75	9.35	11.25
LNG2	12.675	10.175	7.55	6.9	6.4	7.375	7.2	7.2	6.625	7.475	9.15	11.275
LNG3	12.6	10.2	7.5	6.9	6.5	7.5	7.2	7.25	6.6	7.35	9.1	11.3
LNG4	12.6	10.2	7.6	7.1	6.55	7.5	7.2	7.1	6.4	7.2	9.15	11.4
LNG5	12.6	10	7.3	7.1	6.6	7.5	7.2	7.1	6.4	7.3	9.3	11.6
LNG6	12.4	9.9	7.8	7.6	6.8	7.7	7.4	6.9	6.2	7	9	11.3
LNG7	12.4	9.9	7.8	7.6	6.8	7.7	7.4	6.9	6.2	7	9	11.3
LNG8	12.4	9.9	7.8	7.6	6.8	7.7	7.4	6.9	6.2	7	9	11.3
LNG9	12.5	10.4	8.1	7.8	6.9	7.9	7.3	6.7	5.8	6.6	8.8	11.2
KAF1	12.4	8.9	6.5	6.4	6	7.1	7	7.7	7.3	8.2	10.4	12.1
KAF2	12.1	9.1	7.1	6.4	5.7	7	7.1	7.6	7.2	8.3	10.4	12
KAF3	12.4	9	6.6	6.4	5.3	6.8	7.4	7.5	7.3	8.2	10.5	12.6
KAF4	11.65	8.51	6.5	6.1	5.7	6.85	7.55	7.85	7.4	8.46	10.75	12.68
KAF5	13.3	8.8	6.3	6.7	5.3	6.5	7.3	7.2	7.3	8	10.3	13
KAF6	11.7	9	6.8	6.6	5.3	7.2	7.5	7.8	7.2	8.1	10.2	12.6
KAF7	11.6	9.3	6.7	6.9	5.6	7.2	7.5	8.3	7.2	7.8	10	11.9
KAF8	12.4	9.8	7.7	6.9	6.2	6.4	7.7	7.5	6.6	7.3	9.6	11.9
KAF9	12.2	9.7	7.7	6.1	6.3	7.5	7.7	7.4	6.6	7.4	9.6	11.8
KAF10	12.2	9.7	7.7	6.1	6.3	7.5	7.7	7.4	6.6	7.4	9.6	11.8
BAR1	11.7	9	6.8	6.6	5.3	7.2	7.5	7.8	7.2	8.1	10.2	12.6
BAR2	11.7	9	6.8	6.6	5.3	7.2	7.5	7.8	7.2	8.1	10.2	12.6
BAR3	11.7	9	6.8	6.6	5.3	7.2	7.5	7.8	7.2	8.1	10.2	12.6
BAR4	11.7	9	6.8	6.6	5.3	7.2	7.5	7.8	7.2	8.1	10.2	12.6
BAR5	11.7	9	6.8	6.6	5.3	7.2	7.5	7.8	7.2	8.1	10.2	12.6
BAR6	11.7	9	6.8	6.6	5.3	7.2	7.5	7.8	7.2	8.1	10.2	12.6
CHB1	11.7	9	6.8	6.6	5.3	7.2	7.5	7.8	7.2	8.1	10.2	12.6
CHB2	11.7	9	6.8	6.6	5.3	7.2	7.5	7.8	7.2	8.1	10.2	12.6
CHB3	11.7	9	6.8	6.6	5.3	7.2	7.5	7.8	7.2	8.1	10.2	12.6
GWA1	11.7	9	6.8	6.6	5.3	7.2	7.5	7.8	7.2	8.1	10.2	12.6

Table 9 Legend for the Zambia soils map provided.