

Using simple mobile technologies to scale up digital collection & processing  
of climate observation for adaptation actions in Malawi

UNEP CTCN Project: 2022000048

# DIAGNOSIS OF MALAWI'S HYDROLOGICAL & METEOROLOGICAL INFORMATION SYSTEMS

April 2024

FINAL



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## 1. Scope

In the UNEP CTCN technical assistance project, “Using simple mobile technologies to scale up digital collection & processing of climate observation for adaptation actions in Malawi”, Output 3 plays a key role. It is generating comprehensive and foundational feasibility knowledge and guidance for both the project as a whole, but also broadly in Malawi and for countries facing similar challenges with closing the observation data gap.

Specifically, Output 3 is “Diagnosis & pre-feasibility of using simple mobile technologies as a solution to comprehensively collect and digitise weather & climate observations for application in impact modelling and developing climate futures for purposes of adaptation and disaster risk management”.

The first activity, Activity 3.1, entails the diagnosis of the current systems and equipment used by Malawi’s Department of Climate Change and Meteorological Services (DCCMS) and Department of Water Resources (DWR). The activity emanates in four deliverables:

- **Deliverable 3.1.a Diagnosis of hydromet information & systems**
  - Annex A. List - equipment recommendations, barriers & opportunities (3.1.b)
  - Annex B. List - previous similar/complementing initiatives in Malawi (3.1.c)
- Deliverable 3.1.d IT characteristics of DCCMS & DWR data management systems

This report is the first deliverable under Activity 3.1, the rapid diagnosis of hydromet information & systems. This report is the more descriptive and encompassing deliverables within the above package, in order to capture an analysis of the system of hydrometeorology in Malawi. The diagnosis is then supported by the more concise and segmented information in the remaining deliverables.

The diagnosis was performed using information and insights shared by departmental staff in online interviews and in-person meetings, as well as summary information shared over email and WhatsApp.

This diagnosis and associated deliverables constitute the preliminary findings and data on DCCMS and DWR information and systems. During forthcoming travel and engagement onsite by Water in Sight and T-Notch Consulting’s expert, the findings can be validated and expanded. These will be presented in the remaining activities in Output 3, namely identification of barriers, challenges, opportunities, and strengths of systems in place (Deliverable 3.4).

## 2. Department of Climate Change & Meteorological Services (DCCMS)

### Overview

DCCMS holds the government mandate for collecting and managing observation data on weather and climate conditions in Malawi. The agency employs an array of observation and data management technologies to gather, organise, store, data crucial for forecasting, climate research, and informing policy and decision-making across sectors such as agriculture and disaster preparedness.

## Manual observations of weather & climate - synoptic stations

### Collection & equipment

DCCMS operates 21 active manual synoptic stations across Malawi, including at key strategic locations such as airports. At synoptic stations, meteorologists hired by DCCMS measure a range of parameters on weather conditions. These include rainfall, temperature, evaporation, visibility, wind speed and direction, lightning detection, radiation etc. Observations are taken hourly, at standardised intervals and twice daily, 8h00 and 14h00, collated observations are submitted to DCCMS HQ.

Synoptic stations play a central role for two purposes. First, to provide DCCMS's Forecasting Section with near-real time observations used for forecasting. Second, for regional and global weather data exchange (under the auspices of the WMO) using the WMO Global Telecommunication System (box 1). A daily synoptic report is meant to be collated and ready at 08h00 each day. Meteorologists also produce a monthly summary report.

Equipment used for manual measurements are conventional for meteorology. Some sensors at synoptic stations and other locations are fully or partially automated with data transmission capabilities (figure 1). Equipment needs to be replaced, maintained and calibrated. Meteorologists record measurement data in physical synoptic logbooks using for example, synoptic code (figure 2). The WMO is phasing out the use of mercury-based equipment. New equipment can decode measurements and transmit data via satellite, GPRS (2G) or similar, and store in local data logger. To go fully automatic with such equipment, DCCMS wants to install modems. Pressure and temperature observations are monitored with this partial/full automation and rainfall observations recorded manually still.

### Transmission

Transmission of observations from synoptic stations to DCCMS in Blantyre (HQ) consists of four main channels: the daily and monthly synoptic reports and sending logbooks to DCCMS headquarters in Blantyre by phone, WhatsApp, post, and email.



Figure 1. Monitoring equipment for collection of maximum and minimum temperature (left) and pressure, wind speed and direction (right).

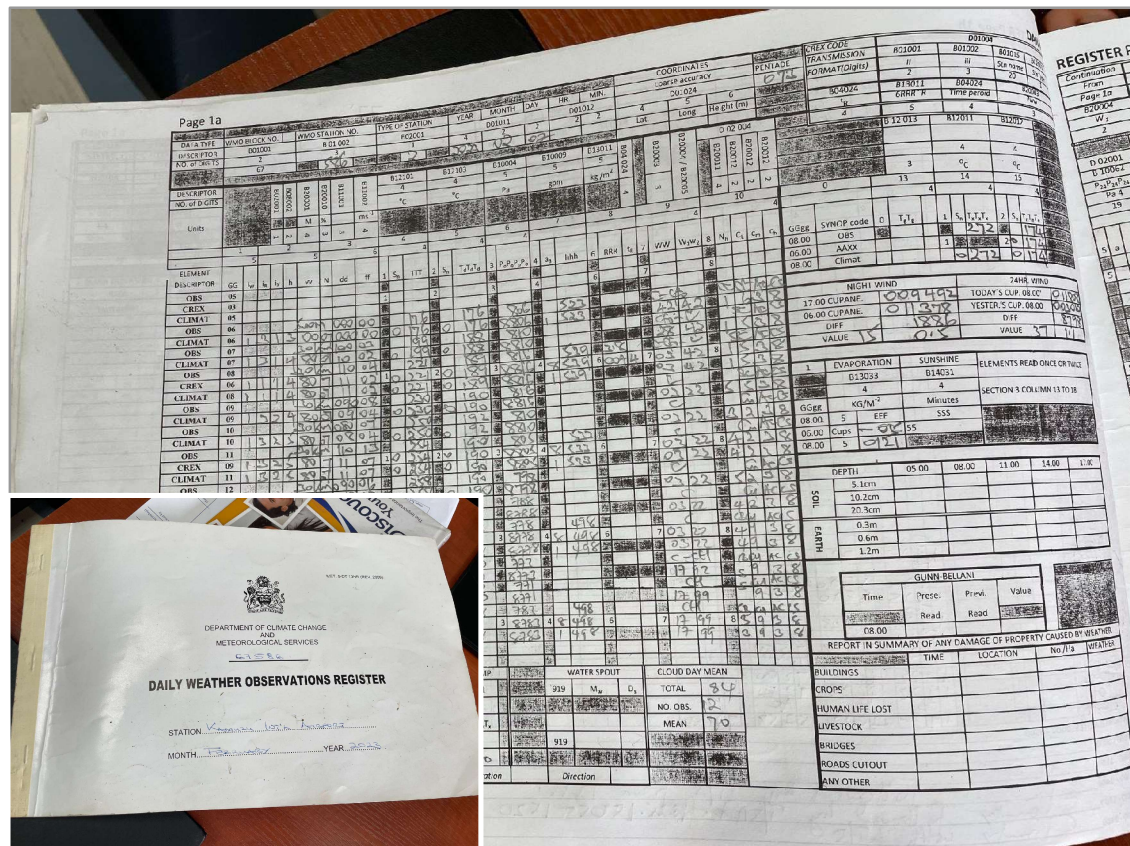


Figure 2. Example of daily weather observation register/synoptic logbook used by DCCMS

The daily synoptic reports for the WMO GTS should be available daily to DCCMS’s communication section at 08h00. After a quality control, the data is bundled and transmitted via an online system (NETSYS) to the WMO’s regional hub at the South African Weather Services in Pretoria, who compile into the GTS.

Daily reports used to be sent via single-band radio from district level to centralised regional hubs: Chilkea (for the southern region), Lilongwe (for the central region), and Mzuzu (for the northern region). And then onwards to DCCMS’s headquarter in Blantyre for the GTS. Radios, however, are no longer in operation and a modified arrangement is in place. Meteorologists can call a central phone number at DCCMS HQ and/or use WhatsApp to report the daily synoptic observations to DCCMS’s communication section. WhatsApp has, however, been cumbersome to manage, disaggregate, and transfer manually at the end point at DCCMS HQ. Consistency of reporting in near-real time from the synoptic stations faces challenges (staff availability, government budget for airtime credit and/or internet connectivity at stations etc.). In 20203, only the synoptic airport stations complied with submitting daily observations in time to be submitted to GTS on time (i.e., airports at Karonga, Mzuzu, Kamuzo International in Lilongwe, and Chileka in Blantyre).

DCCMS’s goal is to improve and digitise data record keeping and transmission at the synoptic stations. A mobile data collection form would be ideal to move away from paper-based work, prioritise monthly summaries of observations, and transmit them directly to Climsoft. One preferred solution is that meteorologists use the software Climsoft at local desktops to enter observations and transmit/make them available to DCCMS HQ in near real time (e.g., for forecasting purposes and value). Computer equipment and software access,

however, is not confirmed and there are challenges with internet connectivity and payment for internet access at the synoptic stations.

The synoptic logbooks and monthly summary reports are sent by post to DCCMS HQ in Blantyre. Once arrived, staff in the Climate section quality control the manual logbooks and reports. The quality-controlled observation data is then directly and manually transcribed into the Climsoft software. Climsoft is accessible on a local server and desktop computers.

