Appendix 5

Site Works Reports

JICA Water Resources Advisor
Site Reconnaissance Report to Upper Reach of Tana River

1. Objectives:
   (1) Explanation of activities to Regional and Sub-Regional Offices in Tana Basin Area
   (2) Inspection and confirmation of proposed gauging stations for capacity building activities
   (3) Inspection of the current status of equipment which was procured during the last advisor activities (2017-2019)
2. Period: July 07 to 09, 2021
3. Participants (From Nairobi):
   (1) Mr. T. Okamura (JICA Expert, Team Leader/Water Resources Management)
   (2) Mr. Y. Kato (JICA Expert, Hydrological Monitoring/Flood and Drought Risk Assessment)
   (3) Mr. Gitau (JICA)
   (4) Ms. Pauline Nyamu (WRA HQ, Surface Water Officer)
4. Itinerary:

Date	Itinerary	Remarks
July 7, 2021 (Wed.)	08:00-10:30 Move from Nairobi to Embu, WRA Tana Regional Office 10:45-12:30 Explanation of Activities to the Regional Manager 12:50-14:00 Lunch Break 14:10-16:10 Move to Nyeri 16:10-16:40 Site Inspection on Gauging Station 4AC04 (New Chania) 16:40-18:30 Move to Embu, Stay in Embu	Weather: Cloudy
July 8, 2021 (Thu)	08:30-10:30 Move from Embu to Meru, WRA Meru Sub-Regional Office 10:50-11:30 Explanation of Activities to the Surface Water Officer of Meru 11:50-13:50 Move to Marimanti 13:50-14:50 Site Inspection on Gauging Station 4F10 (Kathita) 14:50-16:40 Move from Marimanti to Meru 16:40-17:50 Lunch Break 17:50-20:00 Move to Embu, Stay in Embu	Weather: Rainy in the morning and cloudy in the afternoon
July 9, 2021 (Fri)	08:00-09:20 Move from Embu to Muranga, WRA Upper Tana Sub-Regional Office 09:40-10:40 Explanation of Activities to Sub-Regional Manager 10:40-11:10 Move to Ruau 11:10-13:30 Site inspection 4BF01(Saba Saba), 4BF02, 4BC04 13:50-14:50 Lunch Break 15:00-15:30 Move to Thiba Dam Site 15:30-16:50 Site Inspection of Thiba Dam (Mwea Irrigation Project) 16:55-20:00 Move from Thiba Dam to Nairobi	Weather: Rainy in the morning and cloudy in the afternoon

5. Participants in the meeting
   (1) Tana Regional Office (July 7, 2021)
      1) Mr. John Munyao (Regional Manager)
      2) Mr. Phlip K. Munyua (Regional Technical Manager)
      3) Mr. Samuel Ndungu (Surface Water Officer, Tana RO)
   (2) Meru Sub-Regional Office (July 8, 2021)
      1) Mr. Alex M. Kimotho (SWO, Meru SRO)

2) Mr. Billon Gitonga (ICTA, SRO)
3) Ms. Milkah Machoka (AOA/Secretary, SRO)
4) Mr. Job Ochieng (WQPCA, SRO)
5) Mr. Samuel Ndungu (SWO, Tana RO)

(3) Upper Tana Sub-Regional Office (July 9, 2021)

1) Ms. Patricia Musau (Sub-Regional Manager, Upper Tana)
2) Ms. Jane Wairimu (SRO, SWO)
3) Mr. Samuel Ndungu (SWO, Tana RO)

6. Result and Findings

(1) Day 1: July 7, 2021 (Wed)

1) Tana Regional Office:

Regional Manager, Mr. John Munyao accepted JICA Expert Team visit together with Mr. Phlip K. Munyua (Regional Technical Manager) and Mr. Samuel Ndungu (SWO). After explanation of outlines of activities, site visit was made to New Chania Gauging Station (4AC04). It was reported that procured equipment during the last JICA advisor activities are as follows:

a) Data logger: Four sets

One is installed at Meru SRO, 4F10

Other three are kept at SRO of Kerugoya, Muranga, and Garissa. Detailed status of other three equipment should be reported.

2) New Chania Gauging Station (4AC04)

a) It was confirmed that the station 4AC04 is adequate as one of the three representative stations for capacity building activities.

b) Other findings are as shown in photographs below.

	
Photo-01: The road from Nairobi to Embu near Thika. Road widening works started from March 2021 for two more lanes.	Photo-02: Explanation of Activities to Tana Regional Office


Photo-03: Roof water harvesting system installed at Regional Office


Photo-04: One of the terminal computers for Hydrological Database in Tana RO

Photo-05: Gauging station 4AC04 New Chania near Nyeri Town

Photo-06: 4AC04 New Chania Staff Gauge Manual reading

Photo-07: Maximum flood water level is indicated using survey pole, which is slightly below the bridge level.

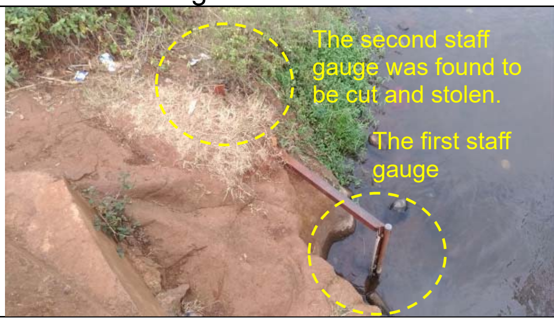

Photo-08: The second staff gauge was found to be cut and stolen. Installation of concrete-made staff is urgently required.

c) River width at gauging station was 9.4 m. The bridge span was 10.6 m. Flood water level was 3.0 m higher than the current river water level (as indicated in Photo-07).

d) The steel made second staff gauge was found to be cut and stolen. Currently only up to 150 cm can be measured. A new gauge staff with concrete pole is recommended to be installed immediately.

(2) Day 2: July 8, 2021 (Thu)

1) Meru Sub-Regional Office:

As the Sub-Regional Manager was not in, Mr. Alex M. Kimotho (SWO) accepted JICA Expert Team visit together with Mr. Billon Gitonga (ICTA). After explanation of outlines of activities, site visit was made to Kathita Gauging Station (4F10).

2) Kathita Gauging Station (4F10)

a) It was confirmed that the station 4F10 is adequate as one of the three representative stations for capacity building activities.

b) Other findings are as shown in photographs below.

Photo-09: Explanation of Activities to Meru Sub-Regional Office

Photo-10: Explanation of Activities to Meru Sub-Regional Office

Photo-11: One of the terminal computers for Hydrological Database in Meru SRO

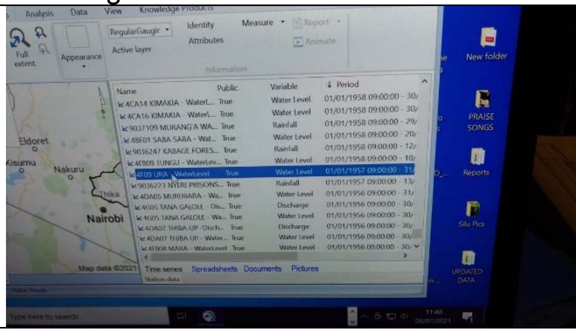

Photo-12: Screen of Hydrological Database (Mike Info)

Photo-13: Sign board of 4F10 Kathita Gauging Station

Photo-14: 4F10 Kathita Gauging Station at the left bank of the river

Photo-15: The first gauge is damaged and slanted caused by flood. The second gauge also has damages but it is still measurable.

Photo-16: Three layers of gabion mattress installed during the previous advisor activities to protect data logger house.

	
Photo-17: Data logger house	Photo-18: Inside the data logger house. Sensor cable is retrieved from the bottom of the first gauge.
	
Photo-19: Opening the data logger box for data retrieval.	Photo-20: Data retrieval trial by using data collector.

c) There are four concrete posts for measurement.

d) The first and the second posts were damaged due to stones brought by flood. The second gauge is still measurable, but the first gauge is slanted. It is required to adjust the position of the first gauge.

e) Data retrieval was executed by using data collector, however, it was not possible to retrieve the data. The cause of the mis-retrieval was rectified by the JICA Expert Team.

f) As a result, due to lack of remaining battery inside the data logger, the data could be retrieved up to March 2019.

(3) Day 3: July 9, 2021 (Fri)

1) Upper Tana Sub-Regional Office (Muranga):

Sub-Regional Manager, Ms. Patricia Musau accepted JICA Expert Team visit together with Ms. Jane Wairimu (SRO, SWO). After explanation of outlines of activities, site visit was made to Saba Saba Gauging Station (4BF01).

Photo-21: Explanation of Activities to Upper Tana Sub-Regional Office

Photo-22: Explanation of Activities to Upper Tana Sub-Regional Office. SRO Manager (Left) and SWO (Right).

Photo-23: Gauging station 4BF01 Saba Saba It is located under the bridge crossing national road. The third gauge can be seen in the center.

Photo-24: The first and the second gauge of 4BF01 Saba Saba looking from upstream.

Photo-25: The first gauge of 4BF01 Saba Saba. There seems to be much sedimentation under the bridge.

Photo-26: The second gauge of 4BF01 Saba Saba.

2) Saba Saba Gauging Station (4BF01)

a) It was confirmed that the station 4BF01 is NOT adequate as one of the three representative stations for capacity building activities, considering the following situation:

- 4BF01 is located under the bridge.
- The upstream and downstream reaches are covered with a lot of vegetation.
- There seems to be much sedimentation under the bridge, which fluctuates the riverbed level so often.
- According to the SWO, the first gauge read is stable for some time, but suddenly changed. For example, 48 cm reading for one week, then, 58 cm for one week.

This means that after the event of big discharge, it is probable that riverbed level changes. This frequent change in riverbed cannot give us correct result of measurement which is measured as water level and converted into discharge.

- Therefore, it is not preferable to apply this station as a representative one.

b) After the site visit to 4BF01, the team visited some other gauging stations. However, so far, there is no other appropriate sites found. It is required to ask Upper Tana or Kerugoya sub-regional office to list up possible candidate location for decision.

<table>
<tr><td>
</td><td></td></tr>
<tr><td>Photo-27: 4BF02 without gauge along National Road A2. According to SWO in Upper Tana SRO, sediment and water quality are being measured.</td><td>Photo-28: 4BC04 along National Road A2. Due to road expansion works, discharge measurement activities will possibly be disturbed. Gauge relocation may be required.</td></tr>
<tr><td>
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</td></tr>
<tr><td>Photo-29: 4BC04 from Downstream. Concrete pier for new bridge can be seen on the left.</td><td>Photo-30: Staff gauge of 4BC04.</td></tr>
</table>

3) Visit to Thiba Dam construction site

a) After the lunch break, JICA Expert Team visited the construction site of Thiba Dam (Mwea Irrigation Project). Design dam height is 40.6 m, and the crest length is 1,108.2 m. It is scheduled to increase the current rice production of the area from 114,000 ton to 200,000 ton. The progress of the works is reported to be at 58%. Currently, dam embankment is underway.

	
Photo-31: A spillway located at the right side of the main dam.	Photo-32: Dam embankment in progress (view from the left bank, the left side is upstream side)
	
Photo-33: Outlet channel for irrigation water. This channel is currently used for river diversion.	Photo-34: Dam embankment view from upstream.

7. Conclusions and recommendations

(1) Confirmation of proposed gauging stations for capacity building activities

1) In the Work Plan, JICA Expert Team proposed candidate gauging stations for (i) river cross section survey, and (ii) discharge measurement, for capacity building activities of H-Q curve preparation.

2) Of the proposed three gauging stations by the JICA Expert Team, inspection results are as follows:

Table Proposed Gauging Stations

Code	Station Name	River	Status/Recommendations
4F10	Kathita	Kathita	● The location is ***<u>appropriate</u>*** for capacity building activities. ● Water level sensor and data logger is installed in the previous advisor activity (2017-2019). ● The first and the second gauges are damaged by flood. It is required to repair/adjust gauges for proper measurement. ● Operation and maintenance procedures for the data logger should be reconfirmed to WRA officer for sustainable measurement and data collection.
4BF01	Saba Saba	Saba Saba	● The location is ***<u>not appropriate</u>*** for capacity building activities.

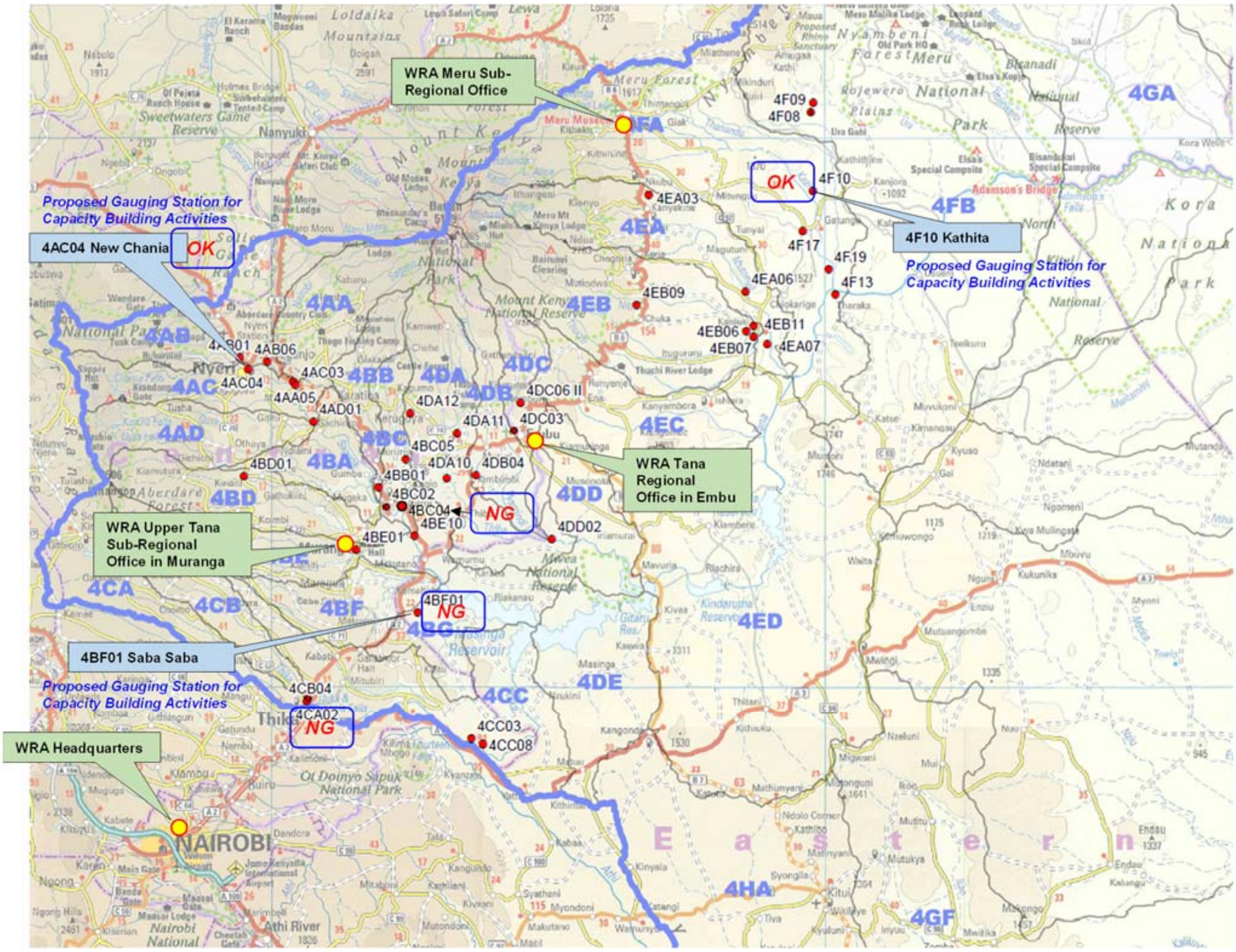
			● The riverbed levels at the measuring point fluctuate frequently, which would give us incorrect discharge data. ● It is required to select some other gauging stations as candidates with photos of the station, a location map, and evaluation by SW officer. Such information should be submitted to JICA Expert Team for further consideration and decision.
4AC04	New Chania	Chania	● The location is ***<u>appropriate</u>*** for capacity building activities. ● The second gauge was found to be cut and stolen. The gauge should be reinstalled, preferably with concrete post. ● To measure flood water level, the third gauge post should be installed.

(2) Gauges affected by road expansion works

1) Some gauges are installed under the bridges along national road. Some national roads are under construction works of expansion of their lanes.
2) Due to construction works, river cross sections at some gauges are changed frequently.
3) It is recommended to shift such gauges to more stable locations. (Please refer to Photos 28 to 30 above.)

(3) Status of procured data loggers

1) During the previous JICA advisor activities, four sets of data logger were procured. One is installed at 4F10 Kathita in Meru SRO.
2) The status of other three data loggers should be rectified. Those three other data loggers were distributed to Kerugoya, Muranga, and Garissa sub-regional offices.
3) It is requested from JICA Expert Team to rectify the status of those three data loggers and it should be reported to JICA Expert Team, so that JICA Expert Team is able to formulate further procurement plan for equipment.



Location Map of the Upper Tana Basin, Offices and Gauging Stations

JICA Water Resources Advisor
Site Reconnaissance Report to Upper Reach of Tana River

1. Objectives:
   (1) Inspection of the current status of equipment at the gauging stations
2. Period: October 26 to 27, 2021
3. Participants (From Nairobi):
   (1) Mr. T. Okamura (JICA Expert, Team Leader/Water Resources Management)
   (2) Mr. Y. Azuma (JICA Expert, Telecom/Innovation Technology)
   (3) Ms. Pauline Nyamu (WRA HQ, Surface Water Officer)
4. Itinerary:

Date	Itinerary	Remarks
October 26, 2021 (Tue)	07:30-10:10 Move from Nairobi to Embu, WRA Tana Regional Office 10:20-11:00 Discussion on itinerary for sites inspection and issue of the telemetric gauging stations, 11:10-11:50 Move to Kerugoya Sub-Regional Office 11:50-12:10 Discussion on the site inspection 12:15-12:35 Move to Gauging Station 4DA11 (Water level gauging) 12:35-12:55 Site Inspection on the Gauging Station 4DA11 12:55-13:30 Move to Upper Tana Sub-Regional Office 13:30-13:40 Discussion on the site inspection 13:40-14:20 Move to Gauging Station 4BB01 (Water level gauging) 14:20-15:00 Site Inspection on the Gauging Station 4BB01 15:00-15:20 Move to Gauging Station 4BE10 15:20-15:50 Site Inspection on the Gauging Station 4BE10 15:50-16:10 Move to Embu 16:10-17:00 Lunch Break 17:00-18:50 Move to Embu and stay in Embu	Weather:Sunny day
October 27, 2021 (Wed)	07:50-08:00 Move to WRA Tana Regional Office 08:00-08:30 Waiting WRA staff 08:30-09:30 Move to Gauging Station 4DD02 (Water level & Rainfall gauging) 09:30-10:20 Site Inspection on Gauging Station 4DD02 10:20-12:20 Move to Kerugoya Sub-Regional Office 12:30-13:10 Move to Upper Tana Sub-Regional Office 13:30-14:00 Move way to 4CC08 14:00-15:00 Lunch Break 15:00-16:00 Move to Gauging Station 4CC08 (Water level gauging) 16:00-16:30 Site Inspection on Gauging Station 4CC08 16:30-18:50 Move to Nairobi	Weather: Sunny and occasional rain in afternoon

5. Participants in the meeting
   (1) Tana Regional Office (October 26 and 27, 2021)
      1) Mr. John Munyao (Regional Manager)
      2) Mr. Samuel Ndungu (Surface Water Officer, Tana RO)
      3) Mr. Wilson Githu (ICTA, Tana RO)
   (2) Kerugoya Sub-Regional Office (October 26, 2021)
      1) Mr. Moses Kasami (Kerugoya SRO)

2) Ms. Jane Njuguna (SWO, Kerugoya SRO)

(3) Upper Tana Sub-Regional Office (October 26 and 27, 2021)

1) Ms. Jane Njoroge (SWO, Upper Tana SRO)

6. Result and Findings

(1) Day 1: October 26, 2021 (Tue)

1) Water Level Gauging Station (4DA11)

a) It is observed that the station 4DA11 is working.

b) Status-quo are as shown in photographs below.


Photo-01: Gauging Station House

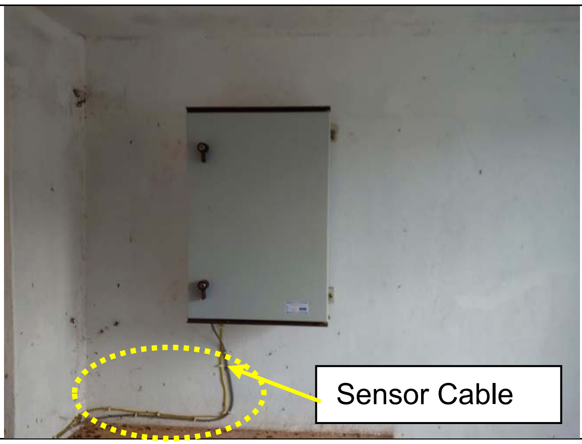


Photo-02: Equipment Panel with a key

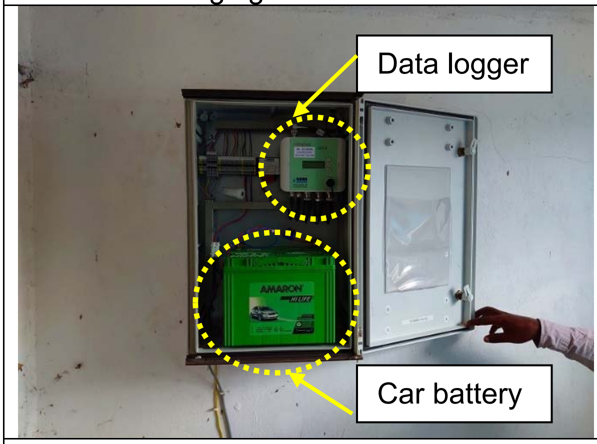


Photo-03: Inside of the Equipment Panel

Photo-04: Data logger (SEBA in Germany)

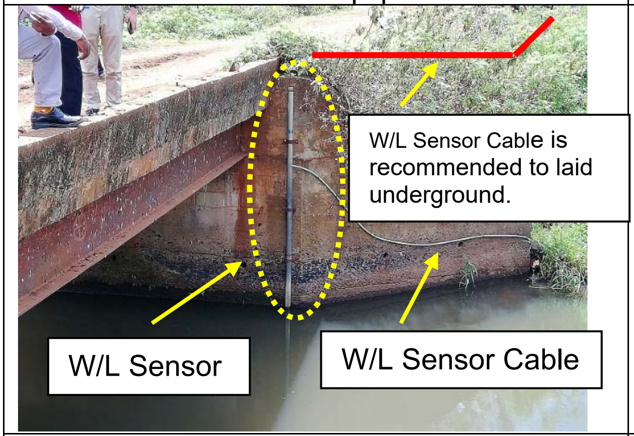


Photo-05: Water Level (W/L) Sensor


Photo-06: Staff Gauge

c) Followings are discovered.

- W/L sensor cable from the data logger to the W/L sensor is recommended to install underground it is because that high possibility to wash out in case of big flood and is subject to vandalism (refer to the Photo-05).
- The Cable inside of the house shall be coved by protector (refer to the Photo-02).

2) Water Level Gauging Station (4BB01)

   a) It is observed that the station 4BB01 is working.

   b) Status-quo are as shown in photographs below.

Photo-01: Gauging Station House

Photo-02: Equipment Panel: Data logger (SEBA in Germany) and Car battery

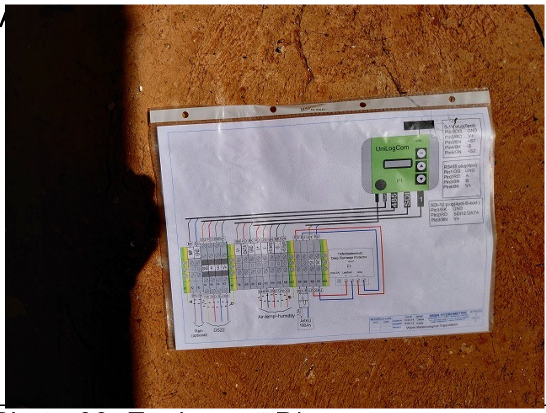


Photo-03: Equipment Diagram

W/L Sensor cable shall be installed properly (like a spaghetti)

Photo-04: Workmanship of cable installation

Photo-05: Old Water Level (W/L) Sensor and Staff Gauge

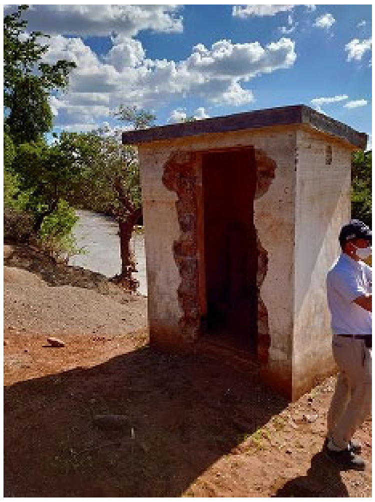
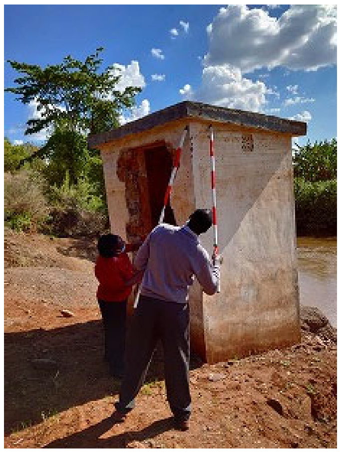
Photo-06: Reinstalled W/L sensor

c) Followings are discovered.
   - The W/L Sensor Cable inside of the house shall be installed properly avoiding a spaghetti and coved by protector (refer to the Photo-04).
   - Adoption of cable box is subject to discussion with WRA, it is easy maintenance but will be subject to vandalism (refer to the photo-06)

3) Water Level Gauging Station (4BE10)

a) It is observed that the station 4BE10 is not working due to vandalism.

b) Status-quo are as shown in photographs below.

	
Photo-01: Signboard of the Project	Photo-02: Gauging House is vandalized
	
Photo-03: Staff Gauges (in total 6 pcs)	Photo-04: Past Flood Level

c) Followings are discovered.
   - Countermeasure for vandalism shall be considered in case of new equipment installation.
   - Gauging house shall be constructed at no-flood level (refer to the Photo-04).

(2) Day 2: October 27, 2021 (Wed)

1) Water Level and Rainfall Gauging Station (4DD02)

a) According to WRA, it is observed that the station 4DD021 is not working due to malfunction of equipment (the data logger made by ISODAQ)

b) Status-quo are as shown in photographs below.

Photo-01: Gauging House

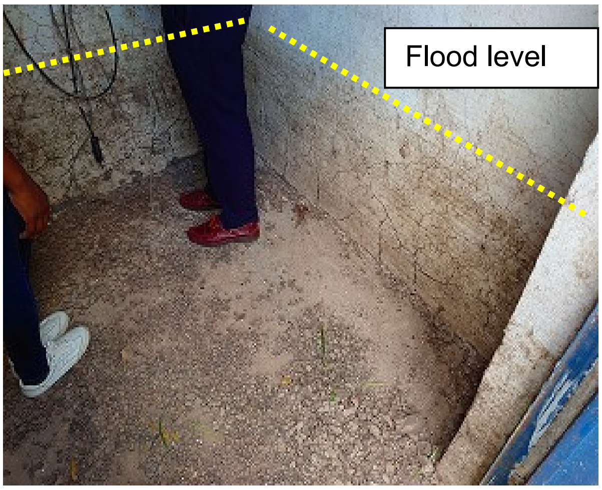


Photo-02: Sedimentation of sand/mud due to past flood inside the gauging house

Photo-03: Data logger (ISODAQ), There is nest inside

Photo-04: Nest of bees inside of the gauging house

Photo-05: Water Level Sensor

Photo-06: Staff Gauges, one is stolen

c) Followings are discovered.
   - The data logger, ISODAQ cannot be opened because special wrench is required.
   - Gauging house shall be constructed at no-flood level (refer to the Photo-02).
   - Clean-up of the gauging house shall be conducted avoiding nest (refer to the Phto-04).
   - 4G signal of mobile network is available, which maybe is not cause of the malfunction of the data logger.

2) Water Level Gauging Station (4CC08)

a) It is observed that the station 4CC08 is working

b) Status-quo are as shown in photographs below.

	
Photo-01: Gauging House	Photo-02: Data logger (SEBA) and Car battery
	
Photo-03: Equipment is supported with wood	Photo-04: Water Level (W/L) Sensor

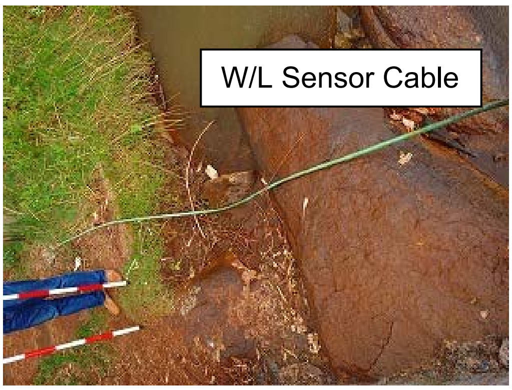



Photo-05: W/L sensor cable is exposed	Photo-06: Staff Gauges

c) Following is discovered.

- The W/L sensor cable is exposed, which is cause of cutting and/or stolen.

7. Study of Data Loggers

(1) ISODAQ data logger

We have discovered unused ISODAQ data logger at WRA Headquarters and opened the equipment as shown in photos below.

Photo-01: Outer box of ISODAQ data logger

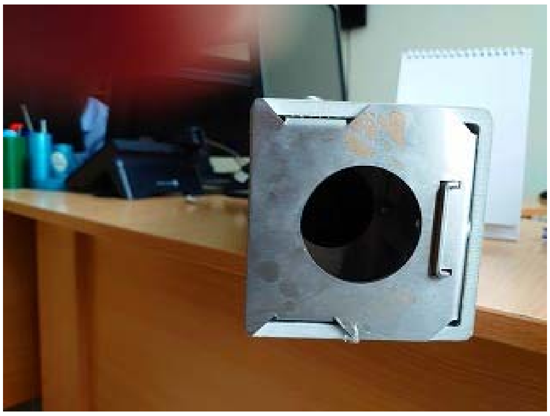


Photo-02: Outer box of ISODAQ data logger

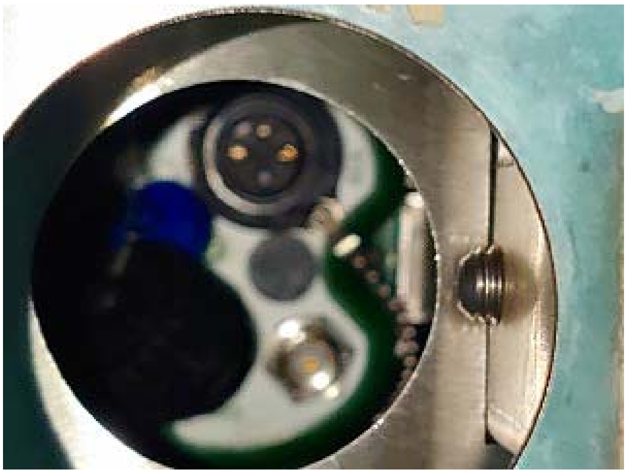


Photo-03: Outer box of ISODAQ data logger

Photo-04: Data logger

Photo-05: Data logger

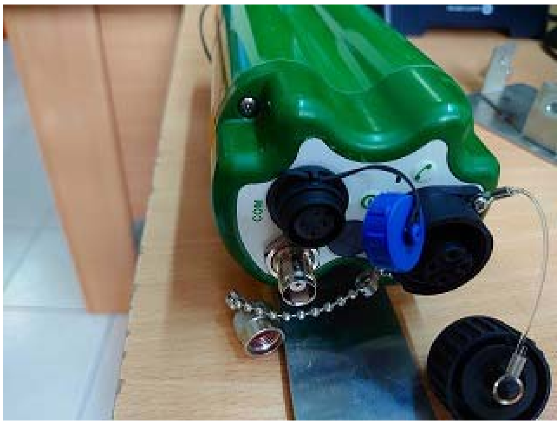


Photo-06: Data logger

We have obtained technical information from home page of ISODAQ thru Internet and main features are as follows:

1) The FROG RX GSM/GPRS telemetry logger is the latest addition to our existing range of robust data logging and telemetry solutions manufactured by Isodaq Technology, a division of Hydro-logic Ltd. In U.K.
2) Isodaq Technology's (UK) Frog RX GPRS data logger is proving a major industry success, with over 1500 units already installed in the water and environmental monitoring sector, both in the UK and overseas, in organizations including local drainage authorities, water companies, government organizations such as the Environment Agency, monitoring contractors, consultants and universities.
3) Digital or Analogue input options, for example
    a) Rainfall gauge: Digital tip-event count
    b) Water level sensor: 4-20ma or SDI12 (Serial Digital Interface at 1200 baud)
4) Ultra-low power battery operated for remote, harsh environments.
5) Hydrometric sensors include tipping-bucket rain gauge, mini-weather station and depth level pressure sensors.
6) FROG's battery power options make it the ideal choice for both low and high-priority applications e.g flood warning. Battery options include an internally fitted Alkaline or Lithium battery pack, both field replaceable, plus a link to an external 12 V lead acid battery.
    a) Min. 5 year life with ultra-low battery power management techniques to extend battery life for many applications using Isodaq's 'check-in' data collection mode, particularly effective when combined with low-cost GPRS 'always-on' protocols.
    b) Up to 2 years life with long life lithium battery with modem always on ready for flood or pollution warning communications. Unlimited life with external rechargeable 12V lead-acid battery fitted to a solar or wind trickle-charging system
7) Logging
    a) Strategies - Periodic, frequency pulse count, event.
    b) Log intervals - User-specified from 10 secs to12 hrs. Data is stored at 'cardinal points' as per specified interval (e.g. 15 minutes logging at 00:00, 00:15, 00:30, 00:45 etc.)
8) Communications: Internal GSM/GPRS modem (800/900/1800/1900 MHz)

(2) Study of SEBA Data Logger

We have obtained technical information from home page of SEBA thru Internet and main features are as follows:

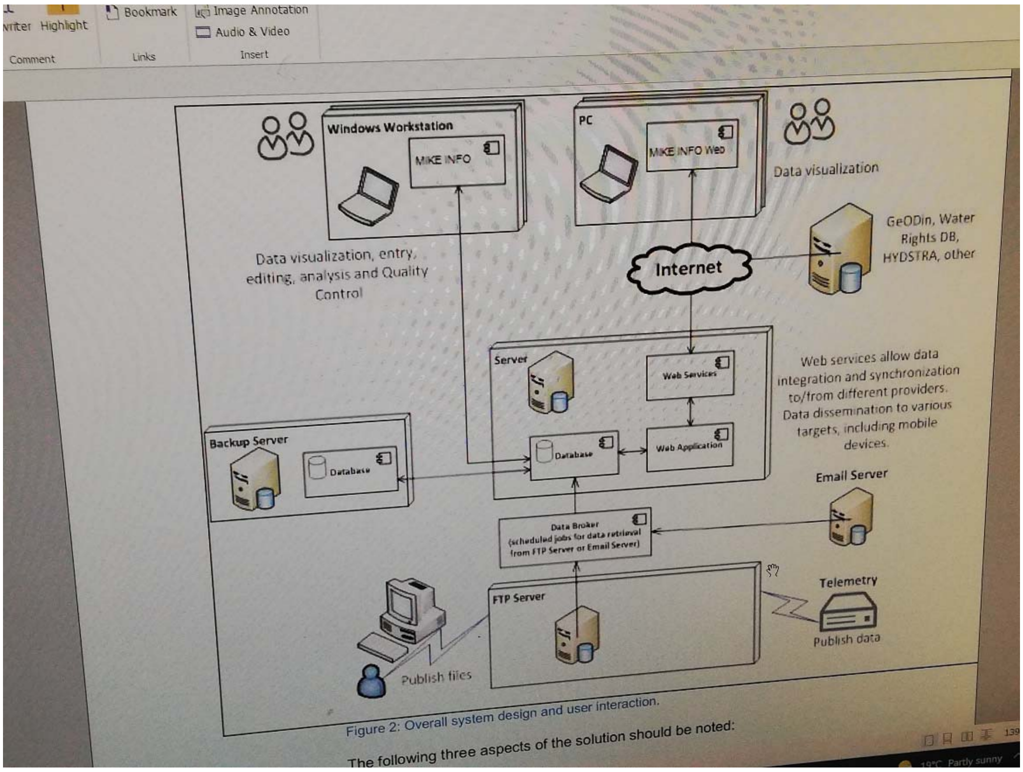
1) The UnilogCom (terminal unit) can digitally record water level or any other parameter such as flow, water quality or rainfall. The implementation of a state-of-the-art serial flash memory enables a relatively high data capacity combined with high data security.
2) The new logger systems also stands out by a lower power consumption and reduced dimensions of the electronic circuit board.
3) The most important features are as follows:
    a) Different registration modes: time-, dynamic- or event controlled
    b) Individual on/off control of attached sensors (optimizing power consumption)
    c) •comprehensive alarm management with cellular modem incl. SMS messaging
4) Controller: 32 Bit Flash controller with integrated WatchDog, RTC-IC Real Time Clock
5) Memory capacity: 16 MB (= 1,120,000 readings)
6) Save intervals: 2 min – 99 hours

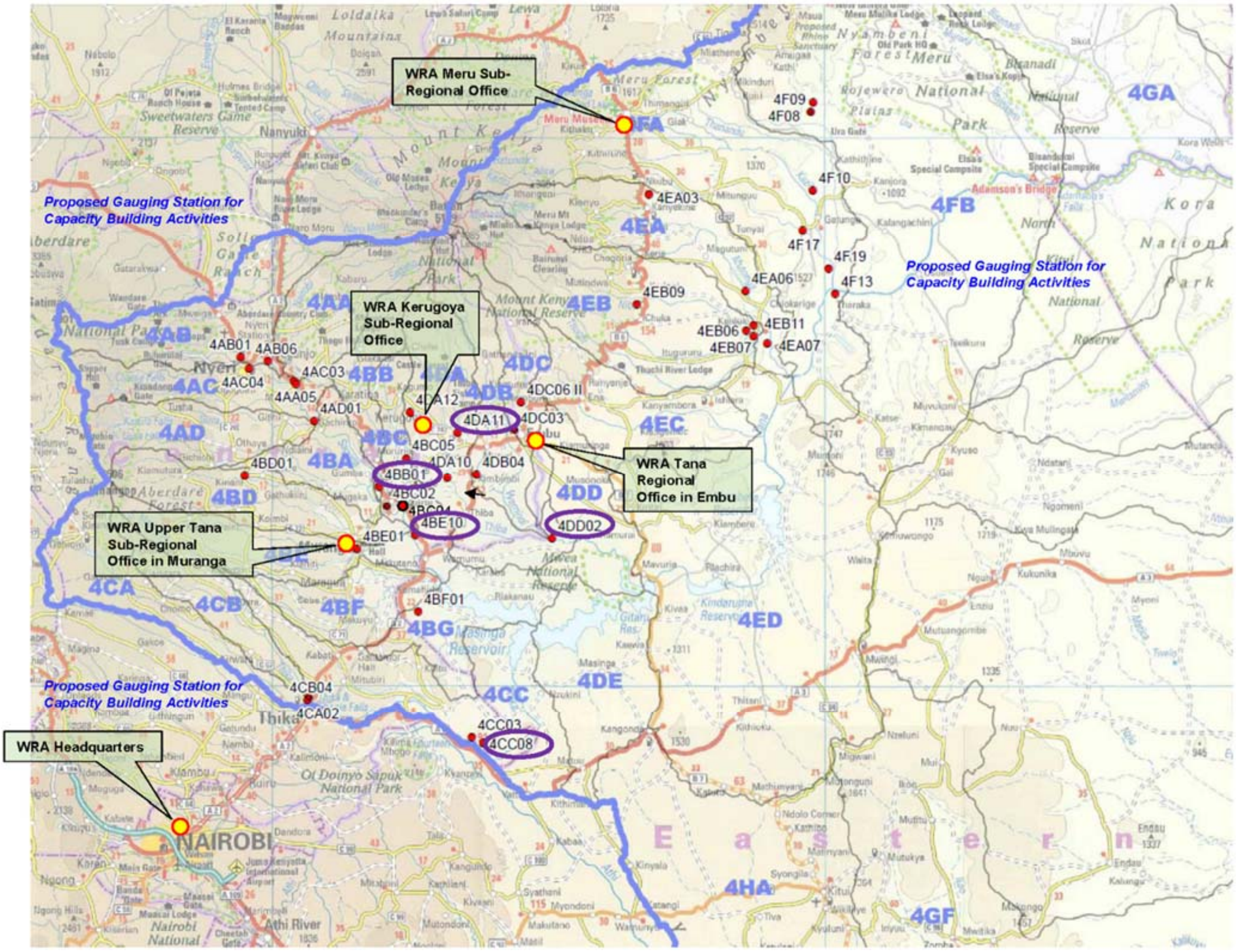
7) Channels: Max. 32
8) Measurement routines: Single value, Average value, Event clock, Delta mode
9) Communication: RS 232 (standard), Bluetooth® (optional)
10) Inputs: RS 485 sensor interface (SHWP), SDI-12 sensor interface, 2 analog inputs (bi/unipolar) for current/voltage (e.g. 0-1 V, 4-20 mA, etc.),
11) Power supply: 12 VDC
12) Operating temperature: -40 °C to +70 °C
13) Modem: GPRS/EDGE/UMTS/HSDPA/HSDPA+/LTE (4G)
14) Frequencies: 800/900/1800/2100/2600 MHz (Worldwide)

8. Data Collection System at WRA Headquarter

Following information are obtained from WRA with hearing.

1) Raw data is transmitted from the gauging stations with one hour interval automatically and processed three hours data thru the FTP server.
2) The raw data is verified comparing the manual reading data.
3) WRA conducts periodic maintenance works with 3 months interval.
4) There are three vendors of the data logger such as pressure type and radar type, i.e.,
   a) Seba
   b) Isodaq
   c) Campbell
5) The equipment was procured thru a bidding/tendering in WB project.
6) There is inventory list of the equipment that describes the vendors name, operational conditions etc.
7) Data collection system is shown in the following drawing.





Location Map of the Upper Tana Basin, Offices and Gauging Stations

JICA Water Resources Advisor

Site Reconnaissance Report to Upper Reach of Tana River

1. Objectives:
   (1) Confirmation of status of water monitoring station
2. Period: June 2 to 3, 2022
3. Participants (From Nairobi):
   (1) Mr. T. Okamura (JICA Expert, Team Leader/Water Resources Management)
   (2) Mr. Gilbert M. Chumo
4. Itinerary:

Date	Itinerary	Remarks
June 2, 2022 (Thu)	07:00-09:50 Move from Nairobi to Embu, WRA Tana Regional Office 09:50-11:20 Interview with Mr. Phillip Karanja Munyua (Technical Manager, Tana RO) on the procedures and status of Surface Water Monitoring 11:20-13:25 Move to Meru 13:30-14:10 Lunch 14:20-16:00 Interview with Mr. Alex Kimotho (Surface Water Officer) , Meru Sub-Regional Office	Weather: Sunny
June 3, 2022 (Fri)	06:30-08:15 Move from Meru to Embu 09:30-12:30 Meeting with Surface Water Officers of Kerugoya and Muranga for the status of the Surface Water Monitoring Stations. 12:30-13:10 Meeting with Mr. Githu (ICT Officer in Tana RO) 13:10-14:10 Lunch 14:10-15:10 Move from Embu to Muranga 15:10-16:40 Move from Muranga to Nairob	Weather: Sunny

5. Participants in the meeting
   (1) Tana Regional Office (June 2, 2022)
   Mr. Phillip Karanja Munyua (Technical Manager)
   (2) Meru Sub-Regional Office (June 2, 2022)
   Mr. Alex Kimotho (Surface Water Officer)
   (3) Embu Regional Office (June 3, 2022)
   Mr. Phillip Karanja Munyua (Technical Manager)
   Ms. Jane Njuguna (SWO, Kerugoya SRO)
   Ms. Jane Wairimu(SWO, Muranga SRO)
   Mr. Wilson Githu (ICT Officer, Tana RO)

6. Findings

(1) Tana RO

On June 2, 2022, Mr. Phillip Karanja Munyua (TM, Tana RO) explained us that Catchment Management Strategy (CMS) 2014 mandated the numbers of regular gauging stations (RGSs) to be monitored. After that Basin Plan was prepared in August 2020 under the Kenya Water Security and Climate Resilience Project (KWSCRP).

Tana RO prepares Water Resources Situation Report (Quarterly) and submit it to WRA headquarters. Mr. Munyua provided us a copy of Water Resources Situation Report for the 1st Quarter of FY2021/2022 i.e., July to September 2021. In the report, 86 RGSs are listed. Based on the list, JICA Expert Team conducted interviews with Surface Water Officers of Meru, Kerugoya and Muranga Sub-Regional Offices to get detailed information on the status of the RGSs.

(2) Meru SRO

On June 2, 2022 in the afternoon, JICA Expert Team visited Meru SRO and had an interview with Mr. Alex Kimotho (SWO). The result of the interview is summarized in the table “Status of Regular Gauging Stations in Tana Basin Area.”

There are 16 RGSs under Meru SRO. Of them 13 are operational and 3 are not operational.

(3) Kerugoya SRO

On June 3, 2022 in the morning, JICA Expert Team had a meeting with Kerugoya SWO Ms. Jane Njuguna in Embu.

The result of the interview is summarized in the table “Status of Regular Gauging Stations in Tana Basin Area.”

There are 13 RGSs under Kerugoya SRO. All of them are operational.

(4) Muranga SRO

On June 3, 2022 in the morning, JICA Expert Team had a meeting with Muranga SWO Ms. Jane Wairimu in Embu.

The result of the interview is summarized in the table “Status of Regular Gauging Stations in Tana Basin Area.”

There are 53 RGSs under Muranga SRO. Of them 47 are operational and 6 are not operational.

7. Photos during the interview

	
Interview with Mr. Munyao, Tana RO, Technical Manager	After an interview with Mr. Kimotho, Meru SRO, Surface Water Officer (center)

	
Interview with Mr. Munyao (Tana RO, TM, right), Ms. Jane Wairimu, Muranga SRO Surface Water Officer (left end), Ms. Jane Njuguna, Kerugoya SRO, Surface Water Officer (2nd from left)	A vehicle in Embu (Tana RO). There seems to be no budget for fuel and maintenance cost of the car. The same situation was observed for three cars in Meru SRO.

<end of report>

JICA Water Resources Advisor
Site Reconnaissance Report to Upper Reach of Tana River

1. Objectives:
   (1) Confirmation of status of water monitoring station
   (2) Requirement of capacity building for surface water officer for monitoring, data arrangement, storage, analysis and publication
   (3) Confirmation on intention to continue discharge measurement/river cross section survey by WRA itself or sublet
2. Period: June 9 to 10, 2022
3. Participants (From Nairobi):
   (1) Mr. T. Okamura (JICA Expert, Team Leader/Water Resources Management)
   (2) Mr. Y. Azuma (JICA Expert, Telecom/Innovation Technology)
   (3) Mr. T. Shimizu (JICA Kenya Office): June 9 only
   (4) Mr. Gilbert M. Chumo
   (5) Mr. Denis Masika
   (6) Ms. Doreen Iluba
4. Itinerary:

Date	Itinerary	Remarks
June 9, 2022 (Thu)	07:00-09:20 Move from Nairobi to Embu, WRA Tana Regional Office 09:20-09:50 Waiting other members 09:50-11:30 Discussion on the issues mentioned in the (1) above 11:30-13:10 Moving 13:10-13:50 Lunch Break 13:50-14:10 Move to Kerugoya Sub-Regional Office 14:10-16:00 Discussion on the issues mentioned in the (1) above 16:10-16:25 Move to Gauging Station 4DA11 (Thiba) 16:25-16:35 Site Inspection on 4DA11 16:35-16:40 Move to Thiba Dam 16:40-17:00 Move to Embu and stay in Embu	Weather: Sunny
June 10, 2022 (Fri)	07:45-08:45 Move to Muranga Sub-Regional Office 09:00-13:30 Discussion on the issues mentioned in the (1) above 13:30-13:45 Move to Gauging Station 4BE01 (Maragua) 13:45-14:25 Site Inspection on 4BE11 14:25-15:25 Lunch Break 15:25-16:40 Move way to 4CB04 (Bule post, Thika) 16:40-17:10 Site Inspection on 4CB04 17:10-18:20 Move to Nairobi	Weather: Sunny

5. Participants in the meeting
   (1) Tana Regional Office (June 9, 2022)
       Mr. John Munyao (Regional Manager)
       Mr. Samuel Ndungu (Surface Water Officer)
       Mr. Philip Karanja Munyua (Technical Manager)
   (2) Kerugoya Sub-Regional Office (June 9, 2022)
       Ms. Jane Njuguna (SWO)

(3) Muranga Sub-Regional Office (June 10, 2022)

Ms. Patricia Musau (Acting Sub-basin Coordinator)

Ms. Faith Mbathi (Hydrologist)

6. Result and Findings

(1) Day 1: June 9, 2022 (Thu)

1) An interview with Mr. Munyao, Regional Manager of Tana Basin Area

According to Mr. Munyao (RM-Tana), there are 42 stations which were requested from WRA HQ to monitor. All the staff at sub-regional office are capable for observation, discharge measurement and survey works, data storage and reporting.

2) Checking of Mike Info database at ICT section of Tana RO

Moved to ICT section and checked the contents of Mike Info. There is a function of Mike Info to prepare H-Q curve. By looking at 4G01 Garissa station as an example, the same rating curve was used from 1985 to 2015.

3) An interview with Ms. Jane Njuguna, SWO at Kerugoya SRO

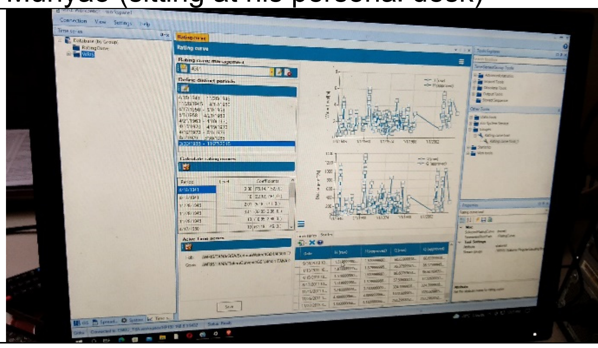
Ms. Jane Njuguna (SWO) shared quarterly water resource situation report (2nd Quarter 2021-2022 i.e., Oct-Dec. 2021). Ms. Njuguna informed that SRO does not have survey equipment (levels) because it was stolen.

4) Water Level Gauging Station (4DA11): previous visit was on October 26, 2021

a) It was observed that the station 4DA11 was working well.

b) Following was discovered.

- There are many nests of bees inside of the gauging house, which seems no clean-up at the gauging house.

	
An interview with Tana Regional Manager Mr. Munyao (sitting at his personal desk)	An interview with Tana Regional Manager Mr. Munyao (sitting at his personal desk)
	
Checking water level data in Mike Info system with ICT Officer, Mr. Githu (center)	A sample screen of 4G01 H-Q curve examination. Mike Info has a function to prepare H-Q curve.

A building of Thiba Sub-Regional Office in Kerugoya

An interview with Ms. Jane Njuguna (SWO) at Kerugoya Office.

Site Reconnaissance at 4DA11 Telemetric Gauging Station. A pressure gauge at the right bank of the river. A building of telemetric equipment on the upper right.

A manual reading gauge at the left side of the river at 4DA11. Site visit with SWO Ms. Jane Njuguna (Kerugoya SRO).

(2) Day 2: June 10, 2022 (Thu)

1) New telemetric meteorological station was constructed in 2022 by Kenya Meteorological Department (KMD).

a) Status-quo are as shown in photographs below.

New telemetric meteorological station at Kerugoya SRO

2) Interview with Sub-Regional Manager and Surface Water Officer in Muranga SRO

	
An interview meeting with Ms. Patricia Musau, Sub-Regional Manager, Muranga SRO (left end) and Ms. Faith Mbati (SWO, center)	An interview meeting with Ms. Patricia Musau, Sub-Regional Manager, Muranga SRO (inner most)
	
Checking the status of Data Logger provided by the previous JICA advisory activity.	Status of the Data Logger yet to be installed.

Ms. Patricia Musau (SRM, Muranga) asked JICA whether JICA can assist water quality monitoring as well. Ms. Musau is a chemist and she is tackling issues of water quality when issuing water permits.

She also requested JICA for support on installation works of Hioki Data Logger which was provided by the previous JICA advisory activities and which is yet to be installed.

After the interview meeting, Ms. Musau and Ms. Mbati guided us to their storage room and showed their equipment.

3) Status of equipment in the storage of Muranga SRO

 	
Three sets of levels together with tripods were stored. (Above) Current meter which was provided by JICA in the previous advisory activities. (Below)	A casting form for concrete post for regular gauging station.
	
Staff gauge plates stored. Most of them were for high water levels. Lower part ones (0 to 100 cm) were missing.	Ms. Faith Mbati explained that they sometimes cut and weld the plates according to the site condition.

 	
A plastic perforated pipe for installation of data logger inside.	A plastic one (left) and a steel one (right). Steel ones are subject to vandalism, and sold to metal market.

4) Telematic Water Level Gauging Station (4BE01)
    a) It is observed that the station 4BE01 is working.
    b) Status-quo are as shown in photographs below.