#### The World Meteorological Organization's Global Telecommunication System (GTS)

The WMO GTS is an international mechanism designed for the timely, reliable, and efficient exchange of meteorological and related information among National Meteorological and Hydrological Services (NMHSs) around the world. The GTS is part of the World Weather Watch Program, which is a cornerstone of the WMO's efforts to enhance the capacity of its member countries to provide weather, climate, and water services. The purpose of the GTS service for sending synoptic reports is to ensure that observational data, forecasts, and other meteorological information are distributed in a standardised format across the globe. This system supports weather prediction, climate research, and meteorological analyses by making crucial data available to all participating countries.

Box 1. WMO's Global Telecommunication System

## Manual observations - daily rainfall

### Collection & equipment

There are approximately 400 manual rainfall gauges owned by the Ministry of Agriculture (MoA) and DCCMS. However, MoA runs the stations, providing a cross-ministerial service. It is not known how many are operational.



Figure 3. Monitoring equipment for manual collection of rainfall observation (left) and rainfall monitoring by Ms Ennett Kondowe at Thylo agricultural research centre.

At the manual rainfall gauging stations, “Observers” are solicited to use conventional rain gauges (figure 3), take one daily observation of total 24 hrs rainfall at 08h00, and record the observation data in physical logbooks. Rain gauges at manual stations are frequently in need of refurbishments - from clearing to replacing the inside measurement cylinder. In addition, care is needed to ensure the rain gauge is maintained at the correct height and that vegetation, shrubs and trees that impact the gauge's collection capacity, are removed.

The conventional rain gauge is easily accessible from suppliers in South Africa, and costs range from USD 75-150. Observers are mostly hired by the ministry or local research station, have formal training, and perform the cross-ministerial service for DCCMS.

### Transmission

The transmission of manual rainfall observations is similar to that of the synoptic logbooks. Books are sent by post, or at times collected by DCCMS staff during visits. Once arrived, staff quality the logbooks and then manually transcribe the observations directly into the Climsoft software.

#### Manual weather observations: needs, barriers & opportunities

##### Needs

- More accurate rainfall observations require glass measuring cylinders.
- Acquisition of new rain gauges is needed as a majority are broken.
- Rain gauges are at times purchased by third parties (e.g., NGOs) that do not meet WMO or DCCMS standards, resulting in problems with data quality rendering the data useless.

##### Barriers

- The digitisation and transfer process for manual observations using WhatsApp, phone calls and logbooks can be described as latent and cumbersome, prone to human error and requiring large staff and financing resources (from purchasing and posting logbooks, to time spent transcribing manually).
- Government funding is lacking to enable and/or remunerate Observers to use online communication to send the data on a daily basis (e.g., WhatsApp). In the 2023/24 financial year, Observers were sponsored only 3 times by the government.
- Data stuck at stations and never sent to HQ
- 

##### Opportunities

- Development of a system that is able to read and transcribe WhatsApp.
- Integration and local use of Climsoft.

Box 2. Needs, barriers and opportunities for manual weather observations

## Automatic Weather Stations

### Collection & equipment

DCCMS boasts 123 automated weather stations (AWS) nationally operating at 80-90% capacity. A number of the AWS are presented in detail with individual inventory data sheets on DCCMS's website: <https://www.metmalawi.gov.mw/our-stations/>.

AWS used by DCCMS are primarily sourced from the meteorological equipment provider [Campbell Scientific Ltd](#). The capital investment costs for the purchase, import and installation of these stations have been financed by a number of large donor programmes in the last decade (World Bank, UNDP/GCF etc.). On average, an AWS can cost 20,000 to 30,000 USD each.

Similarly to other low-resource countries, DCCMS faces a number of challenges in operating and especially maintaining the AWS. Government budget resources often do not cover the maintenance and operations cost that can be as high as 30% of the AWS capital expenditure cost. AWS also stops functioning as vandalism and theft of valuable equipment parts (e.g., batteries, solar panels). Power outages can disrupt data flow from AWS to DCCMS HQ as well. An WMO SOFF [assessment](#) in 2023 found that only 9% of DCCMS's AWS met the WMO Global Basic Observation Network regulations primarily due to hardware, software, and data transfer issues.

These above factors underscore the high vulnerability of using remote infrastructure and equipment where automation and sustained operations require financing, staffing and easy access to replacement costs. Despite these challenges, the automated stations represent a significant step towards modernising meteorological observations in Malawi.

### Transmission

AWSs automatically transmit hourly data using GPRS communication technology (via the telecons Airtel Malawi or Telecom Network Malawi, TNM). GPRS stands for General Packet Radio Service and is the method of data transfer on 2G mobile phone networks. Through GPRS, data from the AWS is transferred to a central server at DCCMS. Campbell Scientific's online data repository also captures observations available through an online software. According to the SOFF diagnostic of 2023, 37 AWS use the WIS2Box system for cloud-based data transfer, enabling global data exchange with meteorological centres. Nine of these are compliant with WMO's Global Basic Observation Network Requirements (WIS2Box is a free and open source reference implementation of a WMO WIS2 Node, a docker and Python-based platform with the capabilities for centres to publish data).

Using a simple script, data from the AWS are moved into Climsoft that requires manual instruction to pull the data from the AWS data repository.

Access to the raw AWS data is restricted to three individuals in the IT department of DCCMS, and provided to DCCMS sections (e.g., forecasting) and external stakeholder on a case-basis (data request is submitted to DCCMS Director who authorises data release). Limited access, and loss of accreditation, licence expiration and power outages can reduce the transmission and application of AWS observation data.

When an AWS stops operating it is hard for DCCMS to be alerted, and interruptions to transmission of data impacts the access to near/real-time observations which in turn impacts forecasting processes at DCCMS. During extreme events, such as Cyclones, communication networks typically fail and disrupt the AWS functions, meaning observation data on extreme events are at times lost.

Under the [THAMO](#) initiative (Trans-African Hydro-Meteorological Observatory), Malawi received inexpensive and robust weather stations installed at 29 schools and government monitoring stations across the country. In partnership with Columbia University International Research Institute for Climate and Society, DCCMS has been provided with a data platform to manage and monitor data and station status of both its AWS and the THAMO stations (figure 4).

### Automated weather observations: needs, barriers & opportunities

#### Needs

- Synchronised and harmonised transmission of AWS data to Climsoft
- Sustained financing to support station operations and maintenance (O&M)

#### Barriers

- Vandalism and theft of valuable and vulnerable AWS equipment parts
- Lack of recurring budget from government or donor to finance O&M, protection of AWS station equipment, and replacement of equipment parts

#### Opportunities

- DCCMS wants streamlined, harmonised data transmission with as high degree of automation as possible (e.g., only want one server with data from all servers/sources)
- WMO's Surface Observation Financing Facility (SOFF) provides funds for O&M in exchange for data transmission to the Global Basic Observation Network system (GBON)
- DCCMS employs WIGOS for data quality management, though national procedures for addressing quality issues based on WIGOS data are still under development

Box 3. Needs, barriers and opportunities for automated weather observations

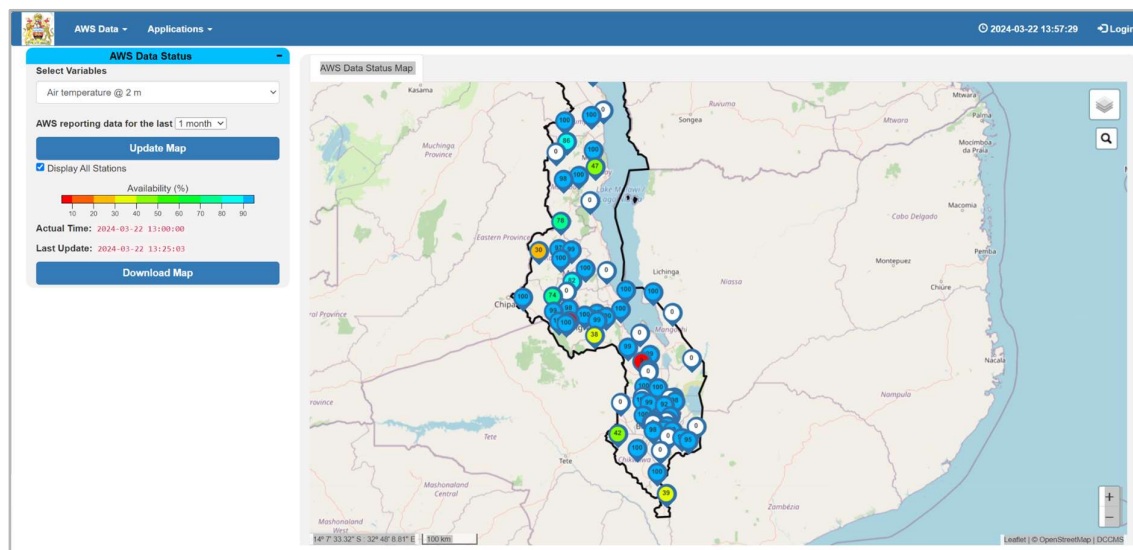


Figure 4. Example of dashboard showing data transmission from DCCMS's Automatic Weather Stations and weather stations under the THAMO project.

### Specialised observation

DCCMS operates a lightning detection system with eight sensors covering 95% of the country. This supports nowcasting and specialised forecasting services. Weather conditions on Lake Malawi, one of Africa's largest and one of the world's deepest freshwater lakes, is monitored by DCCMS with 2 lake buoys for real-time monitoring.

### Satellite observations

Satellite data provides a broad overview of weather patterns, crucial for enhancing local data with global meteorological insights. DCCMS uses satellite information on an ad-hoc basis, with caution and for the purpose of augmenting its forecasting models, or filling longer two to three month gaps of in-situ observation data. Satellite observations are seen as a compliment and DCCMS's main concerns are with calibration and validation with ground-based in-situ observations, as well as resolution. EUMETSAT, for example, is commonly used (<https://www.eumetsat.int/meteosat-second-generation>).