	
Photo-01: Gauge House	Photo-02: Structure for the water level gauge
	
Photo-03: Structure for the water level gauge (box)	Photo-04: Inside of the Box
	
Photo-05: Water level data logger (HOBO)	Photo-06: Data reading from the water level data logger to notebook PC though the coupler

	
Photo-07: Second staff gauge	Photo-08: Old gauging house was vandalized
	
Photo-09: Solar panel is provided on the top of the roof and fixed firmly with mortar (in not visible and not stolen manner).	Photo-10: Location of the gauge house on the right bank of the river. The left one is the newly built one, and the right one is the one which was vandalized.

c) Following is discovered and verbal information at the site

- We have found the new type of water level data logger; it is very compact and easy operation for data reading. Manufacturer: HOBO
- Measured data are water level and temperature of river water
- Data can be archived for three years in the device
- Battery and data storage capacity are monitored when the data reading is made
- Data readings are conducted by monthly base
- Cost of this device is approximately 75,000 Kenya Shilling

7. Detailed information of the water level data logger

Following information are obtained through the home page of the manufacture:

1) Manufacturer name: onset, U.S.A.
2) Brand Name:: HOBO U20L-04
3) Type: Pressure type
4) Operation range of water level: 0 to 4 m
5) Accuracy: +/- 0.1% FS (0.4 cm FS)
6) Pressure Response Time (90%): < 1 second
7) Temperature measurement：-20°C to 50°C
8) Accuracy: +/- 0.44°C
9) Real-time clock: +/- 1 minute per month
10) Resolution: 0.1°C
11) Response Time (90%)：10 minutes in water (typical)

12) Battery: 2/3 AA,3.6 V, lithium, factory-replaceable
13) Battery life (typical use): 5 years with 1 minute interval or greater logging intervals
14) Memory (non-volatile): 64K bytes memory (21,700 pressure and temperature samples)
15) Logging interval: Fixed-rate or multiple logging intervals from 1 second to 18 hours
    a) Dimensions and weight: 31.8 mm diameter and 152 mm length, 154 g
16) Software: HOBOware Pro (at free)
17) Data reading

Optical Interface for data transfer - click to zoom

<end of report>

Location Map of the Upper Tana Basin, Offices and Gauging Stations

JICA Water Resources Advisor
Site Reconnaissance Report to Upper Reach of Tana River

1. Objectives:
   (1) Explanation of activities to newly appointed Basin Area Coordinator and Technical Manager
   (2) Discussion and confirmation on the current activities and issues
   (3) Site reconnaissance on the existing water related facilities
2. Period: January 25 to 27, 2023
3. Participants (From Nairobi):
   (1) Mr. T. Okamura (JICA Expert, Team Leader/Water Resources Management)
   (2) Mr. Gilbert M. Chumo (JICA Expert Assistant for Team Leader)
   (3) Mr. Denis Masika (JICA Expert Assistant Hydrologist)
   (4) Mr. Eugene Mwandoe (JICA Expert Assistant Telemetering)
   (5) Ms. Doreen Iluba (JICA Expert Team Secretary)

4. Itinerary:

Date	Itinerary	Remarks
January 25, 2023 (Wed)	07:30-10:30 Move from Nairobi to Embu, WRA Tana Regional Office 10:30-10:50 Courtesy call to WRA Tana Regional Manager and Regional Technical Manager 11:00-13:00 Discussion and confirmation on the current activities and issues 13:00-14:00 Lunch Break 14:00-17:00 Discussion and confirmation on the current activities and issues (continued) Stay in Embu	Weather: Sunny
January 26, 2023 (Thu)	08:30-10:30 Discussion and confirmation on the current activities and issues (continued)Move to Muranga Sub-Regional Office 10:30-11:00 Tea Break 11:00-13:30 Presentation on JICA Expert Team Activities on Telemetering and Hydrological Monitoring (by Assistant Staff) 13:30-15:00 Move to RGS 4DD02 Thiba 15:25-15:40 Site Inspection to RGS 4DD02 Thiba including illegal abstractions 15:40-17:00 Move to Thiba Dam 17:10-18:30 Site inspection on Thiba Dam 18:30-19:30 Move to Embu Stay in Embu	Weather: Sunny
January 27, 2023 (Fri)	08:00-09:50 Move from Embu to Muranga SRO 09:50-13:25 Discussion and confirmation on the current activities and issues 13:30-14:50 Move from Muranga SRO to RGS 4BE09 (Measuring water level after diversion to Nairobi in Maragua river) 15:00-15:25 Move to Maragua intake for diversion to Nairobi 15:25-16:10 Site inspection on Maragua intake 16:10-17:10 Move to Muranga SRO 17:10-19:10 Move from Muranga to Nairobi	Weather: Sunny

5. Result and Findings

(1) Day 1: January 25, 2023 (Wed)

1) Through discussions with Tana Regional Manager, Regional Technical Manager, Surface Water Officers together with other participants, the following items were realized.
2) For flood related activities of WRA, so far, during the flood, warning is mainly given to the people living downstream area, i.e., Garissa and downstream of Garissa.
3) During the drought WRA initiates water use rationing. During the drought, irrigation water use is stopped during the daytime. Irrigation water can be abstracted only during nighttime.
4) The following stations are used as Flood/Drought specific stations:
    a) 4BE10 Tana Rukanga
    b) 4G01 Garissa
    c) 4G04 Hola
    d) 4G02 Garsen
    e) 4F13 Grand Falls
    f) 4DD02 Thiba

(2) Day 2：January 26, 2023 (Thu)

1) For the Day 2 session, Surface Water Officer (SWO) from Kerugoya came to Tana Regional Office and attended the discussion.
2) JICA Expert Team again queried why Tana RO still observe 87 regular gauging stations, although in the National Water Master Plan 2030, 26 stations are recommended. Tana RO Technical Manager promised to prepare a report on this issue.
3) Tana RO people mentioned that telemeterized stations are maintained by WRA headquarters (HQ). No information is shared with RO and SROs.
4) There is still ambiguity which data is authorized i.e., i) manually read data, or ii) data read by telemetering system.
5) In Tana RO and SROs, it is understood that the reason for telemetering is for real time data acquisition for flood damages mitigation. As a general information, it will cost KSh. 600,000 for civil works of telemetering stations, and KSh. 1.2 million for telemetering equipment.
6) After discussions JICA Expert Team with Kerugoya SWO moved to RGS 4DD02 Thiba for checking the status and observed illegal abstractions by pumping machines.
7) JICA Expert Team then visited Thiba Dam of Mwea Irrigation Project.

(3) Day 3：January 27, 2023 (Fri)

1) For Day 3, JICA Expert Team visited Muranga SRO for discussion of current status and issues.
2) It was reported that riparian marking is promoted by WRA Muranga SRO for flood damage prevention. Riparian marking is done to delineate the maximum flood level in the past flood so that people do not cultivate the land, do not build houses etc. to avoid flood damages. The following photos of riparian marking activities were provided by Mr. Njara in Muranga SRO.

	
Riparian marking activities in Muranga sub-region (during June to August 2022)	Riparian marking activities in Muranga sub-region (during June to August 2022)
	
Riparian marking activities in Muranga sub-region (during June to August 2022)	Sensitization meeting for riparian marking by WRA Muranga SRO (during June to August 2022)

3) Through discussion in Muranga SRO, it was realized that rationing during the drought is one of the issues. To figure out more on the critical water use during the drought, it was decided to take up several RGSs to check the discharge during the drought and numbers of water permits upstream of the RGSs. It was proposed that **4BB01 Ragati** and **4BE01 Maragua** will be taken as samples.
4) After discussion JICA Expert Team and Muranga SRO officers visited Maragua Intake Site which divert a part of Maragua River for water use in Nairobi. Related regular gauging station (RGS) 4BE09 was also visited.

6. Photos of discussions and site visits

	
Day 1 January 25, 2023 (Wed) Courtesy call to New Basin Area Coordinator (Regional Manager) Mr. Abdi Omar (center)	Day 1 January 25, 2023 (Wed) Discussion with Tana RO officers.
	
Day 2 January 26, 2023 (Thu) Presentation on JICA Expert Activities by Assistant staff	Day 2 January 26, 2023 (Thu) Site reconnaissance to RGS 4DD02 Thiba. Several illegal abstractors with pumps are observed at the opposite side of the river.
	
Day 2 January 26, 2023 (Thu) Site reconnaissance to RGS 4DD02 Thiba. Due to sedimentation surrounding the staff gauge, excavation works are done to maintain proper gauge reading.	Day 2 January 26, 2023 (Thu) Site reconnaissance to RGS 4DD02 Thiba. The first and the second gauges.

	
Day 2 January 26, 2023 (Thu) Site Reconnaissance at Thiba Dam of Mwea Irrigation Project. Local Engineer Mr. Andrew Mutua guided us for one hour to major sites of the project.	Day 2 January 26, 2023 (Thu) Site Reconnaissance at Thiba Dam of Mwea Irrigation Project. Flow release of 5 m^3/s to downstream area.
	
Day 2 January 26, 2023 (Thu) Check dam at the upstream end of the Thiba Dam reservoir. Inflow discharge is about 1.2 m^3/s.	Day 2 January 26, 2023 (Thu) Main dam body of Thiba Dam
	
Day 2 January 26, 2023 (Thu) Thiba Dam reservoir and Mt. Kenya	Day 3 January 27, 2023 (Fri) Discussion at Muranga SRO

	
Day 3 January 27, 2023 (Fri) Site visit to RGS 4BE09. The second staff gauge. The first gauge is vandalized and not restored yet.	Day 3 January 27, 2023 (Fri) Site visit to RGS 4BE09. With the gauge reader.
	
Day 3 January 27, 2023 (Fri) Site visit to Maragua Intake for water transfer to Nairobi. Whole view of intake facilities Stilling basin on the left side and fishway on the right side	Day 3 January 27, 2023 (Fri) Site visit to Maragua Intake for water transfer to Nairobi. Intake weir (center) and sand stilling basin (left)
	
Day 3 January 27, 2023 (Fri) Site visit to Maragua Intake View from Up-stream	Day 3 January 27, 2023 (Fri) Site visit to Maragua Intake Tyrolean style wa-ter intake

Day 3 January 27, 2023 (Fri)
Site visit to Maragua Intake
Open spaces between grating and concrete were just covered with timbers.

Day 3 January 27, 2023 (Fri)
Site visit to Maragua Intake
Water leakage observed from the concrete joint.

Day 3 January 27, 2023 (Fri)
Site visit to Maragua Intake
Members of site visit:
From left, Mrs. Jane Wairimu (Muranga SRO), Mr. Okamura, Mr. Njara (Muranga SRO), Mrs. Faith Mbati (Muranga SRO), Mr. Eugene, Mr. Masika, Mr. Chumo (JICA Expert Team Assistant)

7. Attendants list

DATE: 25TH JANUARY 2023
VENUE: EMBU REGIONAL OFFICE
TIME: 10:40AM

NO	NAME	DESIGNATION/INSTITUTION	STATION
1	Doreen Iluba	Office Admin JICA	Nairobi
2	Denis Masika	Hydrologist JICA	Nairobi
3	Gilbert Chumo	Co/Team Leader JICA Expert Team	Nairobi
4	Takeshi Okamura	Team Leader - JICA Expert Team	Nairobi
5	Eugene Mwandoe	Tele-communication Expert JICA	Nairobi
6	Omar Abdi	Tana Basin Area Coordinator	Embu
7	Jackline Mutinda	Tana Regional Technical Manager/Principle Hydrogeologist	Embu
8	Samuel Ndung'u	Surface Water Officer	Embu
9	Judy Njiru	Accounts assistant	Embu
10	Erick Ngesa	Supply Chain Management Officer	Embu
11	Silas Njiru Karanja	Snr. Supply Chain Management Assistant	Embu
12	Nickson Amwoka	Supply Chain Management Assistant	Embu
13	Patrick Masaku	Principle Finance Officer	Embu
14	Joram Kihumba	Snr. Water Quality& Pollution Officer	Embu
15	Hilda Wambeti	Snr. Records Management Assistant	Embu
16	Sophia Mwihaki	Records Management Assistant	Embu
17	Muriithi K. Mbogori	Principle Licensing Officer	Embu
18	Caleb Wendoyh	Attachee	Embu

DATE: 26TH JANUARY 2023
VENUE: EMBU REGIONAL OFFICE
TIME:9:00AM

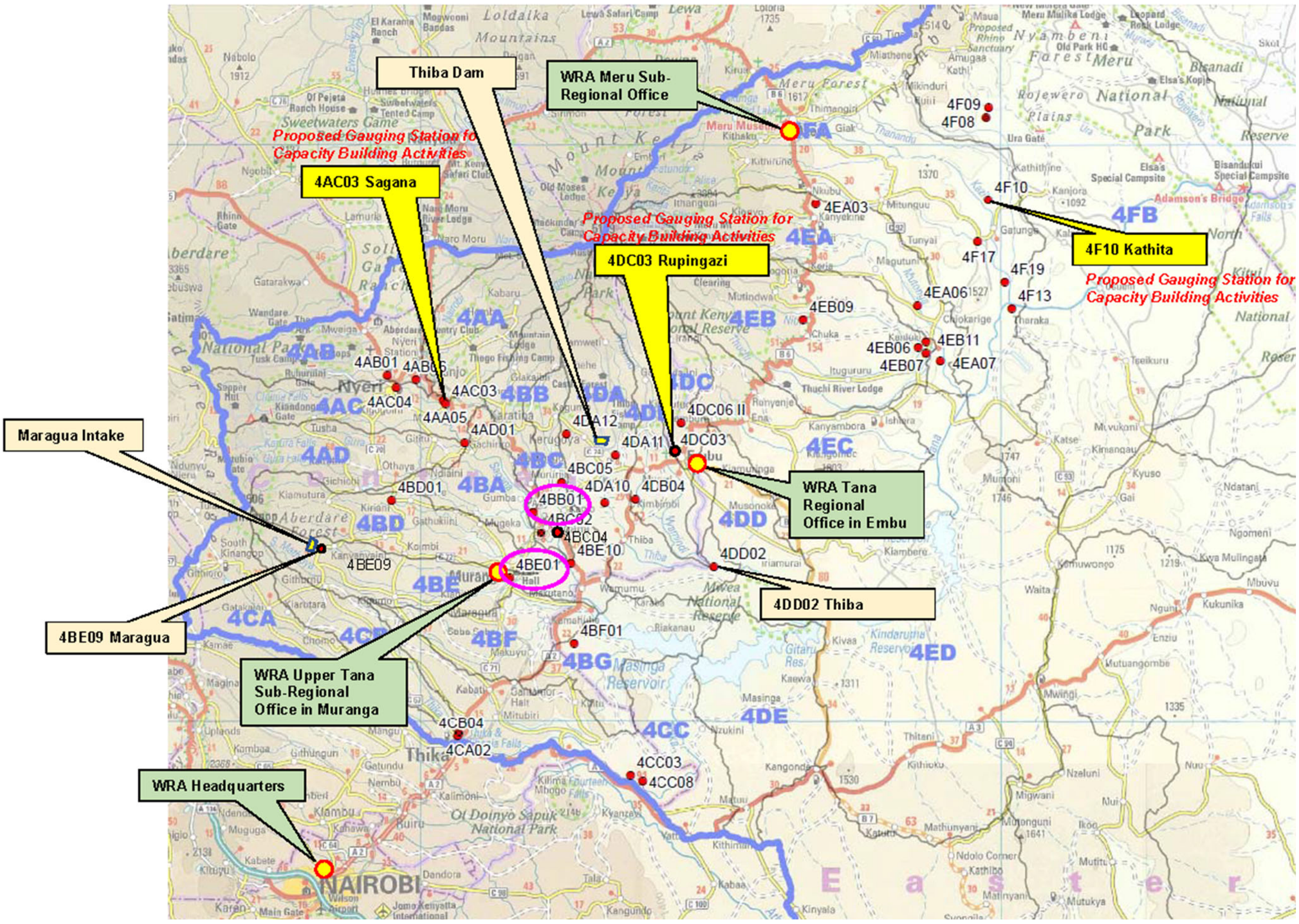
NO	NAME	DESIGNATION/INSTITUTION	STATION
1	Doreen Iluba	Office Admin JICA	Nairobi
2	Denis Masika	Hydrologist JICA Expert Team	Nairobi
3	Silas Njiru	Snr. Supply Chain Management Assistant	Embu
4	Caleb Wendoyh	Attachee	Embu
5	Jane Njuguna	Surface Water Officer	Kerugoya
6	Jackline Mutinda	Regional Technical Manager/ PHG	Embu
7	Samuel Ndung'u	Surface Water Officer	Embu
8	Takeshi Okamura	Team Leader JICA Expert Team	Nairobi
9	Gilbert Chumo	Co/Team Leader JICA Expert Team	Nairobi
10	Muriithi K. Mbogori	Principle Licensing Officer	Embu
11	Joram Kihumba	Snr. Water Quality& Pollution Officer	Embu

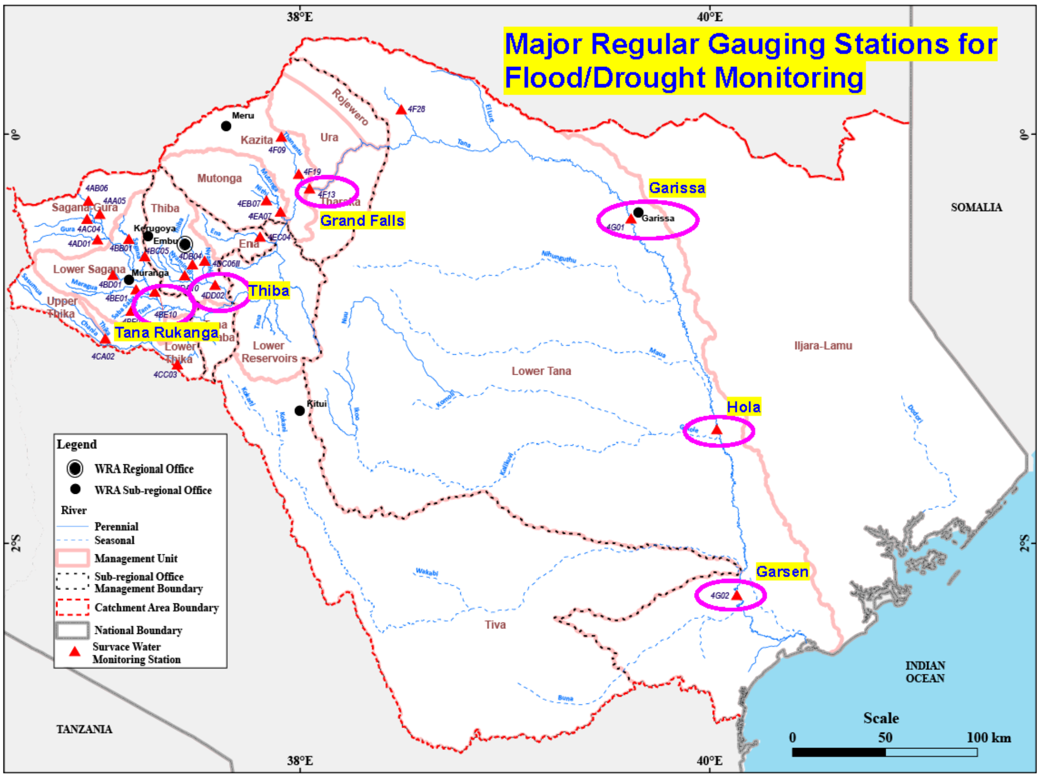
DATE:27TH JANUARY 2023
VENUE:MURANG'A SUB-REGION OFFICE
TIME: 09:54AM

NO	NAME	DESIGNATION/INSTITUTION	STATION
1	Doreen Iluba	Office Admin JICA Expert Team	Nairobi
2	Takeshi Okamura	Team Leader JICA Expert Team	Nairobi
3	Denis Masika	Hydrologist JICA Expert Team	Nairobi
4	Eugene Mwandoe	Telecommunication Expert JICA	Nairobi
5	Zakayo Njara	Water Quality&Pollution Control Officer	Murang'a
6	Gilbert Chumo	CO/Team Leader JICA Expert Team	Nairobi
7	Faith Mbathi	Surface Water Officer	Murang'a
8	Jane Njoroge	Surface Water Officer	Murang'a

<end of report>

Location Map of the Upper Tana Basin, Offices and Gauging Stations





JICA Water Resources Advisor
Site Reconnaissance Report to Upper Reach of Tana River 4F13 Regular Gauging Station

1. Objectives:
   (1) Confirmation on the current conditions of regular gauging station 4F13 Grand Falls and examine the possibility toward telemeterization
   (2) Confirmation on the hydrological records and other related information on 4F13
2. Period: May 22 to 24, 2023
3. Participants (From Nairobi):
   (1) Mr. T. Okamura (JICA Expert, Team Leader/Water Resources Management)
   (2) Mr. Y. Azuma (JICA Expert, Telecommunication/Innovation Technology)
   (3) Mr. Gilbert M. Chumo (JICA Expert Assistant for Team Leader)
   (4) Mr. Eugene Mwandoe (JICA Expert Assistant Telemetering)

4. Itinerary:

Date	Itinerary	Remarks
May 22, 2023 (Mon)	12:00-15:00 Move from Nairobi to Embu, WRA Tana Regional Office 15:00-15:30 Courtesy call to WRA Tana Regional Manager, Explanation of the purpose of site visit to 4F13, Confirmation on the operational status of 4F13 15:30-18:00 Move from Embu to Meru Stay in Meru	Weather: Sunny
May 23, 2023 (Tue)	08:00-09:30 Visit Meru Sub-Regional Office, Confirmation of the current status of RGS 4F13 09:35-11:15 Move from Meru to Marimanti 11:20-12:25 Move from Marimanti to Tana River 4F13 site 12:25-14:00 Site reconnaissance, discharge measurement by float, river depth measurement 14:00-14:55 Move from 4F13 site to Marimanti 15:00-17:00 Move from Marimanti to Meru Stay in Meru	Weather: Sunny
May 24, 2023 (Wed)	08:00-11:10 Visit Meru Sub-Regional Office, Report the result of site reconnaissance to RGS 4F13 to Sub-Regional Manager and Surface Water Officer Collection of water level data of 4F13 and related information 11:10-13:00 Move from Meru to Embu 13:00-14:00 Lunch 14:10-15:40 Visit Embu Regional Office, Report the result of site reconnaissance to Regional Manager, Regional Technical Manger, and Surface Water Officer 15:40-17:45 Move from Embu to Nairobi	Weather: Rainy then Cloudy

5. Result and Findings
   (1) Day 1: May 22, 2023 (Mon)
      1) Report the purpose of the visit i.e., site visit to 4F13 regular gauging station (RGS) to confirm the possibility of installing telemetering equipment to the RGS 4F13, to Tana Regional Manager and Surface Water Officers.

(2) Day 2：May 23, 2023 (Tue)

<Some cars not in operation in the yard of Meru SRO>

1) In the yard of Meru Sub-Regional Office, there are seven number of vehicles out of seven, six number of vehicles are not in operation. JICA Expert Team clarified to the Surface Water Officer on the status of those cars. The result of clarification is as follows:

No.	Car Plate No.	Owner/Project	Status
1	KBJ207U	Imetha (Imenti Tharaka Water Service Provider)	Got punctured, Not in operation
2	GK A 998K	Upper Tana Natural Resources Project	-ditto-
3	GK A 930K	Upper Tana Natural Resources Project	-ditto-
4	GK A 929K	Upper Tana Natural Resources Project	-ditto-
5	GK Z 673	MWSI	-ditto-
6	GK T 040	MWSI	-ditto-
7	KAT 285X	WRA Meru Sub-regional Office	In operation. Shared by Surface Water, Groundwater, and Water Permit Sections.

Cars Nos. 1 to 5 in the above list.

Cars Nos. 6 and 7 in the above list.

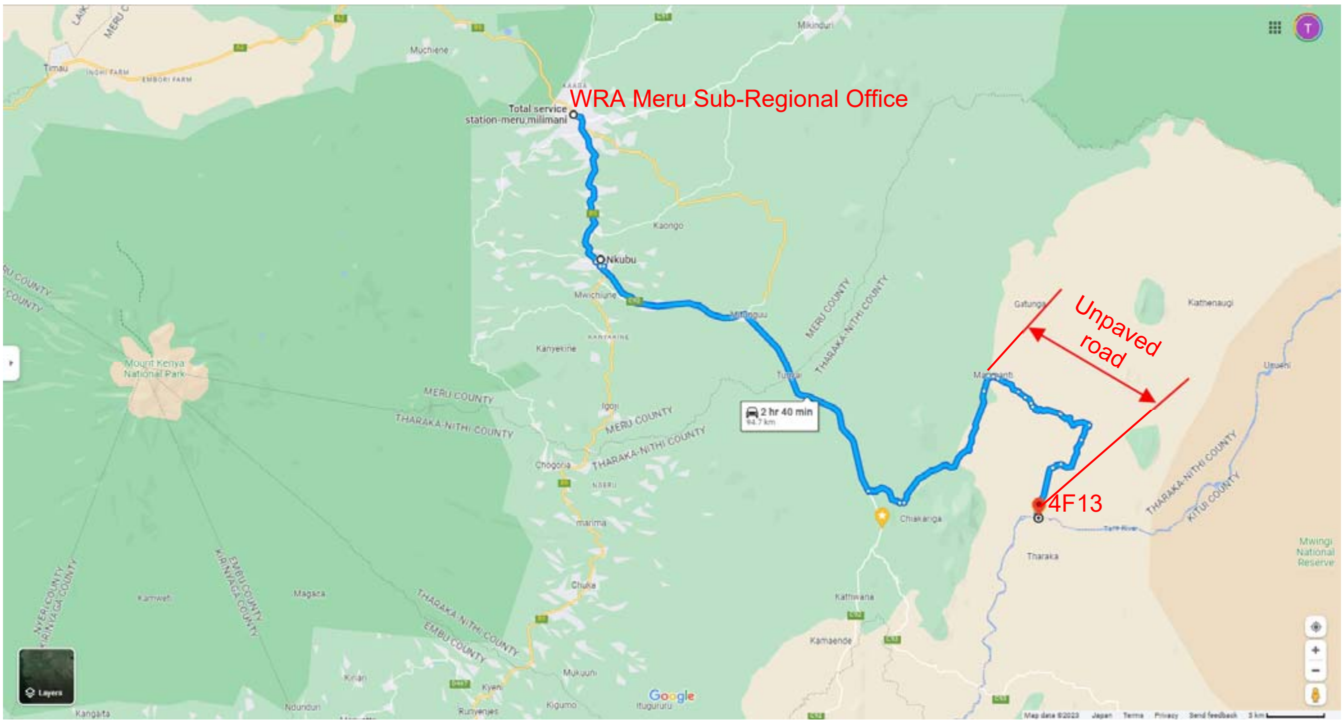
2) It is recommended to secure the budget for the maintenance of those cars, so that those cars can be used for activities of WRA Meru Sub-Regional Office. Currently only one car is in operation in Meru SRO, i.e., KAT 285X and the car is shared by SWO, GWO and Water Permit Officers. To accomplish the duty of each section, at least three cars are required.

<Discussion result to surface water officer in Meru SRO>

3) JICA Expert Team met with Mr. Alex Kimotho (Surface Water Officer) to get information on 4F13. According to Mr. Kimotho, 4F13 has water level records, up to December 2015. After that, the first and the second gauge were washed away and from January 2016 till now, there is no gauge reading done.
4) The historical data files were examined and record of previous installation such as elevation and cross section were obtained for further analysis. Record of water level covering a period of 11 years (2005-2015). A request was made to WRA to issues the updated rating curves for the station including stream gauging data (Discharges vs Levels).
5) A rating curve will be developed for comparisons with the currently used curve.
6) Data from station 4F19 were obtained and hydrological flow analysis will be conducted to establish relationship with 4F13.

	
Discussion with SWO Mr. Alex Kimotho.	Recorded data for 4F13 from 2005 to 2015.

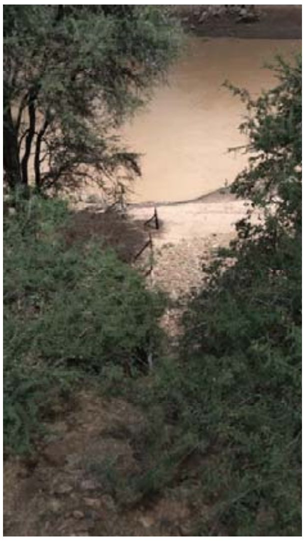
<Result of site reconnaissance to 4F13>



Route Map (from WRA Meru SRO to RGS 4F13 in Tana River)

7) From Meru SRO to 4F13, it took about three hours to access. Mr. Billon Gitonga Ndubi (Senior ICT assistant) of Meru SRO attended the site reconnaissance.
8) Up to the town of Marimanti, most part of the road is paved, but between Marimanti and 4F13 is unpaved road.
9) The road section of the last one kilo meter to 4F13 site is badly deteriorated due to storm water. Perhaps, only 4WD car can reach to the 4F13 site. For construction of some civil works, road repair is necessary.
10) 4F13 regular gauging station (RGS) has nine sets of staff gauges, out of two (the 1^{st} and the 2^{nd}) gauges are washed away.
11) The 4^{th} , 5^{th}, 9^{th} gauges have no plates.
12) The 6^{th} plate is deteriorated and hard to read.
13) The 7^{th} plate is slightly deteriorated but to some extent readable.
14) The 8^{th} gauge is surrounded by bushy trees which needs periodical clearing works for accurate gauge reading.

	
The road condition of the last 1 km to 4F13.	Tana River just downstream of 4F13. A lot of cobble stones with 30 to 60 cm size are flown and deposited on both of the banks.
	
Looking at the section of 4F13 from down-stream. Just downstream of the RGS, a large exposure of rock is seen.	The 3rd gauge out of 9 on the left bank. The 1st and 2nd gauges are washed away and could not be found.
	
Gauges of 7th to 3rd on the left bank (from up down to riverside). No plates for 4th and 5th. 6th is damaged and hard to read the figure on the plate.	The 8th to 6th gauges. Periodical clearing of those trees is necessary for accurate gauge reading.
	
The 9th to 7th gauges. The 9th gauge without plate.	The 4th to 9th gauges looking from upstream side.

	
9^{th} to 3^{rd} gauges looking from upper side.	The 4^{th} and 5^{th} gauges.
	
From the 4F13 RGS point looking upstream.	Possible location for gauging house.
	
9^{th} to 3^{rd} gauges looking from upper side of the left bank.	The pipe and ladder of old self-recording water level gauge, which is no longer in use.
	
The existing cable way for discharge measurement. This device was installed in 1960's.	The existing cable way.

	
An interview to boat owner.	River depth survey by using boat. The deepest point was 4.4 m.

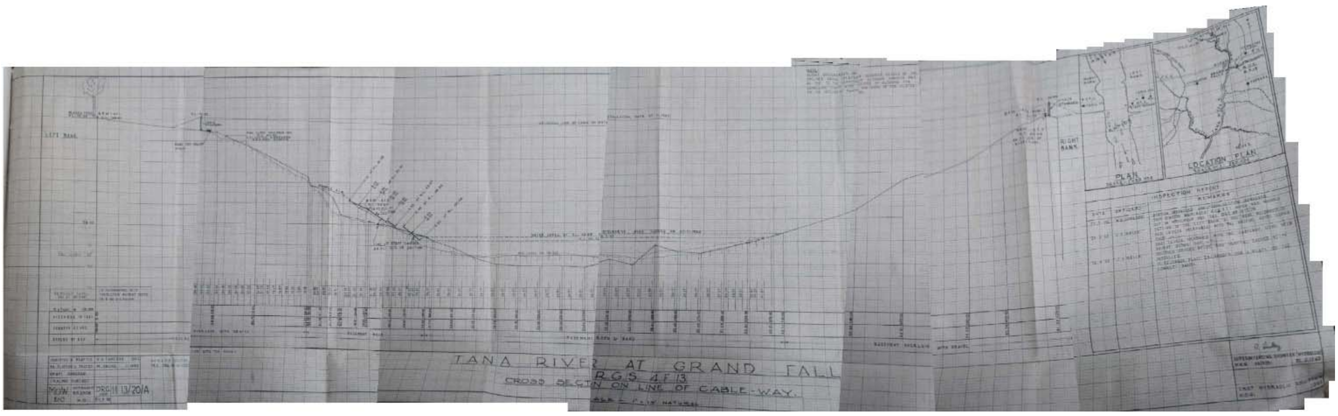
15) Discharge measurement was made by float method.
16) In a 17 m river stretch, surface velocity was 0.85 m/s.
17) River width was 48 m. River depth of two representative locations were 4.4 m and 3.3 m respectively. The average depth can be assumed at 3.8 m.
18) By assuming triangular shape of the river, area of the river can be calculated as: 48 m (W) x 3.8 m (D) /2 = 91.2 m^2.
19) Discharge can be estimated at: 91.2 m^2 x 0.85 m/s x 0.8 (coefficient) = 62 m^3/s.

<4F13 information confirmation at Meru SRO>

20) In the morning of May 24, 2023, related information on 4F13 was collected from the file in Meru Sub-Regional Office.
21) In the file, there were photos at the time of installation of the self-recording water level gauge in 1962. The followings are the photos filed.

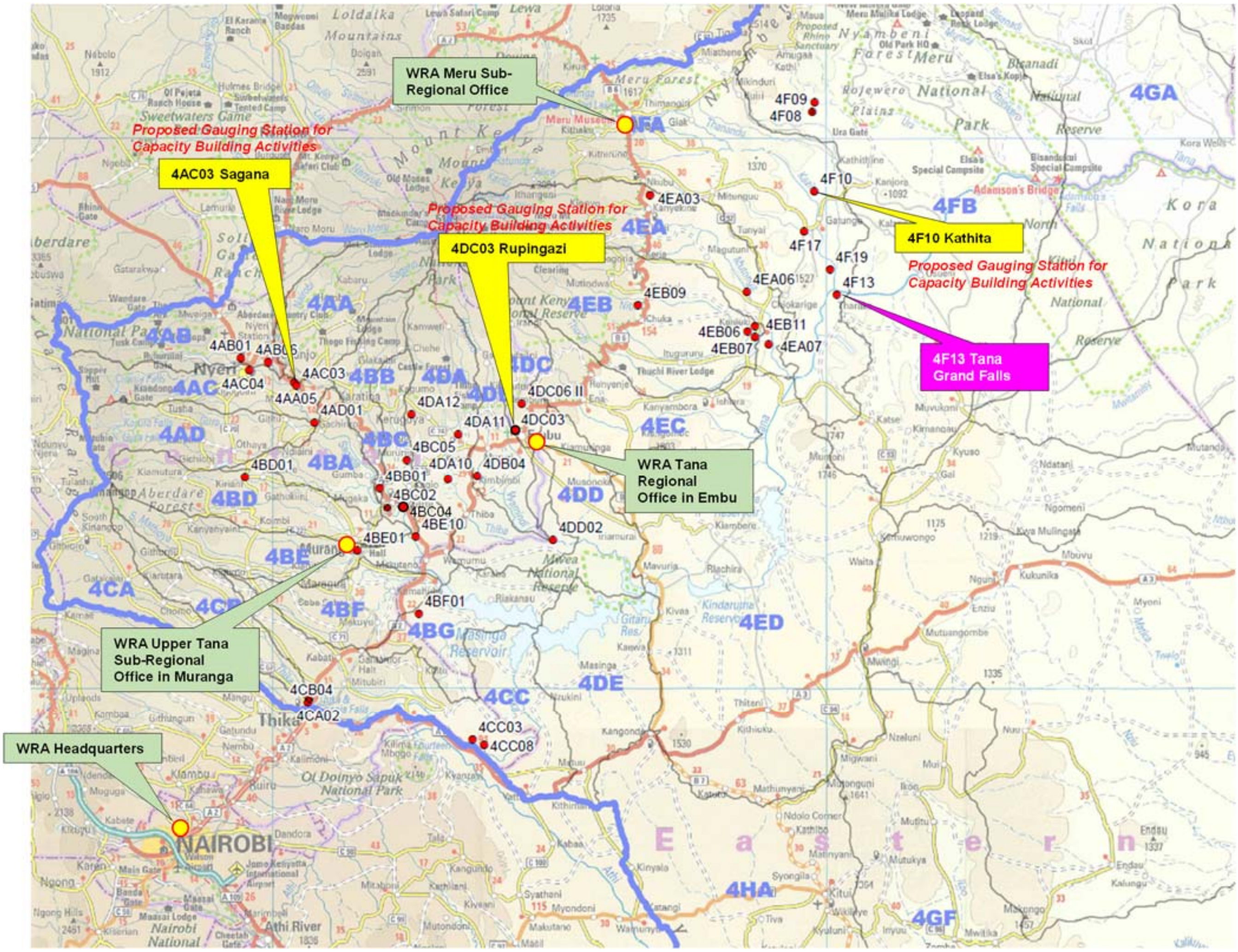
	
RGS 4F13 at the time of installation in 1962.	RGS 4F13 at the time of installation in 1962.

Photos of cableway for discharge measurement and self-recording water level gauge



A drawing of cross section of 4F13 issued on February 22, 1963

Location Map of the Upper Tana Basin, Offices and Gauging Stations



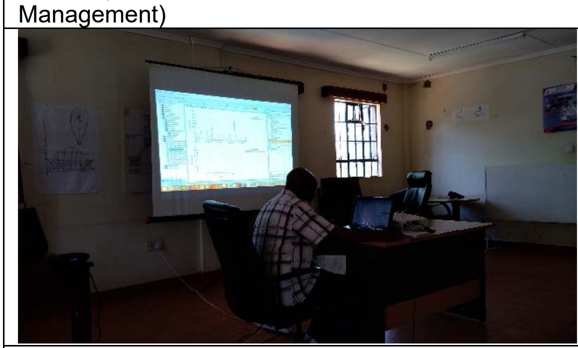
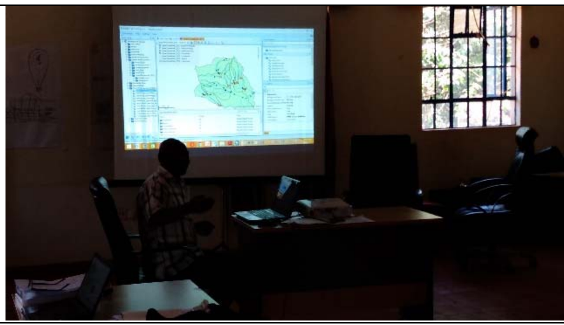
Note: 4F13 RGS is located on the left bank of Tana River.

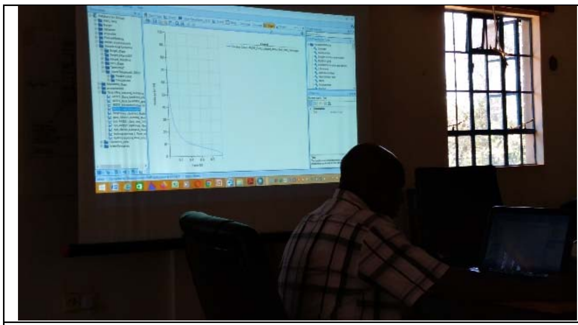
<end of report>

A report on Capacity Building Activities in Embu from October 12 to 13, 2023

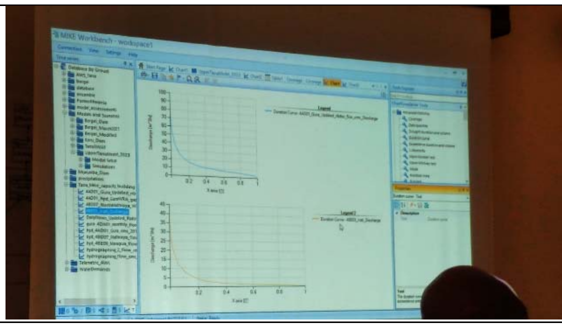
JICA Experts Team

1. Date and Time: October 12, 2023, 9:00 to 16:30, and October 13, 2023, 9:00 to 15:00
2. Venue: Water Resources Authority (WRA) Tana Basin Area Office in Embu
3. Participants: As per attached attendants list
   (1) October 12, 2023 – 23 participants including JICA Experts Team, 3 participants participated online consisted of one from Garissa Sub-Regional Office, and two from Kitui Sub-Regional Office.
   (2) October 13, 2023 – 18 participants including JICA Experts Team, one participant from Kitui Sub-Regional Office.
4. Schedule:
   JICA Experts Team mobilized to Embu in the afternoon of October 11, 2023, for preparation of capacity building activities.
   Capacity building programme is as per attached sheet.
   JICA Experts Team intended to mainly train the Surface Water Officers, but there were so many participants than expected including people in charge of ICT, Community Engagement, Licensing etc.
   Capacity building was done through presentation of the material and exercise using MS Excel in each computer for preparation of Flow Duration Curve etc.
5. Photos of Capacity Building Activities
   <October 12, 2023>

	
An introduction of the programme by Mr. Gilbert Chumo (Co Team Leader/Water Resources Management)	A lecture on analysis using MIKE Workbench by Mr. Eugen Mwandoe (Communication System)
	
A lecture on analysis using MIKE Workbench by Mr. Eugen Mwandoe (Communication System)	A lecture on analysis using MIKE Workbench by Mr. Eugen Mwandoe (Communication System)

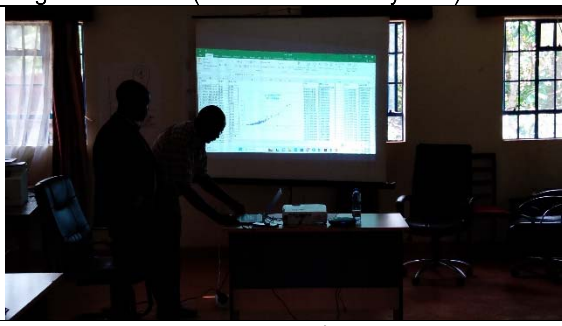


A lecture on analysis using MIKE Workbench by Mr. Eugen Mwandoe (Communication System)



A lecture on analysis using MIKE Workbench by Mr. Eugen Mwandoe (Communication System)

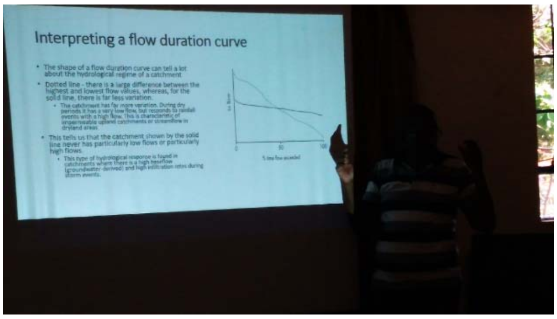
A lecture on development of rating curves by Mr. Denis Masika (Hydrological Monitoring)



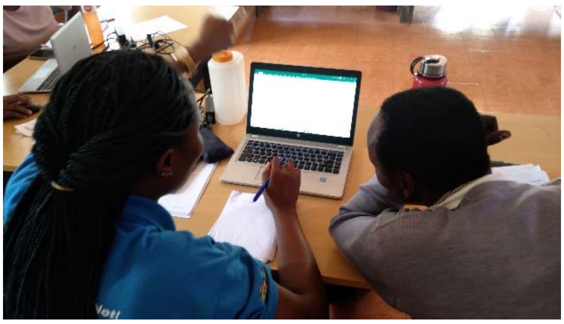
A lecture on development of rating curves by Mr. Denis Masika (Hydrological Monitoring)

<October 13, 2023>

A lecture on analysis flow of the climate change impact by Mr. T. Okamura (Team Leader/Water Resources Management)

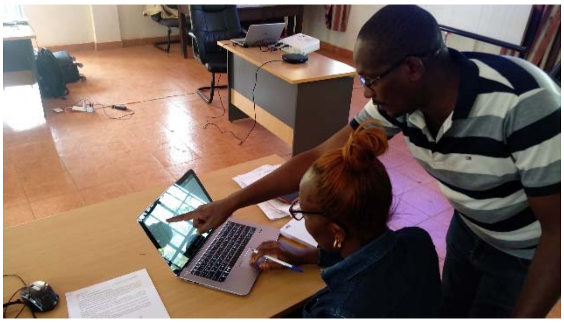
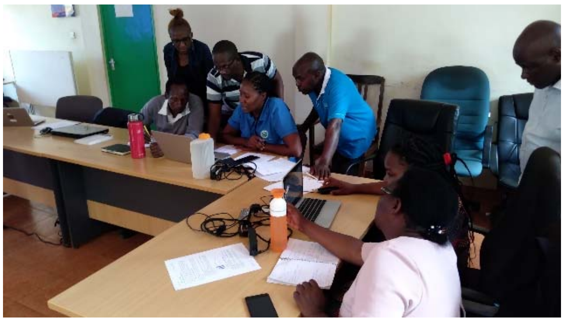
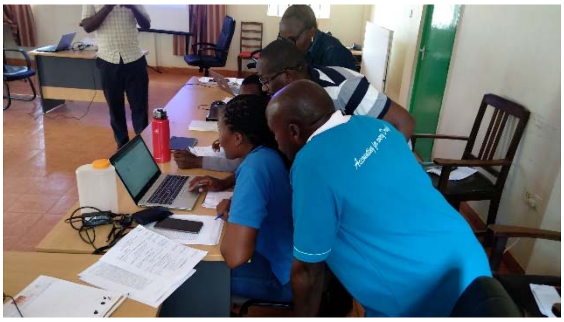


A lecture on preparation of flow duration curve by Mr. Denis Masika (Hydrological Monitoring)



Practices session on preparation of flow duration curve by participants

Practices session on preparation of flow duration curve by participants

	
Practices session on preparation of flow duration curve by participants	Practices session on preparation of flow duration curve by participants
	
Practices session on preparation of flow duration curve by participants	Practices session on preparation of flow duration curve by participants

6. Attachment:
   (1) Capacity Building Activities Programme
   (2) Presentation Material
   (3) Attendants List

<end of report>

JICA WATER RESOURCES ADVISOR

CAPACITY BULIDING SCHEDULE 11th -13th October 2023

UPPER TANA

Date	Schedule	Participants
Wednesday 11th October 2023		
2:30 PM – 3:30 PM Embu Regional Office	**Combined meeting with JICA-WRA Tana Basin** • Briefing and discussions on WRA progress on activities by JICA and upcoming activities. • Report on Collaboration with other Donors. • Other Items on Capacity Building	Embu – Basin Manager-Tana. Technical Manager, PO, SBM JICA team – T. Okamura, Eugene, Masika, Gilbert Doreen
Thursday 12th October 2023		
	Overnight stay in Embu	JICA team – T. Okamura, Eugene, Masika, Gilbert
9:00 – 10:30 AM Embu Regional Office	**Hydrological data Processing** • Data pre-processing (gap filling, verification etc) • Data Analysis – preliminary analysis –Rainfall vs Discharge Graph; Scatter Plots, trend lines and interpretation. • Demonstration using MIKE bench	Participants- WRA Staff (Muranga, Kerugoya, Meru, Garissa and Kitui) JICA team – Masika
10:30-10:45	**Tea Break**	All
10:45 AM-12:45 PM Embu Regional Office	**Frequency Analysis of Hydrological Data** • Frequency Analysis of Extreme events (Flood flow and low flow) - case of upper Tana • Practical Application – Hands-on using excel	Participants- SRO SWO (Muranga, Kerugoya, Meru, Garissa and Kitui) JICA team –Masika
1:00-2:00 PM	**Lunch Break**	All
2:00-4:30 PM Embu Regional Office	**Preparations and Development** • Hydrological Concepts and use of Rating curves • Development of Rating Curves • Gauging site condition • Uncertainties associated with rating curves • Challenges associated with use flow rating curves • Practical session for rating curve development	Participants- SRO SWO (Muranga, Kerugoya, Meru, Garissa and Kitui) JICA team – Masika
	Overnight stay in Embu	JICA team – T. Okamura, Eugene, Masika, Gilbert

Date	Schedule	Participants
Friday 13th October 2023		
9:00-10:30 AM Embu Regional Office	**Analysis on the Impact of the Climate Change** • How the climate change analysis was made during the formulation of National Water Master Plan 2030 (NWMP 2030) • Report on collaboration with other partners • Network Optimization • Example WEAP Results for selected sub-catchment from available data.	Participants- SRO (Muranga, Kerugoya, Meru, Garissa and Kitui) SWO, ICT, PO, WQ JICA team – T. Okamura, Gilbert
10.30-10:45AM	**Tea Break**	All
10:45AM-1:00PM Embu Regional Office	**Discussions on Telemetering Stations for Capacity Building and Optimization of Network** • Overview of WEAP/Mike Zero Adaptor Tools for WAP formulation for Pilot Sub-basins • Pilot station for Capacity Development; Flood warning/Drought Monitoring	Participants- SRO (Muranga, Kerugoya, Meru, Garissa and Kitui) SWO, ICT, JICA team – Eugene
1:00PM – 2:00PM	**Lunch break**	All
2.00PM – 3:00PM Embu Regional Office	**Wrap-up** • Recap • JICA WRA next planned Activities • Any other business	Participants- SRO (Muranga, Kerugoya, Meru, Garissa and Kitui) SWO, ICT, JICA team- T. Okamura
3:00-5:00 PM	**Travel to Nairobi**	JICA team

CAPACITY BUILDING WORKSHOP IN UPPER TANA BASIN AREA

Hydrological data Processing

presented to

WATER RESOURCES AUTHORITY
TANA BASIN REGIONAL OFFICE
October 11, 2023

Hydrological data Processing

Data Cleaning and preparation

Def: Data cleaning -process of fixing or removing incorrect, corrupted, incorrectly formatted, duplicate, or incomplete data within a dataset.

- Data cleaning/ data cleansing/ data scrubbing is very important to achieve quality decision-making

Methods for infilling gaps in hydrological records

Available methods

- range from simple linear models to complex deterministic or stochastic techniques

The most common approaches include
  - simple nearest neighbor method by data transfer
  - interpolation techniques
  - autoregressive models,
  - simple and multiple regressions,
  - classification and regression trees,

Methods for infilling gaps in hydrological records

Available methods for infilling gaps in hydrological records cont.
  - recession methods
  - recursive models
  - nonlinear and storage models
  - satellite data applications
  - dynamic state-space models
  - Artificial neural networks (various forms)

Methods for infilling gaps in hydrological records

Limitations of some methods
- The nearest neighbor method brings discontinuity in the time series
- Interpolation techniques offer a limited representation of the space-time structure of the time series, being therefore unsuitable for periods with floods, major rainfall events, or long sequences of gaps
- Linear regression methods assume linearity between variables, which may not always be valid
- Multiple regression approaches ignore existing information in the target variable and need many explanatory variables, which can lead to multi-collinearity issues
- Auto-regression and recession models require a considerable amount of data for training and validation
- Dynamic state-space models require prior knowledge of the model parameters and the modeling system while the conditioning is done only on past observations
- Regression trees like Random Forests suffer of a lack of understanding of the construction of the trees.
- Artificial neural networks (ANNs) have complex formulations leading to intense calculations with high computational cost and the resulting model parameters generally have no physical interpretation

Method to select in gap-filling cont.

- The choice of an appropriate infilling technique depends on:
  - the length of the gaps
  - seasons of gap occurrence
  - climatic region of the measurement sites
  - length and characteristics of the existing records
  - availability of ancillary or proxy data
  - accuracy of the estimates versus the complexity of the approach
  - purpose of the use of the gap-filled records

NB: There is a lack of quantitative evaluation of the gap-filled data accuracy in most hydrological studies
  - gap-filling using hydrological modeling has little impact on the estimation of annual streamflow and its trends
  - Hydrologists often set up a threshold for the missing data ratio, e.g 1 %, 5%, 10 % 15 % and 20 %. Only those gauges with a missing data rate less than a particular threshold are selected

Methods used for gap-filling the missing data

- Hydrological modelling method is widely used
  - since it fully considers the spatial heterogeneity and temporal variability of climate forcing data
  - can achieve sufficient simulations when it is calibrated against a small number of observations

Reliability of gap-filled data

- There are no comprehensive methods to evaluate the reliability and accuracy of the gap-filled data that are influenced by different thresholds and by patterns of missing data
- The data gaps for streamflow gauges mainly include the following issues:
  - non-sensible records;
  - broken sensors;
  - no recorded data (instrumentation removed);
  - no existing data,
  - no records or records lost

NB

- *Gap-filling in this case only refers to short periods of missing data*
  - Gap-filling an entire year of missing data is likely to impact annual trends.
  - removing all periods of greater than 365 days allow for better fitting of gamma distribution to the number of missing days.

Reliability and consistency of data sets

- There is a need to check the quality of the data.
- achieved by use of determination of data consistency, homogeneity and trends of rainfall and runoff
- achieved using graphical, statistical and ground verification methods
- Consistency check
  - reveals discrepancies caused by factors that are not known to the user
  - determine whether known changes within the catchment have a considerable effect on the amount of runoff measured at the gauge

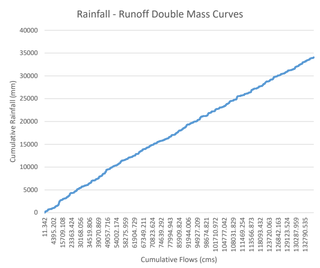
Causes of discharge data inconsistency

- changes in land use,
- changes in the amount of water abstracted from a catchment
- construction of control structures
- constantly shifting rating curves
- changes to measurement methods or practices

Data Analysis – preliminary analysis

Rainfall vs discharge graph

- A double mass curve is a common tool used to check relative data consistency where data at an observation station are generated by the same mechanism that generated similar (e.g. rainfall/ rainfall) or related (e.g rainfall/runoff) data at other stations within the same hydrological region
- Double-mass analysis works on the assumption that a linear relation exists between time series of hydrological data
  - an inflection point on a straight double mass plot indicates an inconsistency in the data sets.
- consistency of data can be analyzed for rainfall-rainfall between stations and rainfall-runoff in the stations within and neighborhood



Preliminary analysis

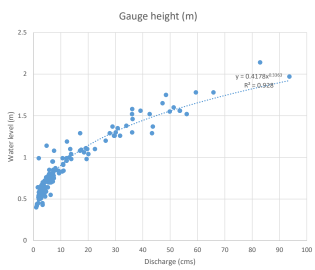
Scatterplots

- Type of graph where corresponding values from a set o data are placed as points on a coordinate plane.
- These plots contain a line of best fit i.e. straight LINE drawn through the center of the data
- It provides a visual representation of correlation/ relationships between two variables
- Correlations depict strength and direction
- The direction of correlation is depicted by whether the correlation is positive or negative
  - Positive correlations - one variable increases the other varia also increases
  - Negative correlations- one variable increases while the othe variable decreases
  - No correlation – no apparent correlation between two varia
- Strength is determined by the numerical values of the coefficient e.g. r=84

Preliminary analysis cont.

- the points indicate a positive relationship between the discharge and water level values
- As the water level values increase, the discharge values increase
- Strength determined by r=0.899
- a **trend line** is significant to estimate unknown outputs for given inputs e.g. discharge and water levels

❑Scatterplots are useful in
  - predicting values based on the relationship revealed
  - Visualize a clear correlation between variables appearing within datasets
  - Quickly compare multiple datasets that use the same variables
  - Recognition of anomalies in variables



Date	Flow_cms	Rain_mm		Cum Rainfall
10/31/1959	11.342	0	11.342	0
11/1/1959	12.057	2	23.399	2
11/2/1959	12.773	8	36.172	10
11/3/1959	8.963	1	45.135	11
11/4/1959	18.565	4	63.7	15
11/5/1959	19.657	1	83.357	16
11/6/1959	16.491	0	99.848	16
11/7/1959	11.931	1	111.779	17
11/8/1959	11.016	3	122.795	20
11/9/1959	10.1	0	132.895	20
11/10/1959	11.342	2	144.237	22
11/11/1959	8.606	4	152.843	26
11/12/1959	7.597	0	160.44	26
11/13/1959	7.597	2	168.037	28
11/14/1959	7.281	5	175.318	33
11/15/1959	8.691	9	184.009	42
11/16/1959	10.1	0	194.109	42
11/17/1959	10.1	0	204.209	42
11/18/1959	9.331	0	213.54	42
11/19/1959	2.084	1	215.624	43
11/20/1959	6.392	16	222.016	59
11/21/1959	12.773	76	234.789	135
11/22/1959	13.668	7	248.457	142
11/23/1959	14.562	19	263.019	161
11/24/1959	13.168	19	276.187	180
11/25/1959	27.008	11	303.195	191

END

Thanks for listening

Q&A

Frequency analysis

JICA WATER ADVISOR TEAM

Presented to

WATER RESOURCES AUTHORITY
TANA BASIN REGIONAL OFFICE
October 12, 2023

Frequency Analysis cont.