According to the 2023 [Country Diagnostic Assessment](#) done under WMO SOFF, the model and satellite accessible to DCCMS include:

- [European Meteorological Satellite data](#) from Meteosat operational system every 15 minutes through a PUMA platform (data originates from EUMETSAT not WMO).
- Numerical Weather Prediction (NWP) data is obtained four times daily; from GFS, ECMWF products (not the model output data), ICON, UM (Unified Model), ARPEGE, UKMO
- Global synoptic observations - GTS via the NetSys MSS
- Tropical Cyclone advisories from [Tropical Cyclone Advisory Centre](#) (La Reunion)
- Aviation meteorological data from Secure Aviation Data Information Service (SADIS)
- Flash-Flood Guidance Data - Southern Africa Flash-Flood Guidance System (SFFGS). There is no direct access between SFFGS and ODSS. SFFGS provides graphical output at 6, 12, 24 hours.

The integration of satellite data with ground observations requires robust IT infrastructure and low band with internet access is a challenge. The application of satellite observations also requires skilled personnel to ensure data accuracy and reliability, as well as a specific application of observation data - such as in forecasting operations.

### Historical data

DCCMS hosts a vast archive of historical observations captured in logbooks. Through various intermittent externally funded initiatives, large sets of observations have been digitised (e.g., wind conditions, 1981-2016). But large swathes of data still reside only on paper, such as rainfall, temp, sunshine hours etc. logbooks are stored at DCCMS's HQ but also at the monitoring stations. Paper archives with observation data constitute a high-value resource to understand past climatic conditions - especially in the assessment of climate change and changing weather patterns.

### Data management system

#### Climsoft

Climsoft is an open source and easy to use climate data management software, with a suite of solutions for "storing climatic data in a secure and flexible manner and for extracting useful information from the data" ([www.climsoft.org](http://www.climsoft.org)). Like many national meteorological agencies in Africa and developing countries, DCCMS uses Climsoft as their central data repository and management system.

In Climsoft, observation data (at meteorological standard intervals) are uploaded at the end of a month period, when the logbooks with data arrive at DCCMS HQ. In Climsoft, data quality control tools can be used to verify accuracy (e.g., data is flagged when over set thresholds, standard deviation or out of normal average ranges). Once checked, data is transferred into a final table in Climsoft (figure 5).

DCCMS's goal with using Climsoft is to have one location where weather observation data is easily accessible, in good quality, and to be ready for use in other applications.

Use of Climsoft is free through the support of the WMO. Access restrictions can be tailored to different types of users.

Noteworthy, Climsoft is not automated, and data needs to be manually pulled from the data sources into the software at local desktop computers at DCCMS HQ. An operational challenge facing DCCMS is when there are power blackouts and Climsoft can not be accessed. As such, the effectiveness of Climsoft is hampered by connectivity issues and the need for manual data entry, particularly in remote stations, and manual instruction to pull data from automated sources.

The Malawi [Country Hydromet Diagnostic](#) found that a significant portion of DCCMS's AWS network struggles with compliance to WMO's Global Basin Observation Network (GBON, 2023) standards due to operational issues.

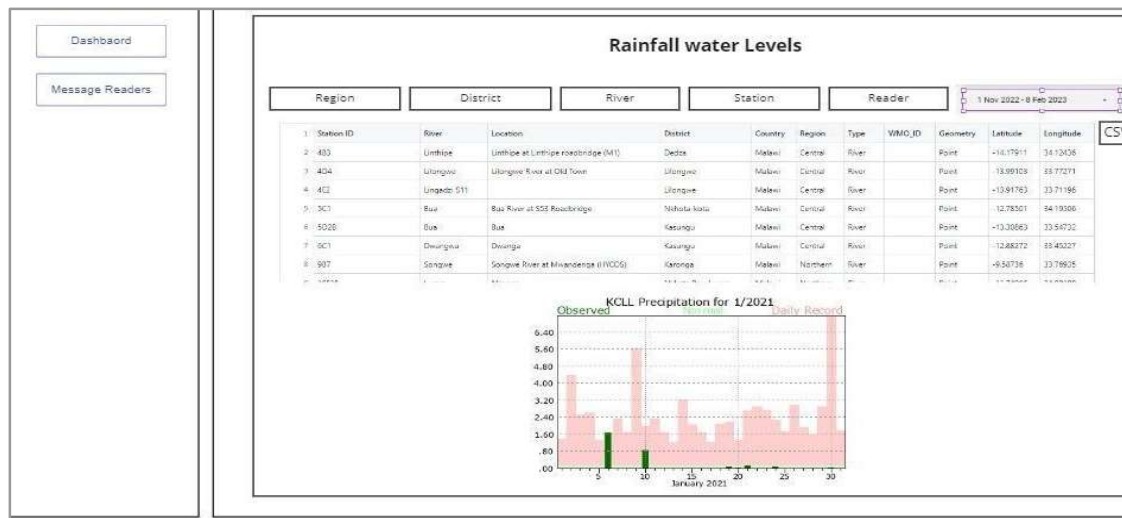


Figure 5. Example of Climsoft interface.

## Forecasting & modelling

In summary, DCCMS's forecasting section primarily uses the daily synoptic reports as real time observation determines the basis for inferring future conditions. The forecasting process is both dynamic and manual, where forecasts are plotted on a weather chart/map to enable analysis of likely patterns.

According to the 2023 Malawi [Country Diagnostic Assessment](#), the forecasting systems deployed by DCCMS include [Synergieweb](#) and [BARON](#) workstations that can be tailored to produce alerts. A PUMA satellite receiving station is also used to acquire [METEOSAT](#) satellite imagery data. Significant weather charts from Southern Africa Weather Services are used to identify potential weather hazards in short-range forecasts. Charts are generated from Numerical Weather Prediction (NWP) analysis and DCCMS uses [ECMWF](#) charts and GFS in their forecasting processes. DCCMS's local NWP model data is also in use, for example for flood monitoring and customised advisories for the agricultural and fisheries sectors.

The forecasting section has access to data from the AWS. Data quality control can be an issue where near/real time AWS data is not considered reliable, and are thus not used in the daily forecasting. For example, the AWS equipment may not be calibrated or the data is inaccurate compared to manual observations at the same site. Stations that host both manual observations and automatic weather stations are important as the local meteorologist/Observer can ensure better data quality.

DCCMS is actively strengthening its forecasting capabilities and has a number of ongoing projects, from installation and training on a new numerical forecasting model through to app development with forecasts ([www.metmalawi.gov.mw/organisation/projects](http://www.metmalawi.gov.mw/organisation/projects)).

### 3. Department of Water Resources (DWR)

#### Overview

DWR holds the primary government mandate for hydrological monitoring in Malawi, covering surface and groundwater resources as well as water quality, as part of its role in managing Malawi's national water resources. Hydrological monitoring is the core function on which the department performs various modelling and analysis to support water resources management and development (e.g., from informing bridge construction to raw water abstractions for urban water supplies). Importantly, early warning systems and flood alerts rest on DWR's national monitoring system.

In 2023, DWR's headquarter office was hit by a fire impacting local servers and daily operations. At the time of the diagnosis, DWR is in makeshift offices and in the progress of moving to new facilities.

#### Additional actors

The 2013 Water Resources Act established the National Water Resources Authority (NWRA) of Malawi ([www.nwra.mw](http://www.nwra.mw)). NWRA's mandate is to "promote the judicious and sustainable management, conservation, use and control of water resources and acquisition and regulation of rights to use water". Monitoring is part of the functions of NWRA's three divisions (surface, groundwater, and water quality). There is, therefore, a degree to which DWR and NWRA functions overlap, and the scale and network design of NWRA's monitoring is not known at the time of the diagnosis. The bearings on the UNEP CTCN project are: 1) learnings can be achieved from their smartphone testing for river level monitoring at approximately 25 stations (completed) and 2) opportunity to connect river level data that was collected to a streamlined repository and flow of data.

Water Boards, the water utilities in Malawi, also perform monitoring especially on water quality and abstraction. Lilongwe Water Board ([www.lwb.mw](http://www.lwb.mw)), for example, runs five manual river gauging stations with the goal and attempts to automate them.

#### Manual observations - river and lake levels

##### Collection & equipment

Daily manual observations of river and lake levels are crucial for DWR's monitoring of Malawi's national water resources, providing data for hydrological analysis and flood risk mapping (i.e., constructing rating curves and estimating discharge rates).

DWR operates 160 manual gauging stations across Malawi. DWR solicits Gauge Readers from nearby communities to go to the river gauge station twice daily, at 08h00 and 16h00, to record the depth. The measurement is captured in a logbook (figure 5 and 6). The Gauge Reader has an additional livelihood or job, commonly subsistence farming. The Gauge Reader is entitled to an honorarium of approximately 25,000 Malawian kwacha (approximately \$25) per month for the observation work.

The equipment used to capture river level or lake level depths (metres) are river gauge plates (figure 5). Gauge level zero - the start of gauge plate 1 - represents the specific height above sea level from which the lake or river depth is monitored. Correct installation, construction and maintenance of the gauge plates themselves and clearance of the surrounding area of the plates, are key to ensure accuracy. For example, gauge plates can be lost or bent during floods or by human use to anchor boats, and vegetation and sedimentation around gauge plates can hinder the river or lake level reaching the plate accurately. Installing a new river gauge station averages \$2,000 each (where travel and allowance constitute the bigger cost items).



Figure 5. Manual river gauge station on the Songwe River at Mwandenga with Gauge Reader Billy Mogha showing the manual logbook for river level observations (Station ID 9B7).

To derive essential streamflow data (discharge rates), DWR needs cross section assessments at the stations. Maintaining accurate cross-section information is labour intensive and a recurring task for DWR and gauge readers, primarily as river channels change shape and course naturally. This is especially the case during and after the rainy season (Oct to March) and after extreme events such as floods. After floods, for example, threshold levels for flood risks may need revisiting.