- Frequency analysis describes how often an event is likely to occur.
- Runoff is a random variable thus the concept of frequency applies to runoff characteristics and rainfall characteristics
- The peak of the discharge hydrograph is an important design variable in hydrology e.g 100-yr peak discharge in their design work
- The frequency concept for runoff can be viewed in terms of either the *return period* or the *exceedance probability*
- Statistical frequency analysis is a commonly used procedure for the analysis of flood data at a gaged location

Frequency Analysis cont.

- statistical theory is applied to analyze how often an event (flooding or low flows and drought) is likely to occur.
  - This technique is a statistical examination of the frequency–magnitude relationship
- The analysis attempts to place a probability on the likelihood of a certain event occurring.
- It is mainly concerned with the low-frequency, high-magnitude events (e.g. a large flood or a very low river flow).
- Flow duration curves **vs** frequency analysis.
  - **Flow duration curves** tell us the percentage of time that a flow is above or below a certain level. This is average data and describes the overall flow regime
  - **Flood frequency analysis** is concerned only with peak flows: the probability of a certain flood recurring.
  - **Low flow frequency analysis** is concerned purely with the lowest flows and the probability of them recurring

Flow Duration Curves

- **Flow Duration Curve (FDC)** - gives the percentage of time during which any selected discharge may be equaled or exceeded
- FDC represents the relationship between the magnitude and frequency of (daily, weekly, monthly, etc) streamflow for a particular river basin
  - provides an estimate of the percentage of time a given streamflow was equaled or exceeded over a historical period.
- FDC provides a simple, yet comprehensive, graphical view of the overall historical variability associated with streamflow in a river basin
- FDC combines in one curve the flow characteristics of a stream throughout the range of discharge, without regard to the sequence of occurrence.
- If the period upon which the curve is based represents the long-term flow of a stream, the curve may be used to predict the distribution of future flows for water-supply, pollution studies, etc.

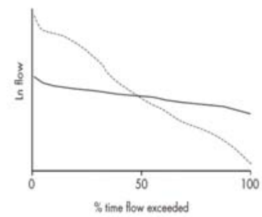
NB: FDC applies only to the period for which data were used to develop the curve or to the period to which the curve is adjusted

Characteristics of FDC

- Daily mean flow data is most commonly used: the average flow for each day (**Note**: This is not the same as a mean daily flow, which is the average of a series of daily flows).
- To derive a flow duration curve the daily mean flow data are required for a long period of time
- The area under the curve is a measure of the total volume of water that flows past the gauging station in the total time considered
- The shape of the flow-duration curve gives a good indication of a catchment’s characteristic response to its average rainfall history
- An initially steeply sloped curve results from a very variable discharge, usually from small catchments with little storage where the stream flow reflects directly the rainfall pattern.
- FDC with a very flat slope indicates little variation in flow regime, the result of the damping effects of large storages
- In the low-flow region:
  - an intermittent stream would exhibit periods of no flow,
  - a very flat curve indicates that moderate flows are sustained throughout the year due to natural or artificial streamflow regulation, or due to a large groundwater capacity that sustains the base flow to the stream

Interpreting a flow duration curve

- The shape of a flow duration curve can tell a lot about the hydrological regime of a catchment
- Dotted line - there is a large difference between the highest and lowest flow values, whereas, for the solid line, there is far less variation.
  - The catchment has far more variation. During dry periods it has a very low flow, but responds to rainfall events with a high flow. This is characteristic of impermeable upland catchments or streamflow in dryland areas
- This tells us that the catchment shown by the solid line never has particularly low flows or particularly high flows.
  - This type of hydrological response is found in catchments where there is a high baseflow (groundwater-derived) and high infiltration rates during storm events.



Statistics derived from a flow duration curve

- The flow value that is exceeded 95 percent of the time (*Q*95). A useful statistic for low-flow analysis.
- The flow value that is exceeded 80 percent of the time (*Q80*). A useful statistic for normal flow analysis
- The flow value that is exceeded 50 percent of the time (*Q*50). This is the median flow value that indicates the flood flow criteria.
- The flow value that is exceeded 10 percent of the time (*Q*10). A useful statistic for analysis of high flows and flooding.

How to determine FDC

- Mean daily discharges are used to prepare a flow-duration curve giving a steep curve.
  - **Step 1**: Sort (rank) average daily discharges for the period of record from the largest value to the smallest value, involving a total of ***n*** values.
  - **Step 2**: Assign each discharge value a rank (M), starting with 1 for the largest daily discharge value.
  - **Step 3**: Calculate exceedance probability (P) as follows:
    - P = 100 * [M / (n + 1)]

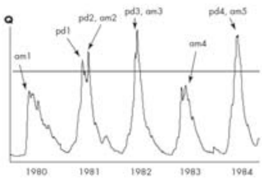
  Where
  - P = the probability that a given flow will be equaled or exceeded (% of time)
    M = the ranked position on the listing (dimensionless)
    n = the number of events for the period of record (dimensionless)

How to determine FDC cont.

- FDC provides a convenient means for studying the flow characteristics of streams and for comparing a basin with another
- The length and timing of the period of record used can also drastically alter an FDC.
  - Longer periods of record provide FDCs that better represent temporally averaged conditions within a basin
  - If shorter periods are used, extreme climatic conditions may influence the results and the applicability of the FDC to a "typical" year
- Shifts in climate, anthropogenic influences (e.g., dam construction, flow diversion), and land use changes may influence the selection of time periods for the development and use of an FDC

Flood frequency analysis

- Flood frequency analysis is concerned with peak flows.
- There are two different ways that a peak flow can be defined:
  - the single maximum peak within a year of record giving an **annual maximum series**;
  - any flow above a certain threshold value, giving a **partial duration series**.



Flood frequency analysis cont.

Challenges when using either data series in flood frequency analysis

- Annual maximum may miss a large storm event where it occurs more than once during a year but it does provide a continuous series of data that are relatively easy to process.
- The setting of a threshold storm is critical in the analysis of the partial duration series - requires considerable experience to get right
- If the data series is longer than ten years then the annual maxima can be used; for very short periods of record the partial duration series can be used
- The first step in carrying out flood frequency analysis is to obtain the data series (in this case annual maxima). The annual maximum series should be for as long as the data record allows.
  - The greater the length of the record the more certainty can be attached to the prediction of the average recurrence interval.
- **Assumption:** The peak flows in flood frequency analysis are independent of each other

Flood frequency analysis cont.

- It is important to grasp the significance of the non-normal distribution for two reasons:
  - Common statistical techniques that require normally distributed data (e.g. t-tests etc.) cannot be applied in flood frequency analysis.
  - It shows what you might expect: small events are more common than large floods, but very large flood events do occur; i.e. a high magnitude, low-frequency relationship.
- NB: Most hydrological datasets are not normally distributed (i.e. it is not a classic bell-shaped curve).

Flood frequency analysis cont.

- Terms used in flood frequency analysis
  - Probability of exceedance: $P(X)$. This is the probability that a flow (Q) is greater than, or equal to a value X. The probability is normally expressed as a unitary percentage (i.e. on a scale between 0 and 1).
  - The relative frequency: $F(X)$. The probability of the flow (Q) being less than a value X. This is also expressed as a unitary percentage.
  - The average recurrence interval: $T(X)$ or return period is a statistical term meaning the chance of exceedance once every T-years over a long record. This should not be interpreted as meaning that is exactly how many years are likely between certain size floods.
- NB: These terms are interrelated mathematically

Methods to Determine Flood Frequency Analyses

Plotting position formula - Weibull formula

- The first step is to rank the annual maximum series data from low to high.

  Assumption: Each data point (i.e. the maximum flood event for a particular year) is independent of any others. This means that the year that the flood occurred in becomes irrelevant.
- Step Two: Calculate the $F(X)$ term using $F(X) = \frac{r}{N+1}$
  - r refers is the rank of an individual flood event (X) within the data series and
  - N is the total number of data points (i.e. the number of years of record)

Methods to Determine Flood Frequency Analyses cont.

- In applying this formula there are two important points to note:
  - The value of $F(X)$ can never reach 1 (i.e. it is asymptotic towards the value 1).
  - If you rank your data from high to low (i.e. the other way around) then you will be calculating the $P(X)$ value rather than $F(X)$. This is easily rectified by using the formula linking the two

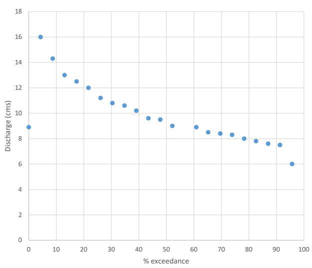
  Note
  - The Weibull formula is simple to use and effective but is not always the best description of an annual maximum series data.
  - The probabilities derived from the Weibull formulae give a good description of the flood frequency within the measured stream record but do not provide enough data when you need to extrapolate beyond a known time series

Methods for fitting hydrological distributions

  - Gumbel distribution
  - Log-Pearson Type III
  - Log-normal
- The choice of distribution is often based on:
  - personal preference and
  - distribution that best fits flow regimes for a particular region

Worked example

Plotting positionm	Discharge (cumecs)	P =m/n+1	Return period T=1/P
1	16	0.043	23
2	14.3	0.087	11.5
3	13	0.13	7.67
4	12.5	0.174	5.75
5	12	0.217	4.6
6	11.2	0.261	3.83
7	10.8	0.304	3.29
8	10.6	0.348	2.88
9	10.2	0.391	2.56
10	9.6	0.435	2.3
11	9.5	0.478	2.09
12	9	0.522	1.92
13	8.9		
14	8.9	0.609	1.64
15	8.5	0.652	1.53
16	8.4	0.696	1.44
17	8.3	0.739	1.35
18	8	0.783	1.28
19	7.8	0.826	1.21
20	7.6	0.87	1.15
21	7.5	0.913	1.1
22	6	0.957	1.05



Low flow frequency analysis

- Low Flow Frequency Analysis (LFFA) is a stochastic approach for characterizing low flow events.
- The aim is to quantify the likelihood that the flow at a particular site will persist below a particular level over a particular duration.
- LFFA is typically utilized where a single statistic or index e.g. Q95 is insufficient to describe the low flow regime.
- LFFA provides a means to quantify the flow-duration-frequency behaviour of the site of interest.
- Individual low flows events can be delineated by considering periods where the flow falls below a threshold level.
- Normally, a D-day average discharge per year is considered.
- low flow characteristics provide threshold values for different water-based activities and is required for such water resource management issues e.g. water allocation for water supply, irrigation etc.

Low flow frequency analysis cont.

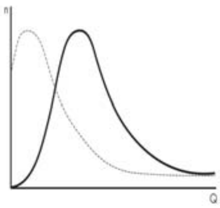
- annual minimum series is derived from a time series for low flows

Challenge:

- Which annual year should be used when you have to assume that the annual minimum flows are independent of each other analysis of when low flows occur needs to be carried

NB: There is a finite limit on how low a flow can be setting the difference between flood frequency and low flow frequency analysis

- In theory, a flood can be of infinite size, whereas it is not possible for a low flow to be less than zero (negative flows should not exist in freshwater hydrology).
- This places a limit on the shape of a probability distribution, effectively truncating it on the left-hand side



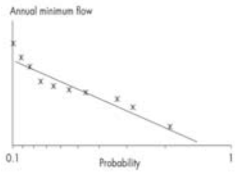
Low flow frequency analysis cont.

- Statistical techniques described for flood frequency analysis assume a full log-normal distribution and cannot be easily applied for low flows.

NB:

- Probabilities calculated from the Weibull formula are plotted against the annual minimum flow values.
- The data fit a straight line, but if we extrapolate the line further it would intersect the x-axis at a value of approximately 0.95.

- Implication - there is a 5 percent chance of having a flow less than zero (i.e. a negative flow).
- The way around
  - Fit an exponential rather than a straight line to the data. This is easy to do by eye but complicated mathematically.



Limitations of frequency analysis

- The estimation technique is only as good as the streamflow records that it is derived from. Where the records are short or of dubious quality very little of worth can be achieved through frequency analysis.
- Do not extrapolate average recurrence intervals beyond twice the length of your data set since very large floods can create problems for flow gauges and therefore this extreme data may be of dubious quality
- The assumption is made that each storm or low flow event is independent of another used in the data set. This is relatively easy to guard against in annual maximum (or minimum) series, but more difficult for a peak threshold series.
- There is an inherent assumption made that the hydrological regime remains static during the complete period of record. This may not be true where land use, or climate change, has occurred in the catchment

Development of Stage-discharge rating

JICA WATER ADVISOR TEAM

presented to

WATER RESOURCES AUTHORITY
TANA BASIN REGIONAL OFFICE
October 12, 2023

Theoretical background

Introduction

- A stage-discharge rating curve (H-Q) represents the relation of water level at a given point in a stream to a corresponding discharge.
- A rating curve is a site- and time-specific relationship used to produce continuous records of streamflow from water level measurements.
- The shape of a curve can be revealed by conducting synchronized measurements of stage and discharge and investigating the pattern of points on a scatter plot.
- Any physical change to the stream channel will alter the relationship
  - The changes must be accounted for in the derivation of a discharge hydrograph from a time series of stage data
- Ideally, 'enough' measurements are expected to empirically characterize the shape of the curve for every channel configuration.
  - Obtaining 'enough' measurements requires an enormous investment in stream gauging
- Only enough measurements are used to define the true shape of the curve and how it changes over time.

❖The real skill in rating curve development is in interpreting these clues to disclose the truth

Purpose of rating curves

- Predict discharge that is difficult to measure continuously, from water level that is easier to determine.
  - the aim is to produce a continuous time series of discharge or suspended sediment or solute concentration.

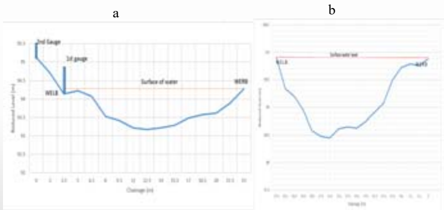
Purpose of rating curves cont.

- Rating curves are constructed using linear or nonlinear (log–normal or log-log) regression, where parameters are fitted by the least squares method.
- A poorly conceived rating curve can produce discharge data that does not pass the test of hydrologic reason
  - Extreme values from curve extrapolation may be too high (e.g. a rainfall-runoff ratio > 1), or too low.
  - The early years of record may have peaks defined by a badly extrapolated curve relative to 'better', more mature, extrapolations resulting in an apparent (but not real) trend in peak flows.
  - The seasonal water balance may be skewed by poorly modeled backwater effects.

Developing a Rating Curve

- Stage-discharge relation is a function of the streambed material and geometry
- each rating curve is unique to a site and a particular period of time

a b



Cross sectional profile at Kathita 4F10 for December 2022 (a) and May 2023 (b)

Developing a Rating Curve cont.

- Rating curves are developed when sufficient stage and discharge data is recorded over time. The paired data sets are plotted, and a line (curve) is drawn through the points to describe the relation
- stage and discharge measurements at high and lower flows change the slope of the rating curve and create a more accurate relation at a larger range of stages

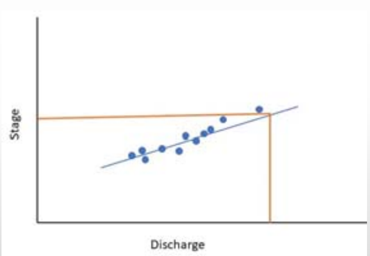
River cross-section survey and discharge measurement at RGS 4AC03 Sagana on December 19, 2022

Development of Rating Curves (H-Q curves)

- Equation of Rating Curve
  $Q=c(H \pm a)^n$

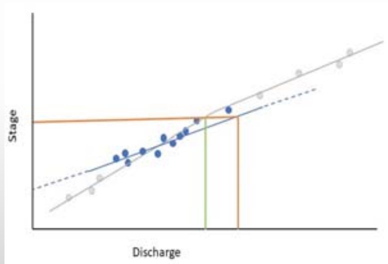
where Q: Discharge (m^3/s)
H: Water Level (m)
c: Multiplier parameter
a: Scale offset parameter
n: Exponent parameter

- Other forms used to obtain a good fit - linear, polynomial functions, power, etc.,



Developing a Rating Curve cont.

- Stage and discharge measurements at high and lower flow affect the slope of the rating curve
  - create a more accurate relation at a larger range of stages

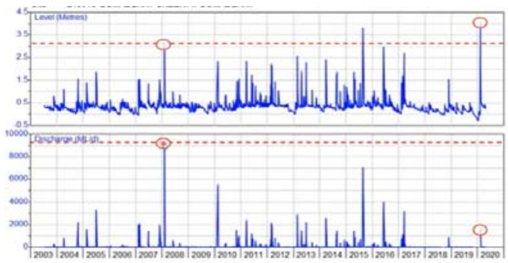


Gauging site condition

- Good control section to govern the relationship between gauge height and discharge at the gauge.
- The section can be a natural feature of the channel e.g. riffle or a man-made section control e.g. weir, a flume, etc.
- Install RGS upstream from the control section where a good stage-discharge relationship is established
- River discharges are measured for various flows and corresponding water surface elevations recorded

Uncertainties associated with rating curves

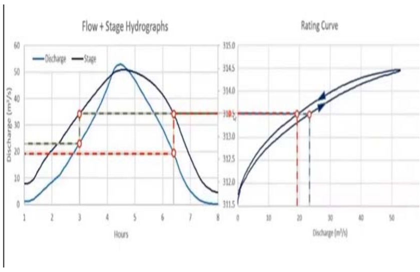
- The H-Q relationship is not constant during its application



Uncertainties associated with rating curves cont.

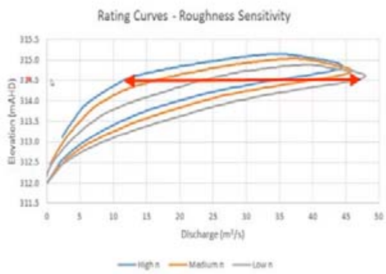
Effect of hysteresis

- **Higher discharges are observed during the rising stage than in the falling stages resulting in looped rating curves.**
- Note the Q after 3 hours in the curve with the same H but different Qs i.e. 24 and 20m³/s from the curve



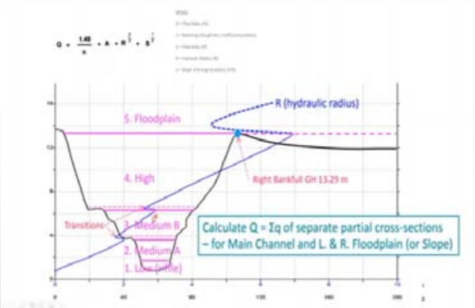
Uncertainty associated with rating curves Cont.

- Roughness sensitivity e.g. vegetation



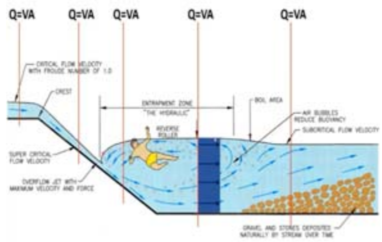
Uncertainties associated with rating curves cont.

- The effect of hydraulic radius



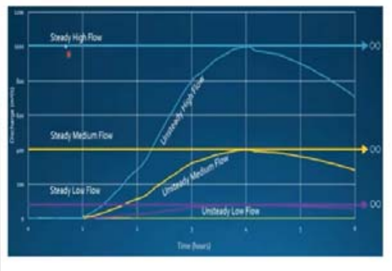
Uncertainties associated with rating curves cont.

- **Effect of Man-made structures like a weir, bridge**
- Q is the same throughout the river system but H has changed significantly. Need to check where you measure the flows/levels



Uncertainty associated with rating curves cont.

- Type of flow in the river i.e. steady and unsteady flow
- Most rating curves are based on 1D steady-state flow which is different from a 2D unsteady-state flow
- The area under the curve represents the volume of water - then the steady high flow will have a high discharge than the unsteady high flow
- higher discharges are observed during the rising stage than in the falling stages resulting in looped rating curves.



Other causes of uncertainties

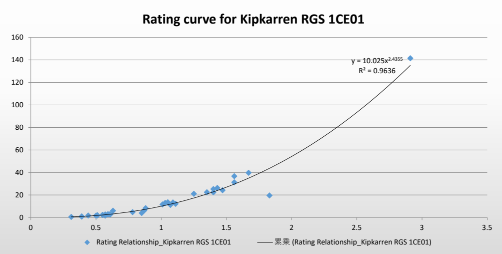
- Sediment transport- causes changes in effective bed roughness where a bed is in motion
  - friction is greater after the flood peak than before thus corresponding discharge for a given stage height will be less after the peak
- Variable channel storage
  - stream overflows onto flood plains during high discharges give rise to different slopes and to unsteadiness effects
- Presence of Ice – not a challenge in the tropics

Challenges associated with use flow rating curves

- Assumption of a unique relationship between stage and discharge is in general not justified
- Discharge is rarely measured during a flood and the quality of the data at the high flow end of the curve might be quite poor
- It is usually some sort of line of best fit through a sample made up of a number of points; sometimes extrapolated for higher stages
- It has to describe a range from no flow through small but typical flows to very large extreme flood events

Example of a rating curve

Date	Level	Flow
12-Aug-1981	2.91	141.44
28-Sep-2003	1.83	19.578
29-Jun-1981	1.67	39.714
28-Aug-1980	1.56	36.742
10-Mar-2001	1.56	31.308
7-Dec-2003	1.47	24.261
12-Oct-1981	1.43	26.275
6-Jun-1977	1.4	22.37
7-Aug-1980	1.4	25.279
17-May-1982	1.35	22.474
3-Aug-1982	1.25	21.107
2-Jul-1985	1.11	12.17
5-Jul-1982	1.09	13.381
15-Aug-1980	1.07	11.166
29-Sep-1982	1.05	13.547
26-May-2004	1.03	12.971
2-Dec-1983	1.01	11.626
3-Dec-2002	0.88	8.308
20-Sep-2002	0.87	6.345
15-Oct-1980	0.85	3.975
7-Nov-1985	0.78	4.787
4-Dec-1985	0.63	6.059
10-Dec-1980	0.61	2.844
15-Feb-1984	0.6	2.891
1-Feb-1982	0.59	2.86
13-Jan-1981	0.57	1.681
10-Dec-1984	0.57	2.719
14-Jun-1984	0.55	2.305
27-Nov-1984	0.55	2.292
7-Jan-1980	0.51	1.812
3-Oct-2004	0.51	2.093
3-Mar-1982	0.5	1.676
19-Feb-1980	0.44	1.764
3-Mar-1981	0.39	1.006
14-Feb-1985	0.39	0.85
13-Mar-1985	0.31	0.557



END

Thank you for listening

Q&A

NIPPON KOEI

Analysis Flow of the Climate Change Impact

Capacity Building Activities for
Kenya Water Resources Advisor (JICA)

2023.10.13
JICA Experts Team

Analysis Flow of the Climate Change Impact

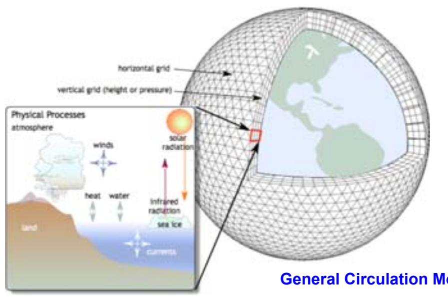
Background

- Climate is changing naturally.
- The rate of change has accelerated significantly due to human activities.
- The National Water Master Plan 2030 targeted to formulate plans for the year 2030, and needed to consider whether the future climate conditions would be the same as current conditions.
- Therefore, the impact of climate change on Kenya was evaluated.

Analysis Flow of the Climate Change Impact

Methodology in the National Water Master Plan 2030 (NWMP 2030)

- A general circulation model (GCM) was applied as a tool to understand the climate and to project future climate conditions.



General Circulation Model (GCM)

Source: https://hogback.atmos.colostate.edu/cmmap/learn/modeling/whatIs2.html

Analysis Flow of the Climate Change Impact

Methodology in the National Water Master Plan 2030 (NWMP 2030)

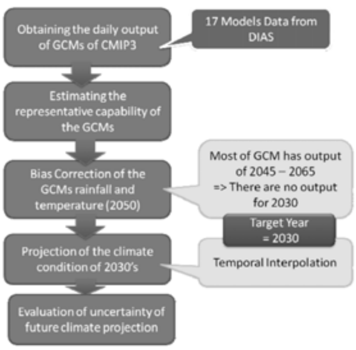
- Many GCMs have been developed in various countries.
- During the study of NWMP 2030, there were 17 GCMs that are available in the daily data sets.
- Those data sets of GCMs were archived in:
  DIAS (Data Integration and Analysis System) Japan, as well as
  CMIP3 (Phase 3 of the Coupled Model Intercomparison Project) ※1
- The above mentioned daily data sets of DIAS were provided from Tokyo University to NWMP 2030 Study Team via JICA.

※1 The data sets of GCMs were updated to
CMIP5 (Phase 5 of the Coupled Model Intercomparison Project) in 2013 and
CMIP6 (Phase 6 of the Coupled Model Intercomparison Project) in 2021.

Analysis Flow of the Climate Change Impact

Methodology in the National Water Master Plan 2030 (NWMP 2030)

- By using DIAS provided from University of Tokyo, multi model ensemble analysis was carried out to evaluate the uncertainty of future climate.
- The figure on the righthand side shows the work flowchart of climate change analysis.



Work Flowchart of Climate Change Analysis

Analysis Flow of the Climate Change Impact

Methodology in the National Water Master Plan 2030 (NWMP 2030)

Scenario of Greenhouse Effect Gas Emission (1/2)

- To study the impact of Climate Change, in the future, greenhouse gas emission scenarios, which describe future release of greenhouse gases.
- A set of four scenarios families (A1, A2, B1 and B2) have been developed as shown in the next slide.
- Of these scenarios, Scenario A1B was selected for NWMP 2030 study because it is physically plausible and consistent, within a realistic and the potential range on future regional climate change.

Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology in the National Water Master Plan 2030 (NWMP 2030)

Scenario of Greenhouse Effect Gas Emission (2/2)

Greenhouse Effect Gas Emission Scenarios

Scenario family	SRES Emission Scenarios	CO_2 Stabilization
A1	A future world of very rapid economic growth, global population that peaks in the mid-century and declines thereafter. Rapid introduction of new and more efficient technologies. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. -A1F1: fossil-intensive -A1T: non-fossil energy sources -A1B: balance across all sources	A1F1: Not stabilise A1T:650 ppm A1B:750 ppm
A2	A very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other scenario families.	Not stabilise
B1	A convergent world with the same global population as in the A1 storyline but with rapid changes in the economic structure toward a service and information economy, with reductions in materials intensity, and the introduction of clean and resource-efficient technologies.	550 ppm
B2	A world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development.	650 ppm

Source: Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA), IPCC

Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology in the National Water Master Plan 2030 (NWMP 2030)

General Circulation Models (GCMs)

- GCMs are the most advanced tools currently available for simulating the response to the global climate system to increasing greenhouse gas concentrations.
- Using GCMs, climatology can be simulated for seasonal and monthly means.
- GCMs cannot be expected to simulate the actual weather observed at individual locations at specific times or the actual seasonal means for a particular region and, for a particular year.

Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology in the National Water Master Plan 2030 (NWMP 2030)

GCMs and their development institutions

No	Model Name	Developers
1	bcc-cm1	Beijing Climate Center, China
2	bccr-bcm2.0	Bjerknes Centre for Climate Research, Norway
3	cccma_cgcm3_1	Canadian Centre for Climate Modelling and Analysis, Victoria, BC, Canada
4	cccma_cgcm3_1_t63	Canadian Centre for Climate Modelling and Analysis, Victoria, BC, Canada
5	cnrm_cm3	Centre National de Researches Meteorologiques, Meteo-France, Toulouse, France
6	csiro_mk3_0	CSIRO Atmospheric Research, Melbourne, Australia
7	csiro_mk3_5	CSIRO Atmospheric Research, Melbourne, Australia
8	gfdl_cm2_0	US Dept of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA
9	gfdl_cm2_1	US Dept of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA
10	giss_aom	NASA/Goddard Institute for Space Studies, New York, USA
11	giss_model_e_h	NASA/GISS (Goddard Institute for Space Studies)New York, NY
12	giss_model_e_r	NASA/GISS (Goddard Institute for Space Studies)New York, NY
13	iap_fgoals1_0_g	LASG, Institute of Atmospheric Physics, P.O. Box 9804, Beijing 100029, P.R. China
14	ingv_echam4	National Institute of Geophysics and Volcanology, Bologna, Italy
15	inmcm3_0	Institute for Numerical Mathematics, Moscow, Russia
16	ipsl_cm4	Institut Pierre Simon Laplace, Paris, France
17	miroc3_2_hires	Center for Climate System Research, Tokyo, Japan / National Institute for Environmental Studies, Ibaraki, Japan / Frontier Research Center for Global Change, Kanagawa, Japan
18	miroc3_2_medres	Center for Climate System Research, Tokyo, Japan / National Institute for Environmental Studies, Ibaraki, Japan / Frontier Research Center for Global Change, Kanagawa, Japan
19	miub_echo_g	University of Bonn, Bonn, Germany, Meteorological Research Institute, Seoul, Korea
20	mpi_echam5	Max Planck Institute for Meteorology, Hamburg, Germany
21	mri_cgcm2_3_2a	Meteorological Research Institute, Tsukuba, Ibaraki, Japan
22	ncar_ccsm3_0	National Center for Atmospheric Research, Boulder, CO, USA
23	ncar_pcm1	National Center for Atmospheric Research, Boulder, CO, USA
24	ukmo_hadcm3	Hadley Centre for climate Prediction and Research/Met office, UK
25	ukmo_hadgem1	Hadley Centre for climate Prediction and Research/Met office, UK

Source: CMIP3 CMIP3 Climate Model Documentation, References, and Links

25 GCMs

Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology in the National Water Master Plan 2030 (NWMP 2030)

Selection of GCMs (1/6)

- The gridded observed data for the following four variables of climate were obtained from the web site of NOAA (National Oceanic and Atmospheric Administration).
  - Precipitation
  - Outgoing Longwave Radiation (OLR)
  - Sea Level Pressure
  - Surface Air Temperature
- Climatology of **monthly mean values** of **the gridded observed data** were calculated from 1981 to 2000.
- 17 GCMs were selected from 25 GCMs, of which daily and monthly data were available in the CMIP3 and DIAS.

Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology in the National Water Master Plan 2030 (NWMP 2030)

Selection of GCMs (2/6)

Selected 17 GCMs

No	Model Name	Developers	Monthly	Daily
-	bcc-cm1	Beijing Climate Center, China	missing	missing
-	bccr-bcm2.0	Bjerknes Centre for Climate Research, Norway	missing	
1	cccma_cgcm3_1	Canadian Centre for Climate Modelling and Analysis, Victoria, BC, Canada		
2	cccma_cgcm3_1_t63	Canadian Centre for Climate Modelling and Analysis, Victoria, BC, Canada		
3	cnrm_cm3	Centre National de Researches Meteorologiques, Meteo-France, Toulouse, France		
4	csiro_mk3_0	CSIRO Atmospheric Research, Melbourne, Australia		
5	csiro_mk3_5	CSIRO Atmospheric Research, Melbourne, Australia		
6	gfdl_cm2_0	US Dept of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA		
7	gfdl_cm2_1	US Dept of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA		
8	giss_aom	NASA/Goddard Institute for Space Studies, New York, USA		
-	giss_model_e_h	NASA/GISS (Goddard Institute for Space Studies)New York, NY		missing
9	giss_model_e_r	NASA/GISS (Goddard Institute for Space Studies)New York, NY		
10	iap_fgoals1_0_g	LASG, Institute of Atmospheric Physics, P.O. Box 9804, Beijing 100029, P.R. China		
11	ingv_echam4	National Institute of Geophysics and Volcanology, Bologna, Italy		
	inmcm3_0	Institute for Numerical Mathematics, Moscow, Russia		missing
12	ipsl_cm4	Institut Pierre Simon Laplace, Paris, France		
13	miroc3_2_hires	Center for Climate System Research, Tokyo, Japan / National Institute for Environmental Studies, Ibaraki, Japan / Frontier Research Center for Global Change, Kanagawa, Japan		
14	miroc3_2_medres	Center for Climate System Research, Tokyo, Japan / National Institute for Environmental Studies, Ibaraki, Japan / Frontier Research Center for Global Change, Kanagawa, Japan		
15	miub_echo_g	University of Bonn, Bonn, Germany, Meteorological Research Institute, Seoul, Korea		
16	mpi_echam5	Max Planck Institute for Meteorology, Hamburg, Germany		
17	mri_cgcm2_3_2a	Meteorological Research Institute, Tsukuba, Ibaraki, Japan		
-	ncar_ccsm3_0	National Center for Atmospheric Research, Boulder, CO, USA		missing
-	ncar_pcm1	National Center for Atmospheric Research, Boulder, CO, USA	missing	missing
-	ukmo_hadcm3	Hadley Centre for climate Prediction and Research/Met office, UK		missing
-	ukmo_hadgem1	Hadley Centre for climate Prediction and Research/Met office, UK		missing

Source: CMIP3 Climate Model Documentation, References, and Links

Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology in the National Water Master Plan 2030 (NWMP 2030)

Selection of GCMs (3/6)

- Climatology of monthly mean values of the **GCMs** were calculated from 1981 to 2000 for all variables.
- Correlation factor and root mean square error (RMSE) were applied for comparison between **observed data** and **GCMs**.

Variable	Standard Name	Notes
pr	Precipitation	Global Precipitation Climatology Project (GPCP) Version 2.2 Climatology Precipitation Acknowledgement: The GPCP combined precipitation data were developed and computed; the NASA/Goddard Space Flight Center's Laboratory for Atmospheres as a contribution to the GEWEX Global Precipitation Climatology Project. from their Web site at http://www.ncdc.noaa.gov/oa/
olr	Outgoing Longwave Radiation (OLR)	20 years(1981-2000) Climatology of OLR from interpolated OLR dataset Created from monthly means of OLR from National Oceanic Atmospheric Administration (NOAA) Acknowledgement: Interpolated OLR data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/
slp	Sea Level Pressure	20 years(1981-2000) Climatology of Sea Level Pressure Created from National Centers for Environmental Prediction (NCEP) Reanalysis monthly Sea Level Pressure Acknowledgement: NCEP Reanalysis Derived data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/
tas	Surface Air Temperature	20 years(1981-2000) Climatology of air temperature Created from NCEP Reanalysis monthly air temperature Acknowledgement: NCEP Reanalysis Derived data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/

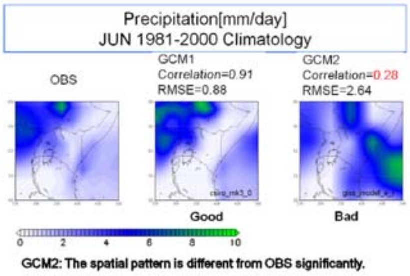
Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology in the National Water Master Plan 2030 (NWMP 2030)

Selection of GCMs (4/6)

- Example of comparison of Precipitation



Source: JICA Study Team with following original data
The GPCP Version 2.2 combined precipitation data, the DIAS dataset, and the CMIP3 multi-model dataset.

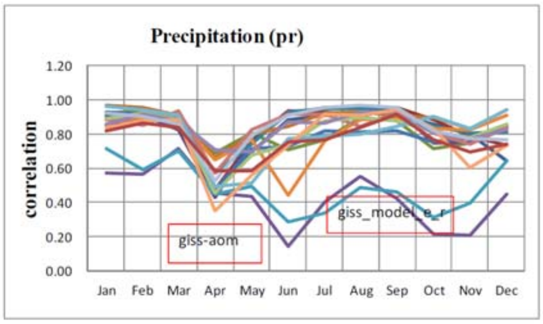
Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology in the National Water Master Plan 2030 (NWMP 2030)

Selection of GCMs (5/6)

- Correlation of 17 GCMs and observed data



Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology in the National Water Master Plan 2030 (NWMP 2030)

Selection of GCMs (6/6)

- Selected 11 GCMs

GCMs		Correlation				RMSE				Selected for Calculation
No.	Name	P	Olr	SLP	TAS	P	Olr	SLP	TAS	
1	cccma_cgcm3_1									Selected
2	cccma_cgcm3_1_t63									Selected
3	cnrm_cm3									Selected
4	csiro_mk3_0									Selected
5	csiro_mk3_5								1	
6	gfdl_cm2_0									Selected
7	gfdl_cm2_1									Selected
8	giss_aom	1								
9	giss_model_e_r	1						1		
10	iap_fgoals1_0_g		1		1				1	
11	ingv_echam4			1						
12	ipsl_cm4									Selected
13	miroc3_2_hires									Selected
14	miroc3_2_medres									Selected
15	miub_echo_g			1						
16	mpi_echam5									Selected
17	mri_cgcm2_3_2a									Selected

Note: In the RMSE and Correlation, the cells inscribed "1" means the model abandoned through the evaluation.
RMSE (Root-mean-square error)
P : Precipitation
Olr :Outgoing Longwave Radiation
SLP :Sea Level Pressure
TAS :Surface Air Tempretune

Source: Evaluated by JICA Study Team with the data obtained from Data Integration and Analysis System (DIAS) dataset, and The Phase 3 of Coupled Model Intercomparison Project (CMIP3) multi-model dataset.

Analysis Flow of the Climate Change Impact

NIPPON KOEI

Bias Correction

Necessity of Bias Correction

- GCMs are effective tools for projection of future climate conditions.
- But GCMs have a bias in simulating 20th century precipitation and temperature. → Cannot be directly used. → Bias correction necessary.
- Well-known problems of GCMs
  - Large diversity of the models
  - Low seasonal representation
  - Low extreme heavy rainfall rate
  - Small number of no rainfall day but long drizzle

Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

General

- **Bias** is a gap between the **observed data** and the **output of the GCMs** for a certain meteorological index such as annual mean rainfall, monthly mean rainfall, rainfall frequency, etc.
- Although the output of GCMs have dates as if it is along with the actual calendar, the daily rainfall it cannot be compared with the actual record of the same date.
- **Bias correction** is made **to adjust** the **simulated** climatology to the **observed** climatology.
- The **methodology for bias correction** that is applied in this study is based on the **idea advocated by Professor Koike of University of Tokyo**.

Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Points of View for Bias Correction

- Bias correction of rainfall is carried out through the following process.
  - a) Correction to monthly climatology
  - b) Correction of no rainfall days
  - c) Correction of high intensity rainfall
- The bias correction corresponds with the problems of the GCMs mentioned before.

Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Correction to monthly climatology - **Procedures**

- The GCMs grid data were re-gridded into the same grid dimension with the gridded observed rainfall data.
- The **grid size** is **0.1 degree** in both of latitude and longitude directions.
- The **monthly mean rainfall** of the **observed** and **20c3m** are computed for the period **from 1981 to 2000**.
- All daily rainfall data of a certain month are extracted and sorted in descending order. For example, the daily rainfall in April for 20 years is counted as 600. The figure below shows a schematic image of this extraction and sorting work.

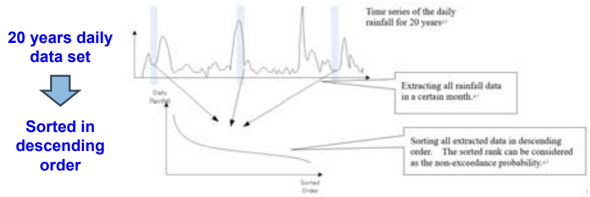
Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Correction to monthly climatology - **Procedures**

- All daily rainfall data of a certain month are extracted and sorted in descending order.
- For example, the daily rainfall in April for 20 years is counted as 600. The figure below shows a schematic image of this extraction and sorting work.



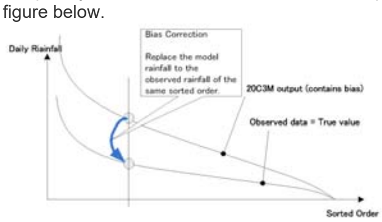
Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Correction to monthly climatology - **Procedures**

- For a certain rank of rainfall of 20c3m, the bias is considered as the gap between 20c3m and the observed data with the same rank.
- Rainfall with a certain rank of 20c3m was replaced by that with the same rank of the observed data.
- Therefore, the bias-corrected climatology of the monthly mean rainfall of 20c3m is to be completely matched with the observed. This procedure is illustrated in the figure below.



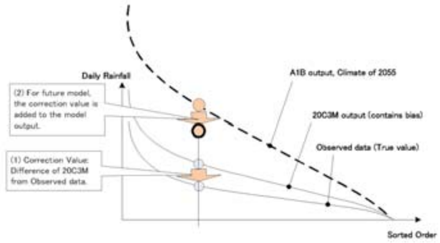
Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Correction to monthly climatology - **Procedures**

- The daily rainfall of the A1B for 20 years from 2046 to 2065 was processed in the same manner with the observed data and 20c3m.
- To correct the bias of the rainfall of a certain rank, the gap between the 20c3m and the observed data of the same rank is added. The procedure is illustrated in the figure below.



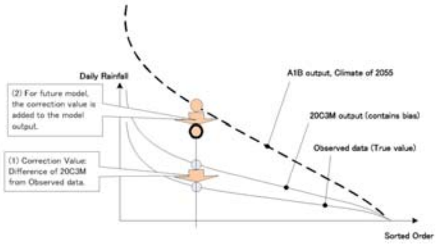
Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Correction to monthly climatology - **Procedures**

- The daily rainfall of the A1B for 20 years from 2046 to 2065 was processed in the same manner with the observed data and 20c3m.
- To correct the bias of the rainfall of a certain rank, the gap between the 20c3m and the observed data of the same rank is added. The procedure is illustrated in the figure below.



Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Correction to monthly climatology - **Procedures**

- Bias correction for temperature was carried out in the same manner.

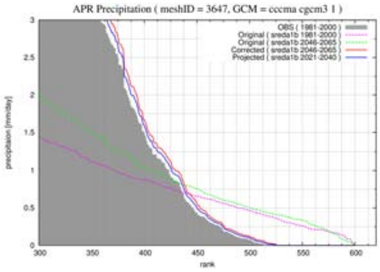
Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Correction of No Rainfall Days

- The number of no rainfall days of GCMs is less than that of the observed data.
- The below figure shows comparison of the observed and the output of GCM.



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Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Correction of No Rainfall Days

- The considered duration is 20 years and rainfall for April was extracted and sorted.
- The rainfall data sets of 600 days were obtained for the observed (gray bar) and simulated.
- The chart shows the tail part of the sorted rainfall.
- The gray coloured area indicates the observed rainfall.
- This chart is for April having heavy rainfall season in Kenya.
- Therefore, there are rainfalls around the rank of 500.
- However, the dotted curve, which is sorted for raw rainfall data in the GCMs, indicate that there are rainfalls up to the end of the data.
- This is a bias of no rainfall days.

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Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Correction of No Rainfall Days - **Procedures**

- The bias correction procedure for no rainfall days is as follows:
  a) The rainfall value of 20c3m of the last observed rainfall is made the threshold of no rainfall day.
  b) The rainfall for the A1B scenario that is less than the threshold is corrected as zero.

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Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Correction of High Intensity Rainfall - **Procedures**

- To cope with the problems of GCMs, **plotting position method** was applied.
- The procedure of the method is as follows:
  a) The **annual maximum daily rainfalls** are extracted from the **observed** and **20c3m data** on a certain grid.
  b) **Cunnane plot** is applied **to estimate the non-exceedance probability** of the extracted rainfalls.
  c) Bias is considered as the gap between rainfall intensity of the observed and 20c3m with the same probability.

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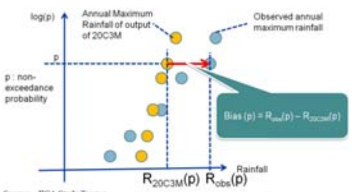
Analysis Flow of the Climate Change Impact

NIPPON KOEI

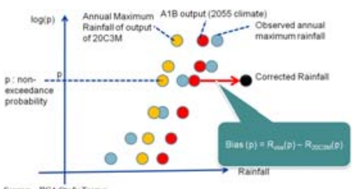
Methodology of Bias Correction

Correction of High Intensity Rainfall - **Procedures**

- The schematic image of the bias of the high intensity rainfall is illustrated below.



Source: JICA Study Team
Schematic Image of Bias of High Intensity Rainfall



Source: JICA Study Team
Bias Correction for A1B (2046-2065) Rainfall

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Analysis Flow of the Climate Change Impact

NIPPON KOEI

Methodology of Bias Correction

Summary for Bias Correction

- GCMs have a bias in simulating 20th century precipitation and temperature.
  → Cannot be directly used. → Bias correction necessary.
- Well-known problems of GCMs
  - Large diversity of the models
  - Low seasonal representation
  - Low extreme heavy rainfall rate
  - Small number of no rainfall day but long drizzle
- Against the above-listed problems, Bias Correction is made for:
  a) Correction to monthly climatology
  b) Correction of no rainfall days
  c) Correction of high intensity rainfall

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Analysis Flow of the Climate Change Impact

Projection of 2030 Climate

NWMP 2030

- The target year of NWMP 2030 is the year 2030.
- For this, the rainfall and temperature data for the period from 2021 to 2040 are needed for the assessment of the impacts of climate change on Kenya.
- Actually, the simulations of every GCM for the period around 2030 have been implemented, but the daily output could not be obtained due to the huge size of the data.
- The 2030 climate was projected from the observed climate (1990) and bias-corrected A1B 2055 climate.

Analysis Flow of the Climate Change Impact

Projection of 2030 Climate

Methodology for Projection

- The target year of NWMP 2030 is the year 2030.
- For this, the rainfall and temperature data for the period from 2021 to 2040 are needed for the assessment of the impacts of climate change on Kenya.
- The simulations of every GCM for the period around 2030 have been implemented, but the daily output could not be obtained due to the huge size of the data.
- The 2030 climate was projected from the observed climate (1990) and bias-corrected A1B 2055 climate.

Analysis Flow of the Climate Change Impact

Projection of 2030 Climate

Methodology for Projection

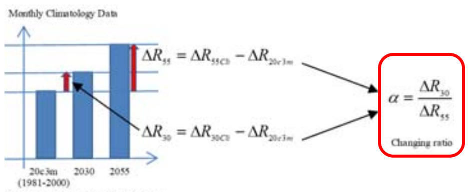
- The projection is based on simple temporal interpolation.
- The **monthly mean rainfall** and **temperature** data of **GCMs** can be obtained from the web site of the **IPCC Data Distribution Center** (http://www.ipcc-data.org).
- The projection of 2030 climate was made using the following procedures:
  a) The **monthly mean climatology of the considered GCMs** was **computed for the 2030 climate**, which has uncorrected bias.
  b) The **monthly climatology** of **20c3m** and **A1B 2046-2065** is calculated in the same manner with the 2030 data for GCMs.
  c) The **changing ratios** of the climatology **for every month** were **evaluated**.

Analysis Flow of the Climate Change Impact

Projection of 2030 Climate

Methodology for Projection

a) The changing ratio (α) is evaluated as the ratio of the difference from the **20c3m (1981-2000 simulated) results** to the **2055 climate** and to the **2030 climate**. The schematic image of this procedure is shown in the figure below.



Source: JICA Study Team

Schematic Image of Projection of 2030 Climate (1)

Analysis Flow of the Climate Change Impact

Projection of 2030 Climate

Methodology for Projection

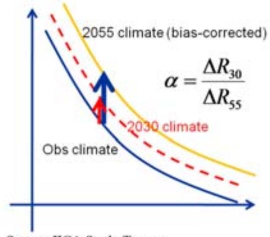
a) The time-series of the **observed grid data** is **a base** time-series for the projection of the **rainfall** and **temperature** of the **2030 climate**.
b) Preliminary data for, a certain month of the **observed** and **bias-corrected A1B 2055 data** are extracted and sorted.
c) **Rainfall** or **temperature** of the **2030 climate** can be projected by applying the **changing ratio (α)** to the difference between values of the bias-corrected 2055 climate and the observed with the same rank.
d) The evaluated rainfall or temperature for the 2030 climate is re-sorted along with occurrences of the observed data. The projected time-series of every GCM are based on the same time-series data.

Analysis Flow of the Climate Change Impact

Projection of 2030 Climate

Methodology for Projection

a) The evaluated rainfall or temperature for the 2030 climate is re-sorted along with occurrences of the observed data. The projected time-series of every GCM are based on the same time-series data.



Source: JICA Study Team

Schematic Image of Projection of 2030 Climate (2)

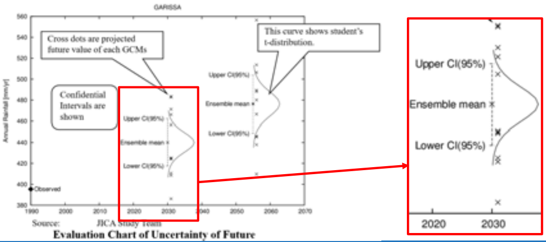
Analysis Flow of the Climate Change Impact

NIPPON KOEI

Projection of 2030 Climate

Evaluation of Uncertainty of Projected Future Climate

a) The projected daily rainfall and temperature data of 11 GCMs were derived through the foregoing process.
b) As there are wide difference among models of GCMs each other.
c) Therefore, uncertainty was evaluated using ensemble mean. Mean values can be considered as the most expected future.

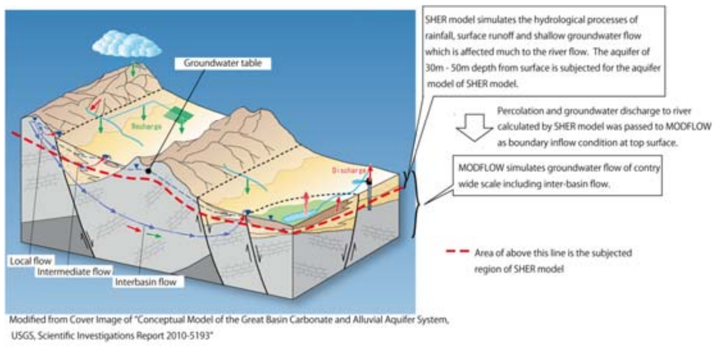


Evaluation Chart of Uncertainty of Future

Analysis Flow of the Climate Change Impact

NIPPON KOEI

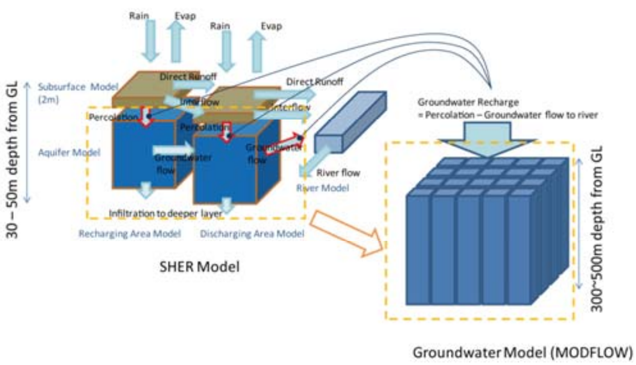
Analysis Model



Analysis Flow of the Climate Change Impact

NIPPON KOEI

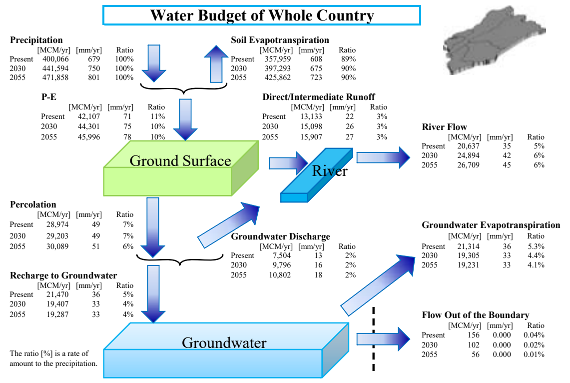
Analysis Model



Analysis Flow of the Climate Change Impact

NIPPON KOEI

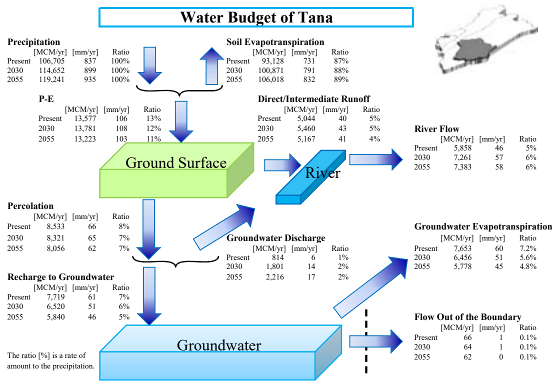
Results of Analysis



Analysis Flow of the Climate Change Impact

NIPPON KOEI

Results of Analysis



Analysis Flow of the Climate Change Impact

NIPPON KOEI

Climate Change Analysis in National Water Master Plan 2030

- To evaluate the effects of future climate change to water resources, future climate around 2050 was projected based on the output of 17 GCMs.
- The emission scenario selected for the climate change projection was A1B scenario.
- Considering data availability for the adopted emission scenario A1B and evaluation of reproducibility of Kenya's climate characteristics, 11 out of 17 GCMs obtained were used for future climate projection for 2030 and 2050.
- The climate of 2030 was interpolated with the climates of 1990 and bias-corrected 2050.
- According to the multi-model ensemble analysis of 11 GCMs, an increase of surface air temperature seems to be unavoidable in the future.