For flood warning purposes, DWR operates 20 river gauging stations that are monitored during the rainy season by Gauge Readers from the local community. The angle irons of the river gauge are painted green, yellow and red to represent different thresholds and levels of danger (figure 7). DWR works with the same Gauge Reader as a conduit to communicate with community members to share alerts locally and with communities downstream (e.g., not to cross rivers, avoid getting stuck behind flood waters). They use a series of means to disseminate alerts, from vuvuzelas to whistles, and drums. These flood warning gauging stations are primarily in the lower Shire River, Chikwawa, Zumba, Mulanje and Mangoshi.

**WATER RESOURCES BRANCH**  
**GAUGE READINGS**

ORIGINAL

SHIRE River at Matope

Month July 2012 R.G.S. No. 1P2

Taken by Cosmas Layon

Date	GAUGE HEIGHT (m)			Mean Flow	COMMENTS Dry, Stagnant, etc.	Date	GAUGE HEIGHT (m)			Mean Flow	COMMENTS Dry, Stagnant, etc.
	a.m.	p.m.	Mean				a.m.	p.m.	Mean		
1	4.85	4.85				18	4.85	4.85			
2	4.84	4.84				19	4.86	4.86			
3	4.84	4.84				20	4.85	4.85			
4	4.84	4.84				21	4.83	4.83			
5	4.85	4.85				22	4.83	4.83			
6	4.85	4.85				23	4.83	4.83			
7	4.85	4.85				24	4.83	4.83			
8	4.84	4.84				25	4.84	4.83			
9	4.83	4.83				26	4.83	4.83			
10	4.83	4.83				27	4.82	4.82			
11	4.83	4.82				28	4.82	4.82			
12	4.83	4.84			Peak flow	29	4.82	4.82			
13	4.84	4.85			K=2000	30	4.82	4.82			
14	4.85	4.85			18/08/12	31	4.79	4.79			
15	4.85	4.85									
16	4.85	4.85									
17	4.86	4.86									

Monthly mean G.H. \_\_\_\_\_ m: Q= \_\_\_\_\_ m<sup>3</sup>/sec

Examined by Entered by Rebecca 31/05/17

Entered in hydromet by Khosa 20-01-2015

Figure 6. Example of log sheet for river depth observations during July 2012 on Shire River at Matope by Gauge Readers Cosmas Layon (Station ID 1P2).



Figure 7. Example of river gauging station monitoring flood risks at threshold intervals

**Transmission**

When DWR district staff visit the gauging stations, they collect the logbooks with river and lake observations. The logbook contains three sheets for each monthly log sheet where written observations are copied over from the top sheet (white, blue and red). One sheet is

kept at the station, one sheet is kept at the district office, and the last sheet is transferred to DWR HQ in Lilongwe. At the same time, the Gauge Reader is paid his honorarium in cash.

Once in Lilongwe, staff at DWR's hydrological section transcribe the observations manually into the software HYDSTRA as the central repository and archive for hydrological observations.

Similarly to the manual rainfall and synoptic stations of DCCMS, the physical transmission of observations is costly, cumbersome and prone to delays. The manual transcription of data into HYDSTRA is also time consuming, at risk of human error. With funding constraints to finance travel to gauging stations, postage of logbooks, and compensation to Gauge Readers, the system of transmission is not functioning as intended. Gauge Readers stop taking observations, gauge plates are not replaced sufficiently fast, cross-section observations are not taken, among other challenges. In addition, without verification that Gauge Readers went to the station, it is expected that at some stations observations are made up.

In summary, the records of river and lake depth observations therefore experience large data gaps, and the trust in data quality and ability to apply data are undermined.

#### Manual surface water observations: needs, barriers & opportunities

##### Needs

- River gauge plate repair and replacement
- Train district hydrologists with technical skills to install and conduct field surveys
- Updated cross-section measurements
- Sustained financial remuneration to Gauge Readers
- Data quality control to remove outliers and incorrect observations
- Communication tools for Gauge Readers to consistently and accurately send observations

##### Barriers

- Data gaps and lack of cross-section measurements on which discharge is derived
- Government funding to remunerate Gauge Readers to use digital communication
- Manual transcription of logbooks
- Cumbersome data quality control procedures

##### Opportunities

- Streamlined and harmonised flow of river gauge data through digital channels, from both within DWR and among other agencies (e.g., NWRA, LWB)
- Use of centralised servers and HYDSTRA software to merge data
- Creation of rating curves from remotely derived estimation
- With decentralisation, Assistant Hydrologists are allocated to work at district level rather than station level, ensuring greater local capacity and skills transfer

Box 4. Needs, barriers and opportunities for manual surface water observations

## Automated surface water sensors

### Collection & equipment

DWR also employs automated data collection methods for water level observations. All monitoring stations are initially set up as manual gauging stations by default, even if designated and earmarked for automation. At some stations, the manual gauging continues as a critical resource for back-up, validation, verification and sustaining observations if equipment fails. DWR operates approximately 65 automatic surface water stations (figure 8). For clarification, automated stations are commonly lost and damaged during seasonal floods. As such, the exact number of operating stations varies.

The station consists of sensors capturing different hydrological parameters, depending on the complexity and purpose of monitoring (e.g., sedimentation, flow, water quality etc.). Data is stored in local data loggers, and/or transmitted via GPRS to supplier software.

Automated stations are commonly sourced from suppliers, such as SEBA hydrometrie ([www.seba-hydrometrie.com](http://www.seba-hydrometrie.com)). The capital expenditure to purchase, import and install the station can average \$25,000. DWR currently operates approximately 37 SEBA hydrometrie stations.

Automated sensors are at high risk of theft and vandalism where sensor cables are pulled out, and solar panels and batteries are removed. During extreme events, automatic stations are also at high risk of damage and loss. During Cyclone Freddy in March 2023, for example, DWR lost half its automated surface and groundwater sensors in the affected areas of southern Malawi.

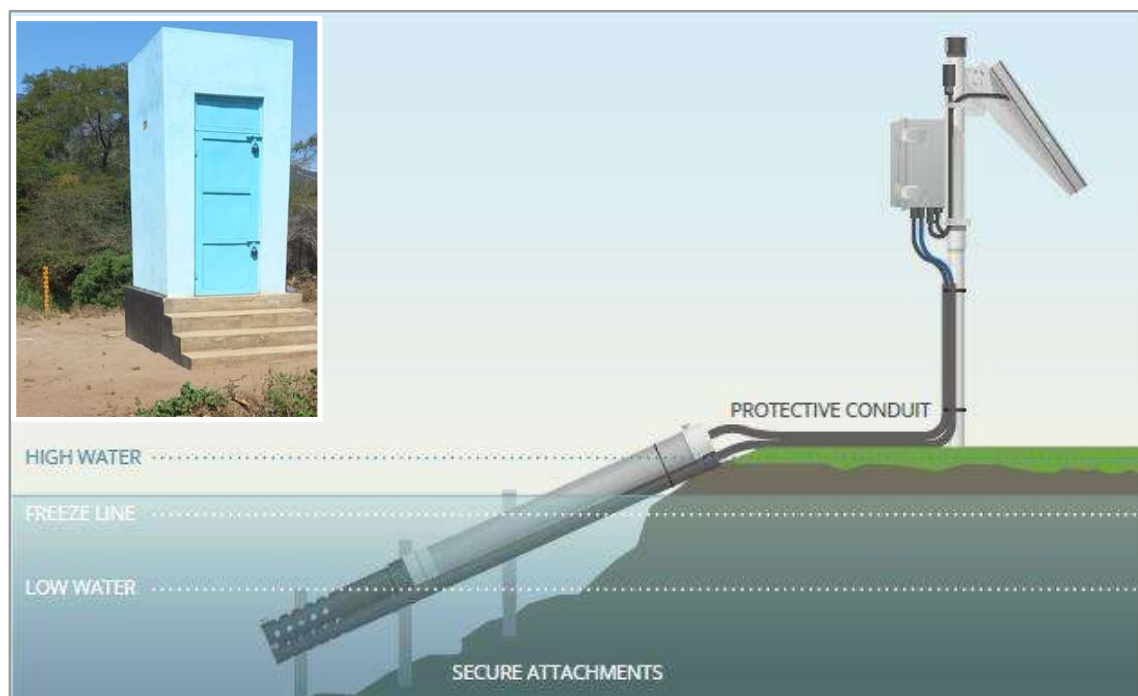


Figure 8. Simplified illustration of automated river observation station, with example of housing automated data loggers at the hydrological monitoring station at North Rukuru River at Uledi (showing manual river gauge plates used in parallel)

### Transmission

Data transmission constitutes one of the major barriers to effective and near real time transmission of data. At the time of the diagnosis there is little access to the data due to the fire at DWR offices at Tikwere house in Lilongwe, where local servers and equipment was housed. At DWR's new offices, provisions are being promised for data management and dedicated rooms for servers and for high-speed internet access.

Most automated sensors deployed by DWR use GPRS to transfer the observation data automatically to servers at DWR headquarters. However, using GPRS requires airtime in the local data loggers (depending on volume and frequency of data transfer). During large, multi-year projects funded by donors, topping up the airtime was easy and sustained transmission of data.

However, once the project ends, funding dries up and observation data is not easily accessible. Challenges can exist with supplier equipment design. The Lilongwe Water Board sought to install automatic sensors at five manual gauging stations. Accessing the data requires physical downloading at the station. But the data logger only stores data from preceding 10 to 20 minutes, and not any historical data. The example highlights the value and the mitigating insurance of manual observations at the station.

Data that is transmitted from automatic stations are accessible through supplier software, such as SEBA Hydrometrie's HydroCenter. In this easy-to-use online platform, DWR can monitor station status and condition, as well as download observation data. Staff at DWR are accredited with login details. There is no licence fee, but a fee is charged for uploading and calibrating a station into the system once installed.

#### Automated surface water observations: needs, barriers & opportunities

##### Needs

- Sustained maintenance of station equipment (e.g., batteries, solar panel) and data transfer solution (e.g., airtime credit for local data loggers)
- Protection against theft, vandalism and extreme events
- Training of district level staff on maintaining stations

##### Barriers

- Transfer of data from sensors to local servers or online repositories
- Government funding to operate and maintain the automatic stations
- Data stuck in data loggers in local stations

##### Opportunities

- Merging automated and manual observations for validation and filling data gaps, enhancing data quality and simplifying the application of data into hydrological analysis

Box 5. Needs, barriers and opportunities for automated surface water observations

### Satellite observations

DWR uses satellite observations in various ways, for example to complement surface and in-situ observation data. This offers better estimates on water levels and supports flood mapping efforts. Satellite observations can also help fill observational gaps and enhance the accuracy of water resource assessments. Collaborations with international data providers, such as GEOGLOWS ([www.geoglows.org/pages/geoglows-streamflow-forecasting](http://www.geoglows.org/pages/geoglows-streamflow-forecasting)), has enhanced DWR's capabilities in utilising satellite data.

### Historical observations

DWR has archives of historical river level observations dating back to 1959. Through ad-hoc initiatives, the historical records have been digitised but much remains in paper format (figure 9).

The benefits of digitising historical records are many. For example: improved climate change impact analysis, long-term trend analysis and assessments, calibration for natural and documentary proxies for plausible extension analysis, improved value and credibility of hydrological analysis, and anomalies detection in real-time data.



Figure 9. logbooks with historical river level data, DWR headquarters 2018

Staff resources, time and funding constraints means that manual transcription of manual observations cannot be prioritised. The paper records deteriorate over time and the loss of

archived data is high. Unfortunately, this means that insights into past hydrological conditions, from hydrological and climate modelling, are hard to assess.

## Data management systems

### Hydstra

The Hydstra software system, supplied by Kistra and designed for water data storage and analysis, is central to DWR's data management strategy ([www.kisters.com.au/hydstra](http://www.kisters.com.au/hydstra)). Hydstra is a "fully featured environmental data management package with automation, quality control, hydrological processes, asset management, extensive analysis and reporting."

Despite its utility, HYDSTRA faces operational challenges due to IT infrastructure limitations, staff resources and the need for a more sustainable funding model for software licensing. Manual processes to transcribe and enter data into Hydstra can be labour-intensive with staff time and skills needed to help clean data even before it is manually entered into Hydstra. Hydstra data records are thus subject to data gaps, misaligned data formats and users' latent access to near real time or recent data observations.

For the automated station data, DWR mostly uses HydroCenter but does not add the observations to Hydstra due to prior need to configure station and data information.

Hydstra is accessible through the local servers/local desktop computer at DWR headquarters (and inaccessible at the time of the diagnosis due to upcoming move to new premises), and online from remote laptops. Power cuts or lack of high speed internet access can limit the use and abstraction of data from Hydstra.

## Hydrological modelling, forecasting & warnings

### Developing rating curves

DWR performs hydrological monitoring for various purposes. For example, the Roads Authority of Malawi will approach DWR for information on river level thresholds to inform the detailed design of bridge construction. For such an assignment, DWR needs to develop rating curves for the specific bridge location and provide these to the client (i.e., the relation between river level depth and discharge rate). The rating curves are derived from the data available, both manual and automatic observation data and at times double checked with satellite observations. A pain point for DWR in developing and comparing rating curves is the need for various sets of information to perform the analysis, from local knowledge of the monitoring station or bridge location through to defined return periods, access to manual, automated and historical observation data. A lot of quality control assessment goes into DWR's modelling. For example, in February 2022, discharge measurements were taken by the Northern Water Board at Lambilami River. But with a manual check of the data, the graphs with rating curves produced identified several outliers.

### Operational Decision Support System (ODSS)

In 2016, an online platform for merging automated and satellite observations and model predictions of future conditions and risks was developed, based on the [MIKE software](#) products for modelling and operational framework - the ODSS Flood and Drought Monitoring System ([www.flooddroughtmonitor.com/data?u=Malawi&p=Malawi](http://www.flooddroughtmonitor.com/data?u=Malawi&p=Malawi)). The first iteration was developed for the Shire River basin under the World Bank supported Shire

River Basin Management Programme, and there are ongoing efforts to scale up the platform to national level and to upgrade hydrological modelling and forecasts using the open source [HEC-RAS](#) software (e.g. with support from the UNDP and the Green Climate Fund). A strength of the ODSS is that automated sensors are integrated into the platform and contribute to its forecasting functions. ODSS does not integrate manual river level observations. The ODSS is especially valuable during the rainy season.

Although very useful, DWR experiences a set of challenges with ODSS that undermines its incorporation into DWR’s core operations. DWR needs resources to visit and calibrate automated stations (especially after every rainy season as cross sections change and river course changes). And licensing is a problem as central government financing and procedures for procuring various software or data management programme licences are very limited. The use of ODSS has thus diminished. There is therefore a trend towards using open source software or identifying alternative purchasing mechanisms.

### Community Based Flood Early Warning System

Under the UNDP supported mClimes project, a community-based flood and early warning system (CBEWS) project involved installation of 24 automatic observation stations with in-built alert systems ([malawi.cbfeWS.com](http://malawi.cbfeWS.com)). The project was managed by the Malawi Department of Disaster Management Affairs (DoDMA) who are custodians of the stations. At the time of diagnosis, several stations had ceased to operate despite serving a central function in warning local communities. On February 25, 2022, at 02h00, the Songwe River flooded at Mwandenga. The CBEWS siren called out in the night, and many in the local community could move to higher ground, possibly saving numerous lives (figure 10). The station equipment was, however, damaged and the station stopped operating a day after. A maintenance challenge exists also for the CBEWS stations whereby DWR encourages DoDMA to visit stations after every rainy season and fix alarm units, among others.



Figure 10. River level above warning threshold at Mwandenga on Songwe River (February 25, 2022)

## 4. Southern Africa

Hydrometeorological information systems, often referred to as climate information systems, play a crucial role in southern Africa, a region frequently impacted by climatic extremes such

as droughts, floods, and cyclones. These systems are vital for disaster risk reduction, agriculture, water resource management, and climate change adaptation strategies.

Assessments, such as those of the World Bank and the WMO, highlight the significance of strengthening observation systems across the region and the needs, challenges, barriers and opportunities identified in Malawi as part of this diagnosis resonates across countries.

Despite the socio-economic benefits of climate information services to both public and private sectors, several countries in southern Africa continue to have sparse observation networks, with a significant number of stations either non-functional or providing data of questionable quality. On average, only 26% of surface observation stations report according to WMO standards (figure 11).

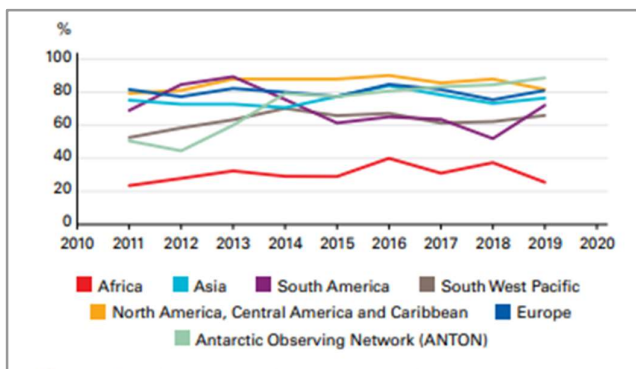


Figure 11. Percentage of dedicated surface stations reporting to GSN requirements for different WMO

regions (2011-2019)

The international donor community comes together in various initiatives to raise funding and generate new financing mechanisms. In the Early Warnings for All initiative, for example, the estimated global budget to address observation and forecasting gaps is \$1.18 billion (figure 12).

Funding constraints further hinders development of robust hydrometeorological information systems. In particular, sustainable financing models are needed to ensure the long-term maintenance and expansion.



Figure 12. Early Warning for All initiative’s four pillars of financing and interventions

## 5. Preliminary findings

The Department of Climate Change and Meteorological Services and the Department of Water Resources form the backbone of Malawi’s meteorological and hydrological information systems.

Both departments have made strides and progress in achieving greater automation and observation coverage in the last decade, showcasing an openness to innovate and leverage new technologies, IT capabilities, and mobile communication channels.

Despite their critical roles and their achievements, both DCCMS and DWR face significant challenges that impact their effectiveness and efficiency in managing and disseminating vital climate and water information.

Key findings include the reliance on predominantly manual and automated observation data collection methods, which, while foundational, are fraught with operational and financing

issues. These include, data gaps, equipment repair and maintenance, airtime for data transfer, and consistent remuneration to staff and volunteering Observers and Gauge Readers.

The assessment of similar and complementing initiatives (Annex B) reflects the opportunities that mobile and cloud technologies are generating. Overall, however, the initiatives that focus on the part of the climate information service value chain that covers digitisation and collection of observations, are few. Another difference is that initiatives vary in maturity, organisational set up and financial backing. Some initiatives are part of global initiatives where the technology and approach are validated and scaled (e.g., use of simple and robust sensors connected to GPRS network communication). Some initiatives are anchored in non-governmental partnerships and associated funding mechanisms. Interestingly, common to all initiatives, is the absence of a business to government (B2G) business model backed by long-term and programmatic donor funding programmes. This finding is echoed in research done by the [GSMA \(2023\)](#) on emerging trends in climate tech innovations: “Few projects targeted government or local authorities, and those that did indicated challenges in generating revenue. Given the importance of collective action, there is scope for more evidence on successful business models that can effectively engage public and private institutions.” GSMA finds that the trend in innovative use of mobile tech is that increased resilience is being built at the individual level, rather than the institutional level. In summary, the team is actively engaging with similar and complementing initiatives to share learnings. Further, whilst the project will explore how to generate a simple and central flow of observation data for DWR and DCCMS, findings will unveil the possibilities of integrating independent approaches (e.g., showcased by Thamo’s approach in figure 4.