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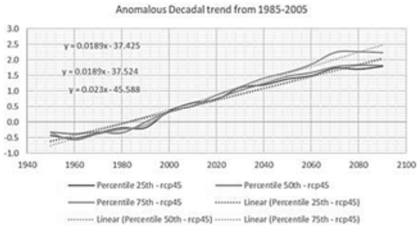
Capacity Building for WRA Staff

Water Evaluation and Planning (WEAP)

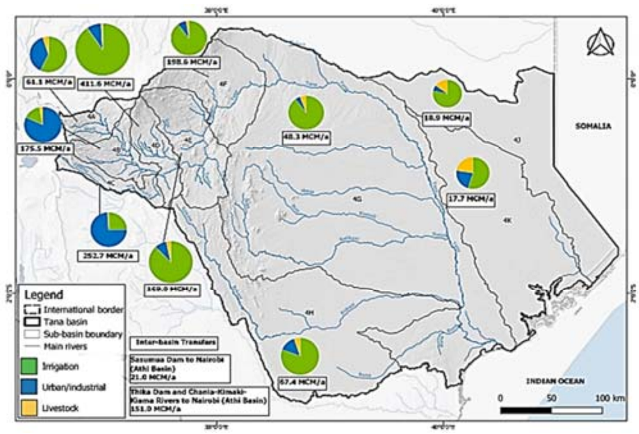
October 13, 2023
Presentation by Gilbert Maiyo
JICA WRA Advisor Team

Climate Situation-Tana Sub-basin

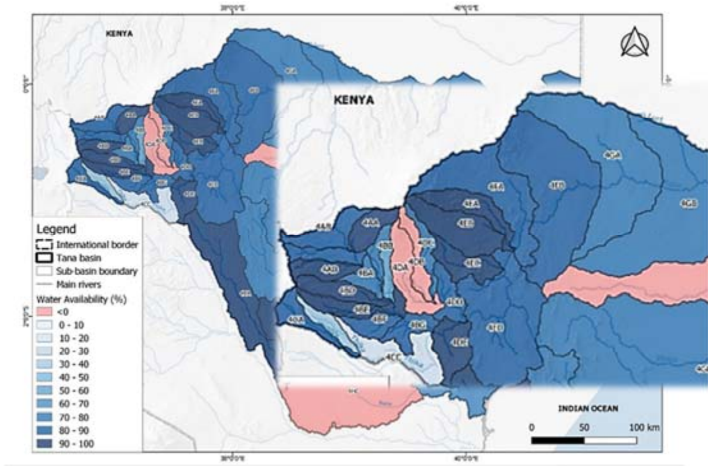
- MAP across the basin will increase from 673 mm to 723 mm by 2050 under RCP 4.5. The climate analysis on precipitation indicates **a consistent Increase in future precipitation in the sub-basins during the 'short' rainy season** and during the months of January and February. **During the 'long' rainy season the increase in precipitation is less pronounced.** –KWSCRP, 2020
- Furthermore, the eastern sub-basins also appear to be much wetter in the future than the western sub-basins. During the dry season from June to October, an overall decreasing precipitation trend is observed.
- The climate analysis showed a general increase (between 0% and 10%) in mean annual precipitation (MAP) across the Tana Basin by 2050



Water Requirements Tana Basin (Urban vs Irrigation)-ICS,2020



Water Balance Tana Basin KWSCRP-ICS, 2020

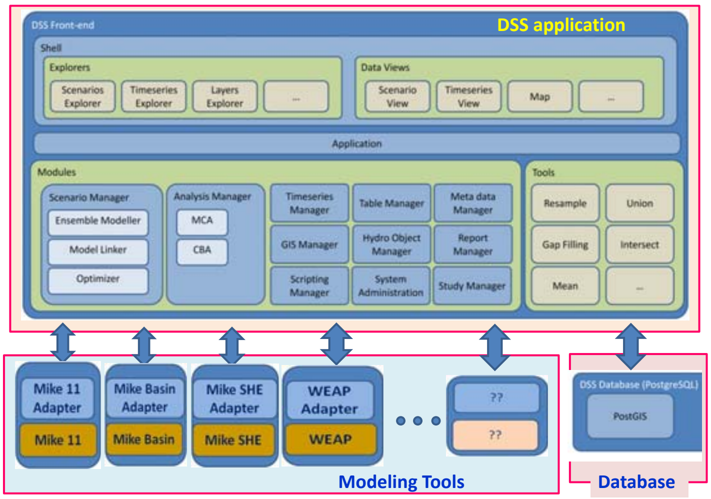


Water Evaluation & Planning

- WEAP (Water Evaluation And Planning system) is a widely used decision support tool for integrated water resources planning. It helps planners simulate different scenarios and evaluate the impacts of various water management strategies.
- WEAP allows users to analyze complex water systems and make informed decisions about water allocation, demand management, and environmental conservation.
- WEAP was developed and distributed by the Stockholm Environment Institute (SEI). You can download WEAP software and find more information about it on the official SEI website:
- **Official WEAP Website:** WEAP Official Website

WEAP REGISTRATION

Mike Workbench & DSS - Software Layout and Components



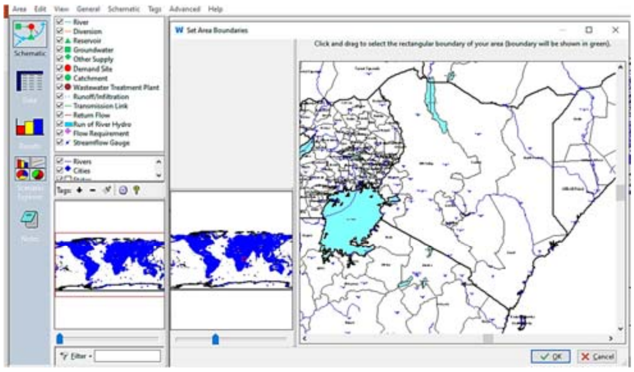
WEAP - MIKE

Aspect	MIKE	WEAP
Developed By	DHI (Danish Hydraulic Institute)	Stockholm Environment Institute (SEI)
Scope and Application	Specialized environmental modeling	Integrated water resources planning
Complexity and Specialization	Highly specialized, complex simulations	User-friendly, simpler models
Professional Users	Engineers, hydrologists, researchers	Decision-makers, water managers, community
Stakeholder Engagement	Less focus on stakeholder engagement	Emphasizes stakeholder participation
Primary Use Cases	Detailed hydrodynamics, water quality,	Water supply and demand assessment,
	sediment transport in various environments	scenario evaluation, impact assessment
Level of Expertise Required	High expertise required for in-depth analysis	Accessible to non-experts and stakeholders

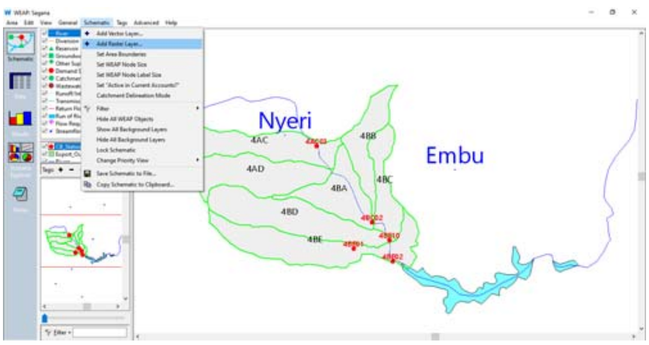
WEAP - MIKE

	WEAP	MIKE Workbench	Combined
Advantages			
User-Friendly Interface	✓ Intuitive and easy to use	✗ Steeper learning curve, complex UI	✓ Combines WEAP's ease with MIKE's power
Modeling Flexibility	✓ Flexible and customizable	✓ Powerful and extensive modeling options	✓ Diverse modeling capabilities
Scenario Analysis	✓ Supports various scenario analyses	✓ Allows for detailed scenario exploration	✓ Enhanced scenario planning
Integration with GIS	✓ Integrated GIS functionality	✓ Seamless integration with GIS data	✓ Spatial analysis for accurate planning
Data Management	✓ Efficient data management tools	✓ Robust data handling capabilities	✓ Improved data accuracy and reliability
Disadvantages			
Learning Curve	✗ Steeper learning curve for beginners	✗ Complex interface may be overwhelming	✓ Combined expertise mitigates complexity
Cost	✗ Commercial license required	✗ Costly software, especially for modules	✓ Shared costs for enhanced value
Technical Support	✓ Strong user community and support	✓ Comprehensive technical support	✓ Access to combined support resources
Integration Advantages			
Comprehensive Planning	✓ Combined expertise for holistic planning		✓ Integrated approach for complete solutions
Enhanced Data Accuracy	✓ Improved data accuracy through GIS		✓ Greater confidence in modeling outcomes
Advanced Modeling Capabilities	✓ Diverse modeling capabilities		✓ Access to both systems' advanced features
Resource Optimization	✓ Optimal allocation based on data		✓ Better resource optimization strategies

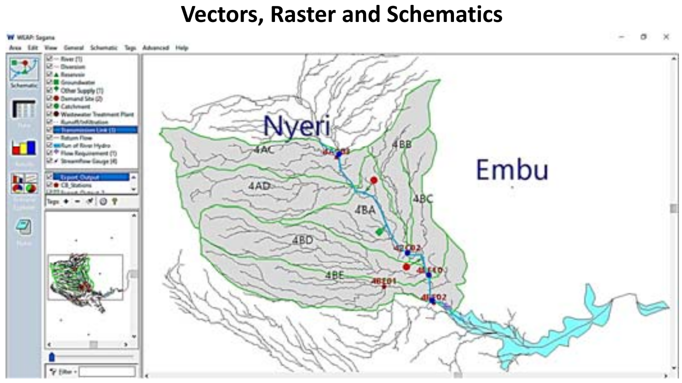
Getting Started and Setting Your Boundaries



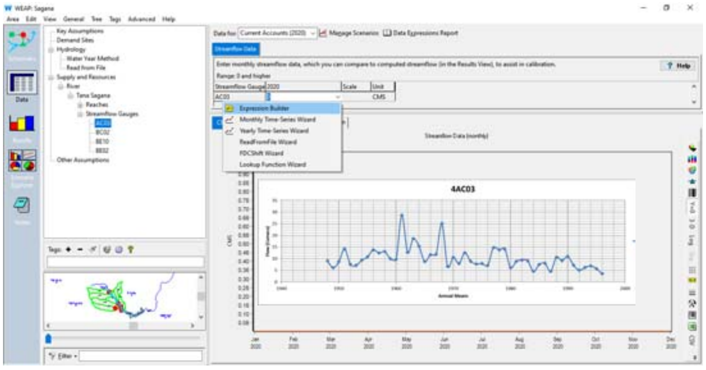
Adding Vector Layers

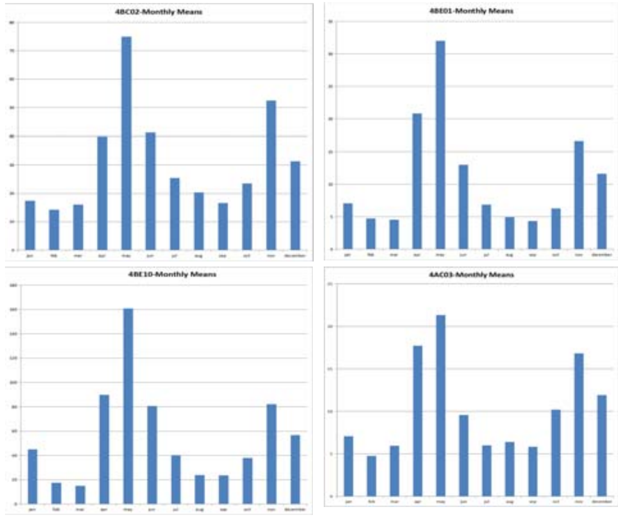


Vectors, Raster and Schematics



Key Assumption, Data Entry





Application Models & Tools for WAP and F&D Early Warning including Climate Change Impacts on WR:

WEAP & Mike Zero Adapter allows both Model Linking:

- ❑ WEAP uses summary data
- ❑ Mike Integrates Hydrodynamic Models – basin-wide

- Updating abstraction water use permits in Real Time
- Association of water use /abstraction data in sub-basin
- Associating telemetric station flow time series in sub-basins
- Associating telemetric station rainfall time series in sub-basins

WRA: Management Unit Water Balance Analysis For Water Allocation Assessment

Hydrological Unit	Management Unit	Area km2	Q	Res.	I+D	LS	FP	Irr.	Trfer	Use	Rest	Qmin
4AA-AD	Sagana-Gura	2,073	18.37	1.14	0.37	0.03	0.19	10.42	0.00	12.15	6.22	3.68
4BA-BF	Lower Sagana	2,723	57.61	4.71	0.50	0.06	0.04	49.55	0.00	54.85	2.76	25.73

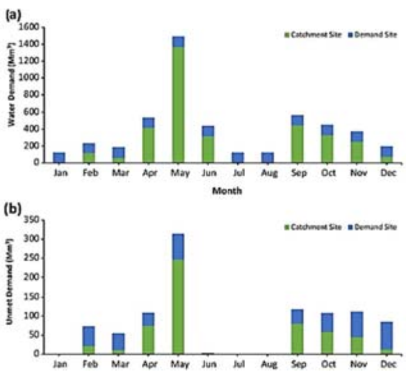
Hydrological Unit	Management Unit	Area km2	SW	GW	Usable returnflow		Total yield
					Irr	ID	
4AA-AD	Sagana-Gura	2,073	17.23	0.01	4.17	0.29	22
4BA-BF	Lower Sagana	2,723	52.90	0.05	19.82	0.40	73

Hydrological Unit	Management Unit	ID	LS	FP	Irr.	Others	Local requirement
4AA-AD	Sagana-Gura	0.37	0.03	0.19	10.42	0.00	11.01
4BA-BF	Lower Sagana	0.50	0.06	0.04	49.55	1.00	51.14

Hydrological Unit	Management Unit	Local yield	Transfers	Local requirements		Balance		Potential for development
				with Irr.	without Irr.	with Irr.	without Irr.	
4AA-AD	Sagana-Gura	21.70	0.00	11.01	0.60	10.69	21.11	
4BA-BF	Lower Sagana	73.17	0.00	51.14	1.59	22.03	71.57	4BB

Hydrological Unit	Management Unit	Area km2	Yield	Requirement	Balance
4AA-AD	Sagana-Gura	2073	8.86	0.29	10.18
4BA-BF	Lower Sagana	2723	21.16	0.59	26.28

EXAMPLE-RESULTS



WRA: Management Unit Water Balance Analysis For Water Allocation Assessment

Requirement/Feature	MIKE	WEAP
Water Balance at GIS Generated Stream Nodes	Can handle detailed hydrodynamic modeling, allowing precise water balance.	Integrates GIS functionality for water balance calculations at specific nodes.
Water Balance at Specific Sites for Water Allocation Planning (WAP)	Allows detailed water balance assessments at specific sites.	Enables modeling of water allocation scenarios and site-specific assessments.
Updated Water Status in the Overall Basin and Each River Reach	Provides detailed information on water status at basin and river reach levels.	Offers water status updates for basin and specific river reaches in scenarios.
Real-time Allocation Modification at Any Channel Point	Supports real-time modification of allocations at specific channel points.	Provides options for real-time allocation adjustments and scenario simulations.
Updated Basin-wide Water Balance Status via Scenarios and Simulations	Supports simulations for decision-making and negotiation of water use.	Allows scenario analysis and simulation for understanding water balance tradeoffs.
Timely WR Status Reports for Informed WAP	Provides detailed reports and analyses for informed water allocation planning.	Offers comprehensive reports and analyses to support decision-making.
Generated Information Products for Flood and Drought Early Warning	Provides tools for flood and drought modeling and early warning systems.	Offers capabilities for modeling and generating early warning information.

Thank You

Capacity Building for WRA Staff

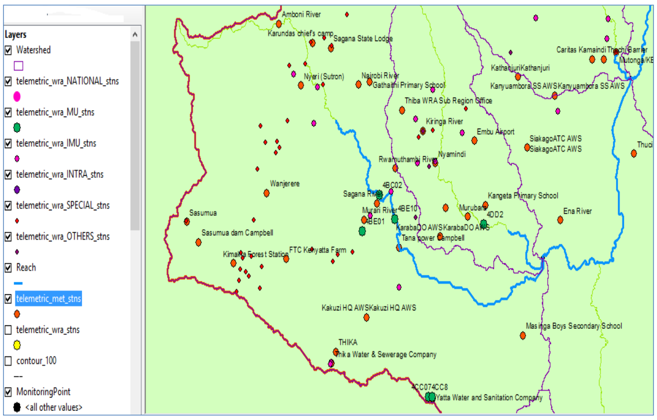
Pre-processing data; historical & telemetric data
Framework for Real Time WAP and;
Early Warning for Flood & Drought Mitigation

October 13, 2023
Presentation by Eugen Mwandoe Mnyamwezi
JICA WRA Advisor Team

Purpose of data pre-processing data

- DATA QC & QA
- Representativeness of reality [Comparative Analysis – graphs, visualization, regression/correlation]
- Identify gaps [Mike Workbench - graphical plots, visualization tools…]
- Infilling missing data: several approaches [Participant feedback]
  - Where are the missing values/gaps [Coverage graph]
  - How many [Time series chart/Table]
  - How to fill gaps[Time interval; daily, monthly, seasonal, annual…]
- MIKE WORKBENCH TOOLS
  - Time Series Manager Tools **[RGS 4BC02 Node data- Input/Output data]**
  - **INFLOW & OUTFLOWS AT NODE LEVEL**
  - **Discuss Node objects [Input and Output]**
  - **For each Node respective Inflows and Outflows**
  - **Water demand Deficit**
  - **Net flow to Node etc**
  - **Duration Curve Analysis & Comparing Two or Time Series**
- Simulation Results displayed at Respective
  - **NODES AS OUTFLOW**

Sample Distribution of Stations Upper Tana Pilot Sub-basin



Correlation & Regression of Daily flows for Pilot Sub-basins

Regression equations between sub-basins daily flows
Tana 4BE02, Tana Sagana 4BC02 and Tana Rukanga 4BE10

Name: SAGANA		Name: TANA SAGANA
MaxFocus: [08.04.1948,30.06.2004]		MaxFocus: [17.01.1948,05.09.2006]
Correlation coefficient:	0.825	
Covariance:	304.257	
Number of valid value pairs:	393	
For the valid value pairs of these series:		
	X-Series	Y-Series
Minimum:	1.02	5.70
Mean:	10.76	33.04
Maximum:	144.51	274.88
Median:	7.08	23.87
Standard deviation:	12.33	29.90
Axis intercept:	-0.4876	11.5237
Regression coefficients:	0.3404	2.0000
X = -0.4876 + 0.3404 * Y	calculate from	
Y = 11.5237 + 2.0000 * X	Comment	

Name: TANA SAGANA		Name: TANA RUKANGA
MaxFocus: [17.01.1948,05.09.2006]		MaxFocus: [01.09.1979,29.03.1997]
Correlation coefficient:	0.709	
Covariance:	1413.906	
Number of valid value pairs:	4163	
For the valid value pairs of these series:		
	X-Series	Y-Series
Minimum:	5.10	5.75
Mean:	31.37	55.65
Maximum:	218.98	560.44
Median:	24.16	29.16
Standard deviation:	29.02	68.67
Axis intercept:	14.6811	2.9984
Regression coefficients:	0.2998	1.6786
X = 14.6811 + 0.2998 * Y	calculate from	
Y = 2.9984 + 1.6786 * X	Comment	

Maragua 4BE01 Versus Tana Rukanga 4BE10

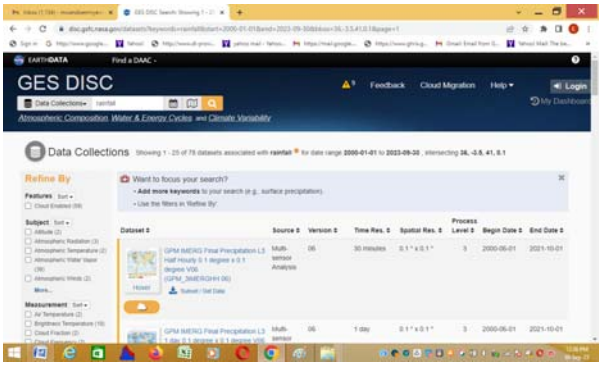
Name: MARAGUA		Name: TANA
MaxFocus: [07.11.1946,29.06.2005]		MaxFocus: [07.11.1958,31.07.1981]
Correlation coefficient:	0.804	
Covariance:	1523.880	
Number of valid value pairs:	7953	
For the valid value pairs of these series:		
	X-Series	Y-Series
Minimum:	0.20	4.57
Mean:	12.09	80.03
Maximum:	326.28	1006.64
Median:	5.85	56.44
Standard deviation:	19.41	97.59
Axis intercept:	-1.9960	39.1361
Regression coefficients:	0.1600	4.0444
X = -1.9960 + 0.1600 * Y	calculate from	
Y = 39.1361 + 4.0444 * X	Comment	

Name: TANA		Name: TANA RUKANGA
MaxFocus: [07.11.1958,31.07.1981]		MaxFocus: [01.09.1979,29.03.1997]
Correlation coefficient:	0.800	
Covariance:	3040.042	
Number of valid value pairs:	558	
For the valid value pairs of these series:		
	X-Series	Y-Series
Minimum:	15.96	7.34
Mean:	139.15	28.79
Maximum:	960.29	98.64
Median:	90.40	17.00
Standard deviation:	146.15	26.00
Axis intercept:	9.7136	8.9757
Regression coefficients:	4.4575	0.1423
X = 9.7136 + 4.4575 * Y	calculate from	
Y = 8.9757 + 0.1423 * X	Comment	

Telemetric Automatic Weather Station (AWS) Satellite Derived Rainfall Data downloads



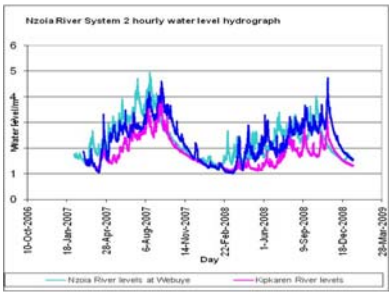
Downloading Global datasets



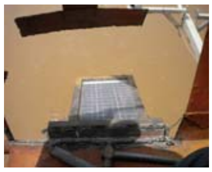
Discharge Measurements: ADCP and Current Meter flow meters

Water level variations between two stations

(estimating time of travel of a flood wave between stations)



Safeguarding against Vandalism



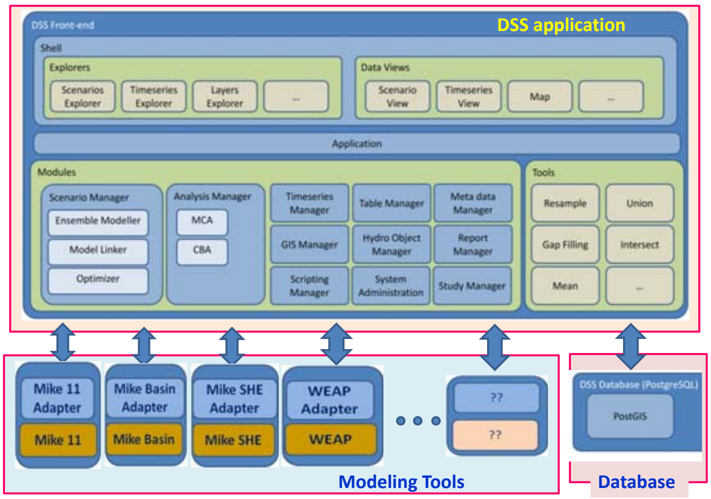
Data acquisition

- Stream flow gauging with an ADCP

Mike Suite Software Approach to Data Pre-processing GIS enabled and Time Series Managers

Summary Information
for Decision on Water Allocation at Management Unit Level and Mike Workbench Node Junction

Mike Workbench & DSS - Software Layout and Components



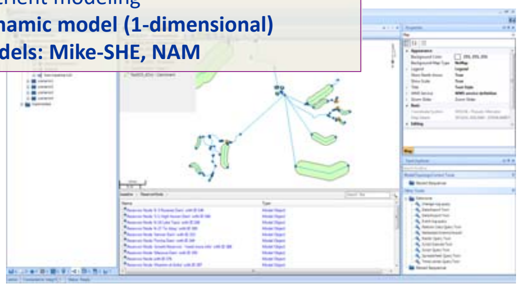
Modeling tools

Mike-Basin/Hydro: Water budget and allocation Model:

- Water allocation scenario modeling
- Reservoir/hydropower operation
- Hydrological modeling (rainfall-runoff)
- Irrigation demand and yield assessment
- In-stream nutrient modeling

Mike-11: Hydrodynamic model (1-dimensional)

Rainfall-runoff models: Mike-SHE, NAM



Real Time Data Analysis for Information Products Generation and Interpretation to Inform WAP and Early Warning for Flood & Drought Mitigation

- DEM analysis for pilot sub-basins delineate sub-basin shape files, characteristics and basic parameters
- Respective Mike Workbench Managers
  - Database Manager linked to real time Telemetric station to download observed data
  - GIS Manager
  - Time Series Manager with historical data for real time updating
  - Indicators Manager (Prescribed threshold for O&M and Development etc
  - Script Manager
  - Spreadsheet Manger
  - Scenario Manager
- Respective Mike Zero Schematic for updating new developments in sub-basins
  - Updating Time Series
  - Updating new projects and stations
  - Updating new abstractions
  - Updating operational changes or enhancements

Establishing a Framework for Real time Water Balance at Sub-basin Level with Telemetric data to support WAP

Application Models & Tools for WAP and F&D Early Warning including Climate Change impacts on WR:

WEAP & Mike Zero Adapter allows both Model Linking:

❑ WEAP uses summary data
❑ Mike Integrates Hydrodynamic Models – basin wide

- Updating abstraction water use permits in Real Time
- Association of water use /abstraction data in sub-basin
- Associating telemetric station flow time series in sub-basins
- Associating telemetric station rainfall time series in sub-basins

Framework for Telemetric Station for Water Allocation Planning (WAP) at Pilot Sub-basins

Data Requirements

- GIS Applications:
- DEM
- Flow stations shape files and flow time series data (daily, hourly, monthly etc)
- Rainfall station shape files and rainfall depth time series data (daily, hourly, monthly etc)
- Evaporation time series data
- Abstraction time series

WRA: Management Unit Water Balance Analysis For Water Allocation Assessment 2005/6

Hydrological Unit	Management Unit	Area km2	Q	Res.	I+D	LS	FP	Irr.	Trfer	Use	Rest	Qmin
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Hydrological Unit	Management Unit	Local yield	Transfers	Local requirements		Balance		Potential for development
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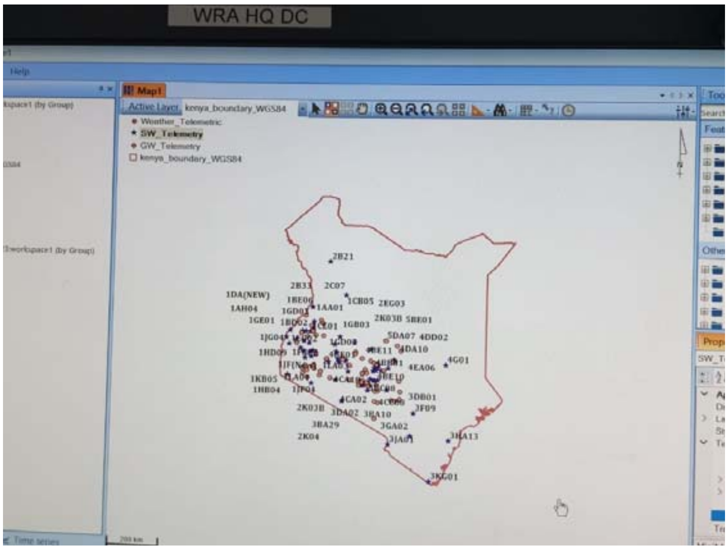
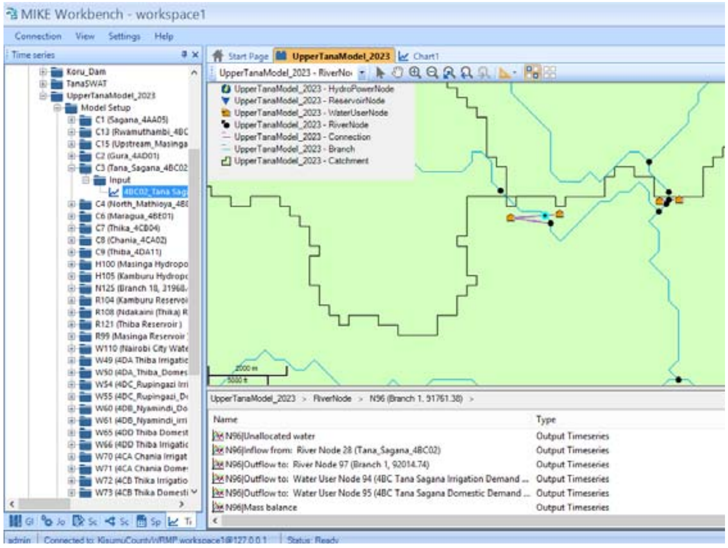




Outputs & Outcomes

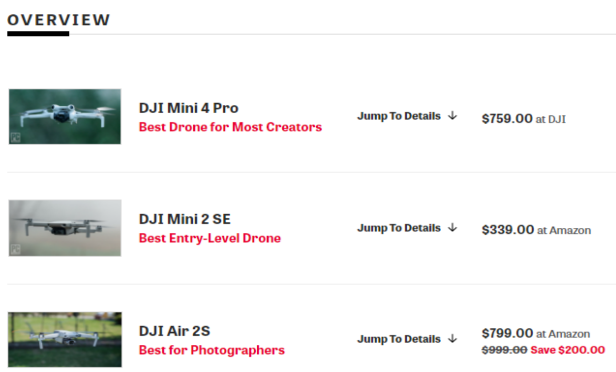
- Water balance at respective GIS generated stream nodes
- Water balance at specific sites for WAP
- Updated water status in the overall basin for all users and in each river reach
- Real time allocation modification at any channel point
- Updated basin-wide water balance status via scenario and simulation for decision and negotiation of water use and tradeoff
- Timely WR Status Reports for informed WAP
- Generated Information Products for Flood and Drought Early Warning

Addressing illegal Water Abstractions

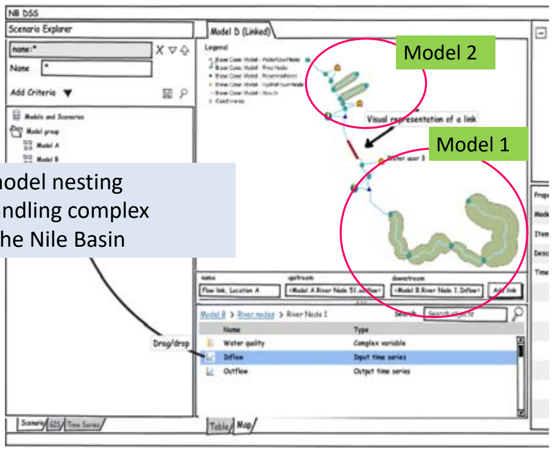
Facility Surveillance
(Real time monitoring CCTV Cameras & Drones)

The dome camera is one most commonly used for indoor and outdoor security and surveillance. The shape of the camera makes it difficult for onlookers to tell which way the camera is facing, which is a strong piece of design, deterring criminals by creating an air of uncertainty.