Furthermore, IT infrastructure deficits, particularly in internet connectivity and power supply, limit the capacity for effective data transmission and processing. Existing software limitations and the predominant use of manual data processing techniques underscore the need for technological advancements and enhanced staff training programs to bolster efficiency and data accuracy.

The prevailing dependence on manual processes in an era increasingly defined by digital solutions, big data computing models and the use of satellite observations, point to an opportunity for system and approach overhauls with dedicated training to equip staff with the skills necessary to navigate and exploit modern technologies and equipment fully.

### Barriers

Barriers impede the full realisation of optimised and scaled hydrological and meteorological information systems in Malawi. The chronic underinvestment in modern IT infrastructure and equipment maintenance, and time-limited project design, represents a fundamental challenge, limiting the scope and reliability of observation data collection and analysis. Additionally, the prevalent issue of vandalism and theft of sensor equipment exacerbates data gaps and imposes a financial and operational strain on already limited departmental budgets and staff capacities from national to district levels.

Software solutions that are not tailored for easy use and particular data management priorities and application purposes, complicate data processing and analysis tasks, while the existing training programs can fail to adequately prepare staff for the complexities of modern data management and analysis technologies.

### Good Practices

Amid these challenges, both DCCMS and DWR have performed substantial exploration of new digitisation opportunities, from working with Water in Sight and TRIM to test viable mobile communication methods for digitisation of manual observation through to incorporating robust weather sensors at schools through the THAMO collaboration.

Although both departments are understaffed, key personnel bring and build upon their high degrees of skills and experiences of operational hydrometeorology, often from international and regional assignments. Willingness to adopt mobile and cloud-based solutions is high, with an emphasis that piloted approaches align with the departmental goals of automation, synchronisation and harmonisation of data flows as well as being financially sustainable and in agreement with departmental mandates and missions.

Learning from both barriers and good practice is key to identifying the best tools for scaling and sustaining Malawi's hydrological and meteorological information systems.

## 6. Annex A. List of monitoring stations and equipment

ACTIVITY 3.1 Diagnosis of the current systems and equipment available in Malawi to gather climate data

DELIVERABLE 3.1.b

NOTE Station inventory is work in progress and will be updated to focus on manual observation stations where digitisation using mobile phones has potential.

Agency	Equipment	Station name	Station ID	Date estab.	Type	Parameters	District
DCCMS	Automatic Weather Station	BALAKA	in progress	2020-06-10	Automatic (land, fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	BILIRA	in progress	2019-04-06	Automatic (land, fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	BOLERO	in progress	1961-01-01	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	BVUMBWE	in progress	1962-01-01	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	BVUMBWE AWS	in progress	2022-10-05	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	CHELINDA - NYIKA	in progress	2015-11-04	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	CHICHIRI	in progress	1965-01-01	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	CHIDOOLE	in progress	2019-08-31	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	CHIKANGAWA	in progress	2019-10-06	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	CHIKWAWA AWS	in progress	2022-10-05	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	CHIKWEO	in progress	2019-10-14	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	CHILEKA	in progress	–	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	CHINGALE	in progress	2019-08-31	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	CHINTHECHE	in progress	2015-11-03	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	CHITEDZE	in progress	1961-01-01	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	CHITIPA	in progress	1955-01-01	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	Chancellor College	in progress	1974-07-01	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	DEDZA	in progress	1961-01-01	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	KALAMBO	in progress	2019-08-31	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	KAMEME	in progress	2020-10-14	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	KARONGA	in progress	1952-01-01	Land (fixed)	Multiple weather parameters	

DCCMS	Automatic Weather Station	KASIYA AWS	in progress	2019-10-15	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	KASUNGU	in progress	1983-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	KASUNGU NATIONAL PARK AWS	in progress	2019-10-05	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	KAWALAZI	in progress	2019-10-07	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	KAYEREKERA	in progress	2019-10-06	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	LENGWE NATIONAL PARK	in progress	2019-08-31	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	LILONGWE INT'L AIRPORT	in progress	1981-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	LIWONDE NATIONAL PARK	in progress	2019-04-05	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	LOBI AWS	in progress	2019-11-14	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	LUCHENZA	in progress	2019-08-30	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	Lilongwe	in progress	–	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MAKANGA	in progress	1961-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MAKANJIRA	in progress	2019-10-15	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MAKOKA	in progress	1964-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MALINGUNDE	in progress	2015-05-07	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MALOMO	in progress	2019-10-05	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MANGOCHI	in progress	1961-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MASAMBANJATI AWS	in progress	2019-08-30	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MAYANI	in progress	2015-07-14	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MBAWA	in progress	2015-11-03	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MBULUMBUZI	in progress	2020-10-08	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MBWAZI	in progress	2019-10-29	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MERU	in progress	2015-11-04	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MIMOSA	in progress	1961-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MIMOSA AWS	in progress	2022-10-05	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MISUKU	in progress	2019-10-05	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MLARE	in progress	2019-10-05	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MLOMBA	in progress	2019-10-14	Land (fixed)	Multiple weather parameters

DCCMS	Automatic Weather Station	MLOWE	in progress	2019-10-05	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MONKEY BAY	in progress	1981-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MPEMBA	in progress	2020-10-07	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MPONELA	in progress	2019-10-15	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MTOSA BENGA	in progress	2019-10-04	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MULANJE	in progress	2022-10-05	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MVERA	in progress	2015-08-18	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MWIMBA	in progress	2015-10-17	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MZIMBA	in progress	1946-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	MZUZU	in progress	1961-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	Mhuju	in progress	2019-10-04	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	N.R.C.	in progress	1985-06-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NAMBUMA	in progress	2019-10-15	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NAMINJIWA	in progress	2022-10-05	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NAMITAMBO	in progress	2019-08-31	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NANKUMBA	in progress	2019-10-16	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NGABU	in progress	1961-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NGABU	in progress	2015-07-09	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NJOLOMOLE	in progress	2015-05-07	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NKHATA BAY	in progress	1961-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NKHOMA UNIVERSITY	in progress	2019-10-17	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NKHOTA KOTA	in progress	1961-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NKHULAMBE	in progress	2019-08-30	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	NYACHILENDA	in progress	2019-08-30	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	RUMPHI	in progress	2020-10-13	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	SALIMA	in progress	1953-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	THYOLO	in progress	1961-01-01	Land (fixed)	Multiple weather parameters
DCCMS	Automatic Weather Station	TOLEZA	in progress	2019-04-06	Land (fixed)	Multiple weather parameters

DCCMS	Automatic Weather Station	ZOMBA AIRWING	in progress	2019-04-04	Land (fixed)	Multiple weather parameters	
DCCMS	Automatic Weather Station	ZOMBA RTC	in progress	2022-10-05	Land (fixed)	Multiple weather parameters	
DCCMS	Rainfall gauging station	Dwangwa illovo	12341003	not available	Manual	Rainfall ((mm/24 hrs)	Nkhotakota
DCCMS	Rainfall gauging station	Mponela	13334004	not available	Manual	Rainfall ((mm/24 hrs)	Dowa
DCCMS	Rainfall gauging station	Nathenje	14332001	not available	Manual	Rainfall ((mm/24 hrs)	Lilongwe
DCCMS	Rainfall gauging station	Nkhotakota Aerodrome	12343000	not available	Manual	Rainfall ((mm/24 hrs)	Nkhotakota
DCCMS	Rainfall gauging station	Bvumbwe Research Center	15353056	not available	Manual	Rainfall ((mm/24 hrs)	Thyolo
DCCMS	Rainfall gauging station	Chataloma Agric	12334004	not available	Manual	Rainfall ((mm/24 hrs)	Kasungu
DCCMS	Rainfall gauging station	Chikwawa Boma Mitole EPA	16342000	not available	Manual	Rainfall ((mm/24 hrs)	Chikwawa
DCCMS	Rainfall gauging station	Chileka Namitete	14331000	not available	Manual	Rainfall ((mm/24 hrs)	Lilongwe
DCCMS	Rainfall gauging station	Chintheche Agric	11343016	not available	Manual	Rainfall ((mm/24 hrs)	Nkhatabay
DCCMS	Rainfall gauging station	Chiradzulu Boma	15353013	not available	Manual	Rainfall ((mm/24 hrs)	Chiradzulu
DCCMS	Rainfall gauging station	Chisenga	9333000	not available	Manual	Rainfall ((mm/24 hrs)	Chitipa
DCCMS	Rainfall gauging station	Chisenga	13324006	not available	Manual	Rainfall ((mm/24 hrs)	Nkhotakota
DCCMS	Rainfall gauging station	Chitedze Research Center	13334006	not available	Manual	Rainfall ((mm/24 hrs)	Lilongwe
DCCMS	Rainfall gauging station	Dedza Met	14341008	not available	Manual	Rainfall ((mm/24 hrs)	Dedza
DCCMS	Rainfall gauging station	Dwambazi Vetc	12341002	not available	Manual	Rainfall ((mm/24 hrs)	Nkhotakota
DCCMS	Rainfall gauging station	Kafukule	11332004	not available	Manual	Rainfall ((mm/24 hrs)	Mzimba
DCCMS	Rainfall gauging station	Kaluluma Agric	12333002	not available	Manual	Rainfall ((mm/24 hrs)	Kasungu
DCCMS	Rainfall gauging station	Kasinthula agricultural research	16342011	not available	Manual	Rainfall ((mm/24 hrs)	Chikwawa
DCCMS	Rainfall gauging station	Kasungu Aerodrome	13331011	not available	Manual	Rainfall ((mm/24 hrs)	Kasungu
DCCMS	Rainfall gauging station	Kavuzi Agric	11343009	not available	Manual	Rainfall ((mm/24 hrs)	Nkhatabay
DCCMS	Rainfall gauging station	Karonga Airport	9334003	not available	Manual	Rainfall ((mm/24 hrs)	Karonga
DCCMS	Rainfall gauging station	Mzuzu Aerodrome	11341001	not available	Manual	Rainfall ((mm/24 hrs)	Mzimba
DCCMS	Rainfall gauging station	Nkhata Bay	11343000	not available	Manual	Rainfall ((mm/24 hrs)	Nkhatabay
DCCMS	Rainfall gauging station	Rumphi Bolero	11332012	not available	Manual	Rainfall ((mm/24 hrs)	Rumphi
DCCMS	Rainfall gauging station	Rumphi Boma	11332002	not available	Manual	Rainfall ((mm/24 hrs)	Mzimba
DCCMS	Rainfall gauging station	Vinthukutu Agriculture	10341008	not available	Manual	Rainfall ((mm/24 hrs)	Karonga

DCCMS	Rainfall gauging station	Zombwe	11332000	not available	Manual	Rainfall ((mm/24 hrs)	Mzimba
DCCMS	Rainfall gauging station	Lisangazi No1	11332005	not available	Manual	Rainfall ((mm/24 hrs)	Nkhatabay
DCCMS	Rainfall gauging station	Lisangazi No2	11334008	not available	Manual	Rainfall ((mm/24 hrs)	Mzimba
DCCMS	Rainfall gauging station	Lobi Agriculture	14341011	not available	Manual	Rainfall ((mm/24 hrs)	Dedza
DCCMS	Rainfall gauging station	Lufita	9333008	not available	Manual	Rainfall ((mm/24 hrs)	Chitipa
DCCMS	Rainfall gauging station	Matindiwizi	11332018	not available	Manual	Rainfall ((mm/24 hrs)	Mzimba
DCCMS	Rainfall gauging station	Meru Rex	9333013	not available	Manual	Rainfall ((mm/24 hrs)	Chitpa
DCCMS	Rainfall gauging station	Mtubwi Epa	15351054	not available	Manual	Rainfall ((mm/24 hrs)	Liwonde
DCCMS	Rainfall gauging station	Mwalanthunzi	16351021	not available	Manual	Rainfall ((mm/24 hrs)	Thyolo
DCCMS	Rainfall gauging station	Mwamsambo	13341001	not available	Manual	Rainfall ((mm/24 hrs)	Nkhotakota
DCCMS	Rainfall gauging station	N.R.College	14332002	not available	Manual	Rainfall ((mm/24 hrs)	Lilongwe
DCCMS	Rainfall gauging station	Namilombwa	13334009	not available	Manual	Rainfall ((mm/24 hrs)	Lilongwe
DCCMS	Rainfall gauging station	Alumenda	16342020	not available	Manual	Rainfall ((mm/24 hrs)	Chikwawa
DCCMS	Rainfall gauging station	Chichiri Met	15353036	not available	Manual	Rainfall ((mm/24 hrs)	Blantyre
DCCMS	Rainfall gauging station	Chingale	15351007	not available	Manual	Rainfall ((mm/24 hrs)	Zomba
DCCMS	Rainfall gauging station	Makoka	15353035	not available	Manual	Rainfall ((mm/24 hrs)	Zomba
DCCMS	Rainfall gauging station	Masambanjati	16351023	not available	Manual	Rainfall ((mm/24 hrs)	Thyolo
DCCMS	Rainfall gauging station	Monkey Bay Fisheries	14342008	not available	Manual	Rainfall ((mm/24 hrs)	Mangochi
DCCMS	Rainfall gauging station	Ngabu Mission	16342010	not available	Manual	Rainfall ((mm/24 hrs)	Ngabu
DCCMS	Rainfall gauging station	Ntubwi Liwonde	15351001	not available	Manual	Rainfall ((mm/24 hrs)	Machinga
DCCMS	Rainfall gauging station	Walker's Ferry	15344011	not available	Manual	Rainfall ((mm/24 hrs)	Mwanza
DCCMS	Rainfall gauging station	Walker's Ferry	15344011	not available	Manual	Rainfall ((mm/24 hrs)	Mwanza
DCCMS	Rainfall gauging station	Nkumano	10332002	not available	Manual	Rainfall ((mm/24 hrs)	Chitipa
DCCMS	Rainfall gauging station	Salima Aerodrome	13344000	not available	Manual	Rainfall ((mm/24 hrs)	Salima
DCCMS	Rainfall gauging station	Thyolo Agriculture	16351010	not available	Manual	Rainfall ((mm/24 hrs)	Karonga
DCCMS	Rainfall gauging station	Tomali	16342018	not available	Manual	Rainfall ((mm/24 hrs)	Chikwawa
DCCMS	Rainfall gauging station	Vinsenthe Agric	11333018	not available	Manual	Rainfall ((mm/24 hrs)	Mzimba

DCCMS	Rainfall gauging station	Zidyana EPA	13341006	not available	Manual	Rainfall ((mm/24 hrs)	Nkhotakota
DWR	River gauge station	Balaka water office	Mw/1R/001	not available	Manual	River depth (m.asl)	Balaka
DWR	River gauge station	Bua	5D2B	not available	Manual	River depth (m.asl)	Kasungu
DWR	River gauge station	Bua River @ S53 Roadbridge	5C1	not available	Manual	River depth (m.asl)	Nkhota-kota
DWR	River gauge station	Bua River at Mchinji	5E6	not available	Manual	River depth (m.asl)	Mchinji
DWR	River gauge station	Chambo River at Yotau Nyondo	9A13	not available	Manual	River depth (m.asl)	Chitipa
DWR	River gauge station	Chia Lagoon River @ Mtanga	15B6	not available	Manual	River depth (m.asl)	Nkhotakota
DWR	River gauge station	Chileka water office	Mw/5E/001	not available	Manual	River depth (m.asl)	Lilongwe
DWR	River gauge station	Chiwisi River at Bula (Usisya Road Bridge)	16G2	not available	Manual	River depth (m.asl)	Nkhatabay
DWR	River gauge station	Domasi River at Domasi T.T.C. (Domasi MIE))	2C3	not available	Manual	River depth (m.asl)	Zomba
DWR	River gauge station	Dwangwa River at Khwengwere (Kwengwere)	6C1	not available	Manual	River depth (m.asl)	Kasungu
DWR	River gauge station	Enqcongolweni Sch.	Mw/ 16F/001	not available	Manual	River depth (m.asl)	Mzimba
DWR	River gauge station	Kabwiri sere	Mw/4C/001	not available	Manual	River depth (m.asl)	Salima
DWR	River gauge station	Kakuyu dam	Mw/5E/002	not available	Manual	River depth (m.asl)	Lilongwe
DWR	River gauge station	Kalenje River at Chipwera		not available	Manual	River depth (m.asl)	Chitipa
DWR	River gauge station	Karonga @ Chilumba	17C1	not available	Manual	River depth (m.asl)	Karonga
DWR	River gauge station	Karonga @ Wowwe	17C11	not available	Manual	River depth (m.asl)	Karonga
DWR	River gauge station	Karonga water office	Mw/17A/001	not available	Manual	River depth (m.asl)	Karonga
DWR	River gauge station	Kuti well field	Mw/4C/002	not available	Manual	River depth (m.asl)	Salima
DWR	Lake gauge station	Lake Chilwa at Kachulu	2C10	not available	Manual	Lake depth (m.asl)	Zomba
DWR	Lake gauge station	Lake Malawi @ Monkey Bay	3A2	not available	Manual	Lake depth (m.asl)	Monkey Bay
DWR	Lake gauge station	Lake Malawi @ Nkhata Bay	16G1	not available	Manual	Lake depth (m.asl)	Nkhata Bay
DWR	River gauge station	Lichenya River @ Milonde	14C8	not available	Manual	River depth (m.asl)	Mulanje
DWR	River gauge station	Lifuliza @ Chitedze	15B14	not available	Manual	River depth (m.asl)	Nkhotakota
DWR	River gauge station	Lifuliza River at Nyoni	15B14	not available	Manual	River depth (m.asl)	Nkhotakota
DWR	River gauge station	Lilongwe River at Nkwenembela	4C2	not available	Manual	River depth (m.asl)	Lilongwe
DWR	River gauge station	Lingadzi @S11	4E2	not available	Manual	River depth (m.asl)	Lilongwe

DWR	River gauge station	Linthipe at Linthipe roadbridge (M1)	4B3	not available	Manual	River depth (m.asl)	Dedza
DWR	River gauge station	Linthipe River at Malapa 2	4B9	not available	Manual	River depth (m.asl)	Dedza
DWR	River gauge station	Linthipe River at Salima Rail bridge	4B1	not available	Manual	River depth (m.asl)	Salima
DWR	River gauge station	Lumbadzi River at Simakumi	4F6	not available	Manual	River depth (m.asl)	Dowa
DWR	River gauge station	Lumphasa River at Kango	16F20	not available	Manual	River depth (m.asl)	Nkhatabay
DWR	River gauge station	Lunyangwa River at Zombwe (Ekwendeni - Mpherembe Bridge)	7D8	not available	Manual	River depth (m.asl)	Mzuzu
DWR	River gauge station	Luviri River at Ng'onga (Roadbridge)	7G13	not available	Manual	River depth (m.asl)	Rumphi
DWR	River gauge station	Mchinji water office	Mw/5F/001	not available	Manual	River depth (m.asl)	Mchinji
DWR	River gauge station	Milenje River at Entandweni	6D11	not available	Manual	River depth (m.asl)	Kasungu
DWR	River gauge station	Mmanga school	Mw/ 1S/001	not available	Manual	River depth (m.asl)	Machinga
DWR	Lake gauge station	Monkey bay	Mw/3A/001	not available	Manual	Lake depth (m.asl)	Mangochi
DWR	River gauge station	Mulanje water office	Mw/14C/001	not available	Manual	River depth (m.asl)	Mulanje
DWR	River gauge station	Mulunguzi at William Falls	2B11	not available	Manual	River depth (m.asl)	Zomba
DWR	River gauge station	Mwanza prison	Mw/1K/001	not available	Manual	River depth (m.asl)	Mwanza
DWR	River gauge station	Nadzipokwe River at Mua Mission	3E1	not available	Manual	River depth (m.asl)	Dedza
DWR	River gauge station	Namikokwe River at Kampanikiza	3E5	not available	Manual	River depth (m.asl)	Dedza
DWR	River gauge station	Namwera well field	Mw/11A/001	not available	Manual	River depth (m.asl)	Mangochi
DWR	River gauge station	Ngabu water office	Mw/1H/001	not available	Manual	River depth (m.asl)	Ngabu
DWR	River gauge station	Nkhata Bay, Lweya	16F15	not available	Manual	River depth (m.asl)	Nkhata Bay
DWR	River gauge station	Nkhotakota water office	Mw/15B/001	not available	Manual	River depth (m.asl)	Nkhotakota
DWR	River gauge station	Nkhotakota well field	Mw/15B/002	not available	Manual	River depth (m.asl)	Nkhotakota
DWR	River gauge station	Nkhula @ Galeta	15B16	not available	Manual	River depth (m.asl)	Nkhotakota
DWR	River gauge station	North Rukuru River at Mwanjenja (HYCOS))	8A5	not available	Manual	River depth (m.asl)	Karonga
DWR	River gauge station	North Rumphi River at Chiweta	7H3	not available	Manual	River depth (m.asl)	Rumphi
DWR	River gauge station	Sekwa River at Wenga	9A5	not available	Manual	River depth (m.asl)	Chitipa
DWR	River gauge station	Shire River @ Mangochi	1T1	not available	Manual	River depth (m.asl)	Mangochi
DWR	River gauge station	Shire River @ Matope	1P2	not available	Manual	River depth (m.asl)	Blantyre
DWR	River gauge station	Shire River @ Tengani	1G3	not available	Manual	River depth (m.asl)	Nsanje

DWR	River gauge station	Shire River at Liwonde	1B1	not available	Manual	River depth (m.asl)	Machinga-Liwonde
DWR	River gauge station	Songwe River @ Mwandenga (HYCOS)	9B7	not available	Manual	River depth (m.asl)	Karonga
DWR	River gauge station	South Rukuru @ Phwezi	7G3	not available	Manual	River depth (m.asl)	Rumphi
DWR	River gauge station	South Rukuru River @ Mlowe	7G18	not available	Manual	River depth (m.asl)	Rumphi (Mlowe)
DWR	River gauge station	South Rukuru River at Phwezi	7G14	not available	Manual	River depth (m.asl)	Rumphi
DWR	River gauge station	Thondwe in Zomba	2B22	not available	Manual	River depth (m.asl)	Zomba
DWR	Automatic hydrological stations	Shire River at Liwonde	not available	not available	Automatic	River depth (m.asl)	Machinga
DWR	Automatic hydrological stations	Shire River at Chikwawa	not available	not available	Automatic	River depth (m.asl)	Chikwawa
DWR	Automatic hydrological stations	Lisunge River at Rail-bridge	not available	not available	Automatic	River depth (m.asl)	Neno
DWR	Automatic hydrological stations	Thuchila River at Chonde	not available	not available	Automatic	River depth (m.asl)	Mulanje
DWR	Automatic hydrological stations	Thangadzi East River at Gooke	not available	not available	Automatic	River depth (m.asl)	Nsanje
DWR	Automatic hydrological stations	Ruo River at Old M1 Road-Bridge	not available	not available	Automatic	River depth (m.asl)	Mulanje
DWR	Automatic hydrological stations	Shire River at Tengani	not available	not available	Automatic	River depth (m.asl)	Nsanje
DWR	Automatic hydrological stations	Ruo at Sandama	not available	not available	Automatic	River depth (m.asl)	Thyolo
DWR	Automatic hydrological stations	Bua River at Chizuma	not available	not available	Automatic	River depth (m.asl)	Nkhotakota
DWR	Automatic hydrological stations	Luewya River at Zayuka	not available	not available	Automatic	River depth (m.asl)	Nkhatabay
DWR	Automatic hydrological stations	South Rukur River at Mlowe	not available	not available	Automatic	River depth (m.asl)	Rumphi
DWR	Automatic hydrological stations	North Rumphi River at Chiweta	not available	not available	Automatic	River depth (m.asl)	Rumphi
DWR	Automatic hydrological stations	Shire River at Salewa	not available	not available	Automatic	River depth (m.asl)	Neno
DWR	Automatic hydrological stations	Dwambadzi River at Nhtanda	not available	not available	Automatic	River depth (m.asl)	Nkhotakota
DWR	Automatic hydrological stations	Linthipe at Malapa	not available	not available	Automatic	River depth (m.asl)	Salima
DWR	Automatic hydrological stations	Shire River at Matope	not available	not available	Automatic	River depth (m.asl)	Neno

## 7. Annex B. List of similar/complementing initiatives

ACTIVITY 3.1 Diagnosis of the current systems and equipment available in Malawi to gather climate data

DELIVERABLE 3.1.c

Organisation	Goal	Approach/Technology	Period	Learnings	Region	Links
TRIM	Community based weather forecasts	Smart phone app for observation data entry and forecast access	Ongoing	Linking data submission incentive to receipt of forecasted weather information	Africa	<a href="https://cbon.trimweb.it/">https://cbon.trimweb.it/</a>
Thamo	Weather sensors and forecasts	Sensors at schools, easy data transmission, online access to analysis	Ongoing	Integration with schools has strengthened operational sustainability. Integration of THAMO and AWS stations into joint platform has provided DCCMS with an operational assimilation overview.	Africa	<a href="https://tahmo.org/">https://tahmo.org/</a>
mWater	Water & Sanitation monitoring & management	Smartphone app for data entry and analysis (complex, scaled) - focus on groundwater in MW	Ongoing	Focus on water supply and sanitation operations in addition to groundwater observation	Global	<a href="https://www.mwater.co/platform">https://www.mwater.co/platform</a>
Malawi Red Cross	Early warning system in northern Malawi	SMS and online alert systems	2023	Not known at diagnosis	Global	<a href="https://510.global/2024/04/leveraging-localized-flood-models-in-malawis-battle-against-rising-waters/">https://510.global/2024/04/leveraging-localized-flood-models-in-malawis-battle-against-rising-waters/</a>
Smartphone4water	Water data entry	Smartphone app for citizen science/community based monitoring	Ongoing	Integration with students and research has supported sustained data capture and necessary user skills. National agencies are hesitant to use data.	South Asia	<a href="https://s4water.nepal.smartphones4water.org/">https://s4water.nepal.smartphones4water.org/</a>

Organisation	Goal	Approach/Technology	Period	Learnings	Region	Links
NWRA	Test smartphone app to digitise manual river gauge reader observations	Smartphone App for 25 Gauge Readers to record river level, send GPS location and photo of gauging plate	2023	DWR has login credentials to data. Sustained data submission is a challenge - some Gauge Readers continue to send observations, but some do not.	Malawi	No online publication
TEMBO	Cost-effective innovative sensor networks that can be financed by the climate services we develop using these sensors	Provision of three revenue bearing services in reservoir management, flood and early warning systems, and agricultural services - derived from cost-effective use of existing data and simple sensors (e.g., image velocimetry using OpenRiverCam for river velocity estimation, dry bed bathymetry using photogrammetry in OpenDroneMap, and wet bed bathymetry using sonar via a fish finder.)	Planned	Smartphone use to capture river velocity is simple and only requires a physical stand on which the phone is rested when capturing observation. Integration into manual river systems is needed for scaled use.	Africa	<a href="https://temboafrika.eu/">https://temboafrika.eu/</a>
NORAD	Develop simple weather forecast app at district level	SAREPTA project	Ongoing	not available at diagnostic	Africa	<a href="https://bistand.met.no/en/Sarepta">https://bistand.met.no/en/Sarepta</a>

Organisation	Goal	Approach/Technology	Period	Learnings	Region	Links
Photrack	Easy surface water, velocity and discharge measurement	Smartphone app that is non-intrusive, and enables optical flow measurement for natural water streams, irrigation, and waste water channels.	Ongoing	Sustained observations a challenge	Global	<a href="https://discharge.ch/">https://discharge.ch/</a>
WeatherSignal	Transforming your smartphone into a weather station	Smartphone app designed to leverage the power of your device's built-in sensors, capturing real-time atmospheric conditions and offering a unique approach to weather data collection.	Ongoing	Limited application update	Global	<a href="https://weathersignal.en.uptodown.com/android">https://weathersignal.en.uptodown.com/android</a>
Water Rangers	Easy in-field water quality monitoring	Citizen science with easy-to-use water quality testkits and open data platform to assist collection of water quality data for fresh and ocean water	Ongoing	Limited update by NHMS	USA	<a href="https://www.waterrangers.ca/">https://www.waterrangers.ca/</a>