Price Range $800 - > $1500 for our case

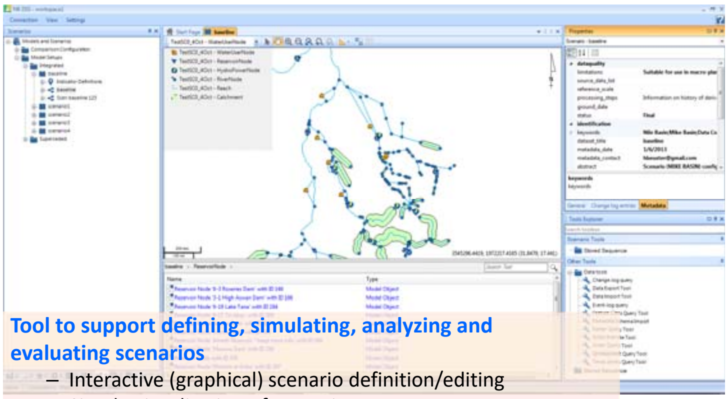


Model linking/nesting tool



- Facilitates model nesting
- Useful for handling complex hydrology of the Nile Basin

Scenario management



Tool to support defining, simulating, analyzing and evaluating scenarios

- Interactive (graphical) scenario definition/editing
- Simple visualization of scenarios
- Scenario simulation
- Scenario Comparison

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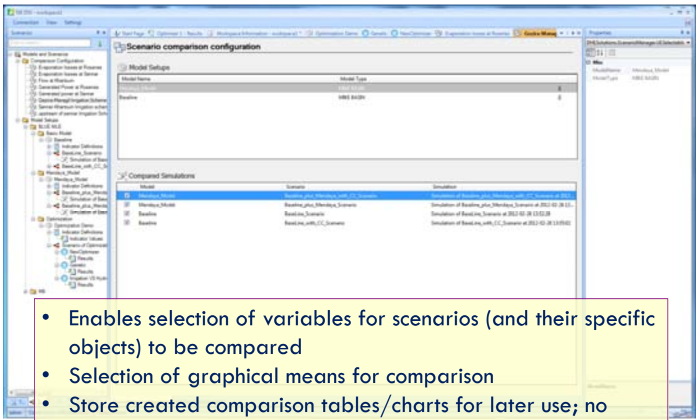
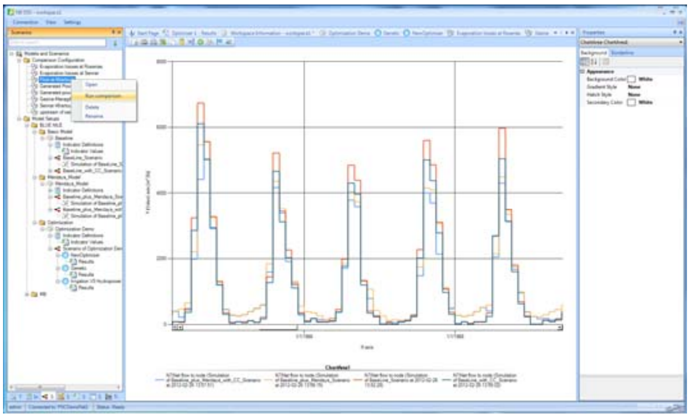
Scenario Comparison tool



- Enables selection of variables for scenarios (and their specific objects) to be compared
- Selection of graphical means for comparison
- Store created comparison tables/charts for later use; no need to re-create the comparison configuration

Scenario Comparison tool – Example



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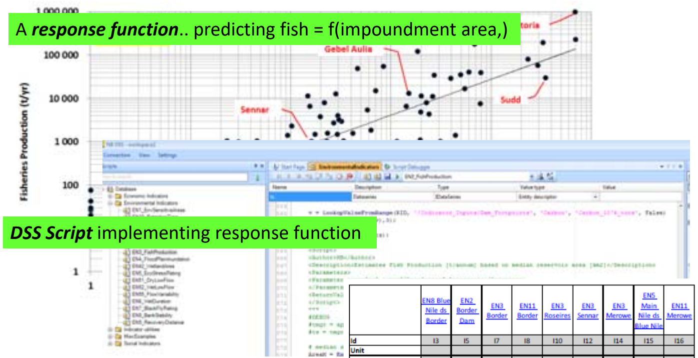
Integrating environmental objectives *in decision making*



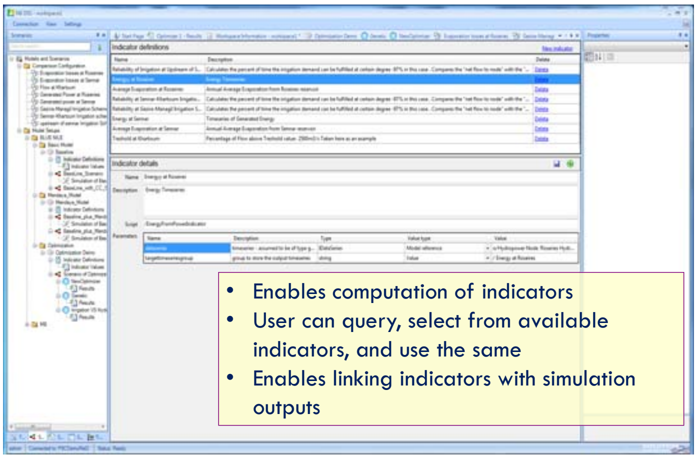
A ***response function***.. predicting fish = f(impoundment area,)

DSS Script implementing response function

Environmental indicators for each scenario

	EN8 Blue Nile ds Border	EN2 Border Dam	EN3 Border	EN11 Border	EN3 Roseires	EN3 Sennar	EN3 Merowe	EN5 Main Nile ds Blue Nile	EN11 Merowe
Id	I3	I5	I7	I8	I10	I12	I14	I15	I16
Unit									
ENJMP Scenario 1 WU	-1	2.263	1191.6	51.9	2613	292.5	1720.3	-3	28.7
cenario 3 WU	0	2.263	1034.4	33.7	2677.5	324.2	1720.3	-3	27.7
ENJMP Scenario 3a WU	-1		1034.4	29.8	2622.8	292.5	3393	-3	53.7

Indicator Manager



- Enables computation of indicators
- User can query, select from available indicators, and use the same
- Enables linking indicators with simulation outputs

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Indicator Definitions - sample

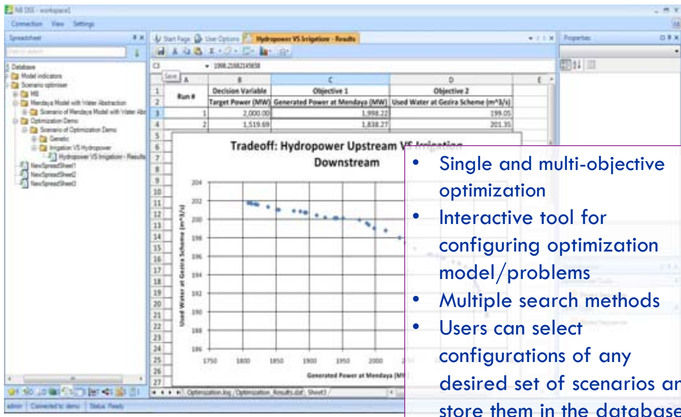
Environmental

Category	ID	Name (Indicator)	Units (Indicator)	Description (Driver)	Units (Driver)
Footprint Areas	EN1	Environmentally Sensitive Area	km2	Extent of Environmentally Sensitive Area within dam / irrigation scheme / canal footprint	km2
	EN1_1	Environmentally Sensitive rating	Index	Size of environmentally sensitive area / IUCN category in footprint	number
		...al hotspot	Index	Wetlands of international importance (Ramsar Sites) and Important Bird Areas (IBAs) that fall outside of protected areas, but within primary impact zones, are classified equivalent to IUCN Categories I & II (i.e. rating 5).	number
					km2 ...

Social

Category	ID	Name (Indicator)	Units (Indicator)	Description (Driver)
Water Availability	SO1	Change in availability of water for riparian users: domestic consumption, subsistence agriculture and livestock	% Change from Baseline	Dry season low flow: Median flow during lowest consecutive 3 months in dry season
Community Health and Safety	SO2	Susceptibility of irrigation scheme areas to malaria based on WHO malaria incidence map for Africa	Mean malaria endemicity of population within irrigation area footprint (%)	Malaria incidence map of Africa AND location of new irrigation schemes
	SO3	Prevalence of diseases resulting from pest species	Index	Proxy: EN7 - Abundance of Pest blackflies (refer to Table 5-4)
	SO4	Water pollution d/s major urban areas	Time of decay (h) to acceptable coliform concentrations	Defined load factors; Constituent loads/concentrations in river; biological decay relationships
	SO5	No households within the 100 year flood	% Change from	100 year flood envelope

Multi-objective Optimization



- Single and multi-objective optimization
- Interactive tool for configuring optimization model/problems
- Multiple search methods
- Users can select configurations of any desired set of scenarios and store them in the database (optimal, non-optimal)

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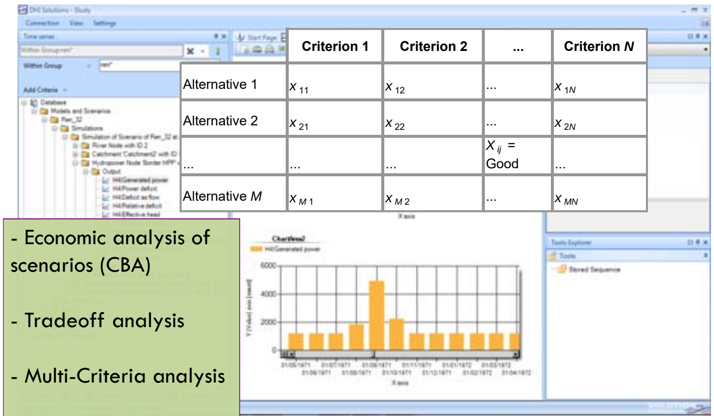
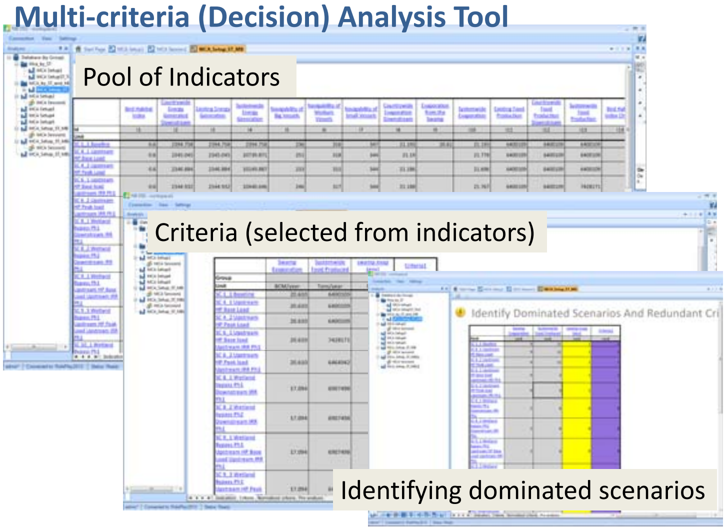
Decision making tools



- Economic analysis of scenarios (CBA)
- Tradeoff analysis
- Multi-Criteria analysis

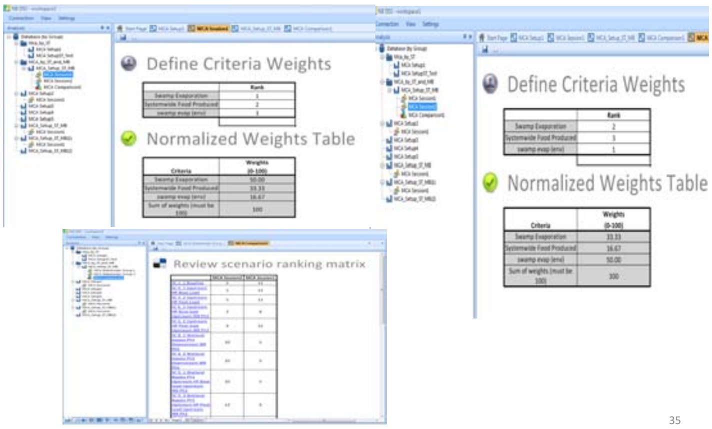
Abdulkarim H. Seid, DSS - Lead Specialist 33

Multi-criteria (Decision) Analysis Tool



Multi-criteria (Decision) Analysis Tool

Incorporating stakeholder preferences



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JICA NIPPON KOEI

Water Resources Authority (WRA)

Kenya Water Resources Advisor

Progress of Activities and Schedule

October 11, 2023

1. Goal of activities

Strengthening of WRA's Capacity on Hydrological Data Management (Observation, Arrangement, Storage, Analysis, and Utilization)

2. Expected Outputs

- **Output 1**
  Hydrological Monitoring Network Update in accordance with the Purpose of Observation
- **Output 2**
  Capacity Building on Hydrological **Monitoring**
- **Output 3**
  Capacity Building on **Arrangement and Storage** of Hydrological and Meteorological Data
- **Output 4**
  Capacity Building on **Analysis and Utilization** of Hydrological and Meteorological Data

3. Progress of Activities

- **Output 1**
  Hydrological Monitoring Network Update in accordance with the Purpose of Observation

Activity 1-1: Survey on recent flood and drought damages as well as countermeasures for such damages.

1. **Flood and Drought information** was collected for the period from 2015 to 2023. There were 15 cases of flood and 14 cases of drought. Those information are as listed from the next slides.
2. **News paper articles** were also collected from the period of April 2022 to March 2023. Flood and drought related articles were collected. Of the total 48 articles collected, 25 were drought related one was related to flood, and others were related to: water, food security, climate change etc.


National News
Thousands grapple with hunger as drought hits Marsabit County
County's Sh11 billion plan for response to natural disasters
Disaster looms as key rivers dry up across the country

3. Progress of Activities

Activity 1-1: Survey on recent flood and drought damages as well as countermeasures for such damages.

Summary of Flood and Drought Incidents Tana Basin

Flood Incidences

No.	Date	Comments	Area	Impact	Link
F1	18th December 2015	Kenya Red Cross dispatches relief food to Tana River flood victims	Handaraku	2440 households and 15,000 people affected	https://www.kbc.co.ke/kenya-red-cross-dispatches-relief-food-to-tana-river-flood-victims/
F2	10 April 2017	**Farmers In Garissa Counting Losses After River Tana Burst Its Banks**	Sankuri, Balich	Crops swept away , 14 families marooned by flood water	https://www.citizen.digital/news/farmers-in-garissa-counting-losses-after-river-tana-burst-its-banks-163211
F3	10th April 2018	Death toll from Tana River floods rises to 6 after body of woman is found	Bakuyu, Bura Town, Madogo, Mororo	Loss of lives, 400 families displaced	https://barakafm.org/2018/04/10/death-toll-from-tana-river-floods-rises-to-6-after-body-of-woman-is-found/
F4	12th April 2018	**Five killed in Tana River Flooding**	Bilbil	Loss of lives- 2 small boys	https://infonile.org/en/2018/04/five-killed-in-tana-river-flooding/
F5	3rd May 2018	**Schools fail to reopen as rains persist**	Secondary schools;Kipini, Daku, Waldena, Galole Model, Nanighi. Primary schools: Bangale, Huruma, Furaha, Mapenzi, Hurara, Chewani, Hola, Rafiki, Mbalambala, Mulanjo, Ziwani, Mororo, Hatata. Other schools: Kalalani, Kanelati, Titila, Dada, Makadala, Wayuboru, Wayuduka, Kottita, Haroresa, Galili, Idhowe, Gamba, Odole, Kilelengawani, Ozi, Hewani, Wema	Schools shut down/partially closed; classrooms marooned and others destroyed, pit latrines sink	https://www.standardmedia.co.ke/amp/health-science/article/2001279028/schools-fail-to-reopen-as-rains-persist

3. Progress of Activities

Activity 1-1: Survey on recent flood and drought damages as well as countermeasures for such damages.

No.	Date	Comments	Area	Impact	Link
F6	8th May 2018	**Tana River Residents In Distress**	Gamba (Bandi & Gatheri villages)	32 villages sunk by flood water, 30,000 homesteads destroyed, 64,000 people displaced	https://www.citizen.digital/news/tana-river-in-distress-as-homes-submerged-in-floods-199417
F7	18th May 2018	**KenGen: We are not to blame for Garissa, Tana River floods**	Garissa, Tana River	IDPs, flooded homes and destruction of properties	https://www.businessdailyafrica.com/bd/news/kengen-we-are-not-to-blame-for-garissa-tana-river-floods-2203704
F8	18th May 2018	**Red Cross situation report on 'KenGen floods'**	Garissa, Tana River, Kitui Counties	97 people injured, 186 lost their lives(exclusive of deaths related to disease outbreaks), infrastructure damaged and crucial services such as transportation and health paralysed, 68780 acres of farmland submerged in water and crops destroyed.	https://reliefweb.int/report/kenya/kenya-floods-mdrke043-operations-update-no-1
F9	19th November 2019	Over 3,000 People In Garsen Are Marooned Following The Bursting Of River Handarakulagha	Konemasa,Katsangi,Handaraku,Semi-karo (S.L)	Road network cut-off, over 3,000 people marooned,national exams disrupted	https://www.kenyanews.go.ke/over-3000-people-in-garsen-are-marooned-following-the-bursting-of-river-handarakulagha/
F10	24th December 2019	**Locals in distress as floods submerge villages in the Tana delta**	Mwanja, Odhole, Samicha, Handaraku, Sogan	Submerged homes, several families displaced	https://www.the-star.co.ke/counties/coast/2019-12-24-locals-in-distress-as-floods-submerge-villages-in-the-tana-delta/
F11	27th April 2020	Floods Wreak Havoc In Ijara And Tana River	Tana River- Mikinduni, Kilindini : Ijara Garissa - Mansabubu, Gababa, Masalani,Boji	Crops swept away, transport network cut off, several families affected	https://www.kenyanews.go.ke/floods-wreak-havoc-in-ijara-and-tana-river/
F12	28th April 2020	Floods paralyze transport in Tana river leaving hundreds stranded	Dukanotu	Roads completely cut off, over 500 households affected	https://barakafm.org/2020/04/28/floods-paralyze-transport-in-tanariver-leaving-hundreds-stranded/

3. Progress of Activities

Activity 1-1: Survey on recent flood and drought damages as well as countermeasures for such damages.

No.	Date	Comments	Area	Impact	Link
F13	10th May 2020	Heavy rains destroy homes, cause landslides in Murang'a	Kagarii -Gatanga; Mariira-Kiharu; Maporomoko-near Thika; Mioro; Murarandia-Kahuru	Several families displaced and homes destroyed	https://www.the-star.co.ke/counties/central/2020-05-10-heavy-rains-destroy-homes-cause-landslides-in-muranga/
F14	15th May 2020	3,000 residents stranded in Tana Delta floods	Mwanja, Odhole, Samicha, Handaraku, Kikomo villages	7000 people displaced, 3000 others stranded in flooded villages	https://www.the-star.co.ke/news/2020-05-16-3000-residents-stranded-in-tana-delta-floods/
F15	6th April 2021	Tana River Residents Decry The State Of Impassable Road	Bilbil	Lack of basic commodities due to broken road network	https://www.kenyanews.go.ke/tana-river-residents-decry-the-state-of-impassable-road/

Drought Incidences

No.	Date	Comments	Area	Impact	Link
D1	14th March 2017	Garissa fights disease, hunger, in long drought	Fafi, Balambala	Famine leading to starvation and malnutrition, lack of pasture deteriorating livestock health	https://www.hiiraan.com/news4/2017/Mar/141031/garissa_fights_disease_hunger_in_long_drought.aspx
D2	28th February 2021	Garissa faces severe water crisis as drought worsens	Bahuri-Dadaab; Abdisamat, Shimbirey,Shentabacaad-Balambala; Lagdera,Ijara, Hulgho	water pans dried up and boreholes broken down	https://www.the-star.co.ke/counties/north-eastern/2021-02-28-garissa-faces-severe-water-crisis-as-drought-worsens/
D3	18th June 2021	**Water shortage hits Tana River, locals pray for rainfall**	Garsen town and its environs	Households use so much money to get little water, Water from TIS causes infections among children	https://www.standardmedia.co.ke/counties/article/2001415994/water-shortage-hits-tana-river-locals-pray-for-rainfall

3. Progress of Activities

Activity 1-1: Survey on recent flood and drought damages as well as countermeasures for such damages.

No.	Date	Comments	Area	Impact	Link
D4	6th September 2021	**Over 60,000 people facing starvation in Tana River county**	Tana North- Lakole, Hosingo, Titila Tana River- Gururi, Goticha, Wayu-Duka, Haroresa	Severe food and water shortage;63,000 people hunger stricken and water sources have dried up	https://www.standardmedia.co.ke/coast/article/2001422756/over-60000-people-facing-starvation-in-tana-river-county
D5	7th September 2021	The agony of Assa village in Tana River County as drought bites	Assa-Garsen	Hunger & starvation, disruption of normal routine in search of water such as schooling	https://thecounty.co.ke/the-agony-of-assa-village-in-tana-river-county-as-drought-bites/
D6	30th September 2021	**Pastoralists lose livestock as drought ravages Tana Delta**	Bula-Tarrassa	Death of livestock	https://www.standardmedia.co.ke/north-eastern/article/2001424897/pastoralists-lose-livestock-as-drought-ravages-tana-delta
D7	1 October 2021	Meru farmers, Isiolo herders unite to survive drought	Lachathuriu-Tigania west;Tigania East,Maraa-South Imenti;Kamweline,Ithata,Ngitana,Murara,Kachiuru,Nginyo-Igembe North	More than 120000 people in need of food	https://www.breakingkenyanews.com/2021/10/meru-farmers-isiolo-herders-unite-to.html
D8	7 October 2021	Tana River County Drills Boreholes Across County As Part Of Drought Response Initiative	Ngao, Gururi, Waldena, Lakole	Residents walking hundreds of kms in search of water, many households affected by famine	https://shahidinews.co.ke/2021/10/07/tana-river-county-drills-boreholes-across-county-as-part-of-drought-response-initiative/
D9	8th March 2022	Drought Hits Tana River, Residents Seek Food Aid	Tana River County	68,000 people affected due to famine, declined crop and livestock production	https://www.kenyanews.go.ke/drought-hits-tana-river-residents-seek-food-aid/

3. Progress of Activities

Activity 1-1: Survey on recent flood and drought damages as well as countermeasures for such damages.

No.	Date	Comments	Area	Impact	Link
D10	13th June 2022	Children Hit Hard By Drought	23 Arid and semi-arid countries	malnutrition in children due to famine, livestock death, poor health conditions of livestock due to little pasture regeneration	https://www.kenyanews.go.ke/1million-children-malnourished-in-drought-affected-regions/
D11	4th July 2022	'The conflict takes two forms': How worsening droughts are fueling tensions in Kenya	Tana River County- Matanya village, Subo village, Ruko village	Dried water pans, livestock death, conflicts, long search of water and pasture	https://www.thejournal.ie/conflict-over-drought-in-kenya-5805313-Jul2022/
D12	4th July 2022	Red Cross to buy off livestock hit by drought in 14 counties	Tana River County- Tana North, Tana Delta and Tana River sub- counties	Dried water pans, famine, livestock death	https://www.the-star.co.ke/counties/coast/2022-07-04-red-cross-to-buy-off-livestock-hit-by-drought-in-14-counties/
D13	19th September 2022	Drought worsens in hungry. Thirsty Garissa County	Garissa county- Lagdera, Daadab	Livestock death, close to 378000 people facing starvation, malnutrition, source of livelihood destroyed	https://www.the-star.co.ke/counties/north-eastern/2022-09-19-drought-worsens-in-hungry-thirsty-garissa-county/
D14	1st February 2023	Give us water, not fertilizer; Mt. Kenya farmers say as region suffers food crisis	Embu, Meru, Kirinyaga counties	Lack of food and water(close to 500,00 people starving), failed season crops, livestock death, malnutrition, Human-wildlife conflict	https://nation.africa/kenya/counties/give-us-water-not-fertiliser-mt-kenya-farmers-say-as-region-suffers-food-crisis--4106958

3. Progress of Activities

Activity 1-1: Survey on recent flood and drought damages as well as countermeasures for such damages.

3. As one of **countermeasures against flood**, **Riparian Marking** is being executed by WRA. The following pictures show activites initiated by Muranga sub-basin office.

Riparian marking activities in Muranga sub-region (during June to August 2022)

Riparian marking activities in Muranga sub-region (during June to August 2022)

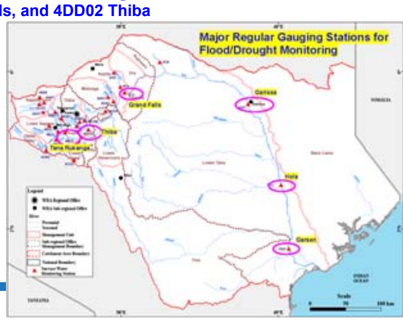
Riparian marking activities in Muranga sub-region (during June to August 2022)

Sensitization meeting for riparian marking by WRA Muranga SRO (during June to August 2022)

3. Progress of Activities

Activity 1-1: Survey on recent flood and drought damages as well as countermeasures for such damages.

4. As one of **countermeasures against drought**, **Rationing Activities** are being executed by WRA.
5. As one of **countermeasures against flood and drought**, the following six regular gauging stations are used for monitoring:
   4BE10 Tana Rukanga, 4G01 Garissa, 4G04 Hola, 4G02 Garsen, 4F13 Grand Falls, and 4DD02 Thiba



3. Progress of Activities

- **Output 1**

Hydrological Monitoring Network Update in accordance with the Purpose of Observation

Activity 1-2: Survey on **support activities by other development partners**.

So far JICA Experts Team surveyed other development partners' activities as follows:

1. Kenya Water Security and Climate Resilience Project (**KWSCRP**) supported by the World Bank: Flood warning system and watershed management components of **Nzoia River** in the Lake Victoria North Basin Area
2. Capacity Development for Effective Flood Management in Flood Prone Area (**CDEFM**) implemented by **JICA from 2011 to 2014**, and Flood Control Officers (FCO) in WRA: Completed.
3. **Groundwater survey by USAID** in South Turkana and Marsabit
4. Monitoring for Information and Decision using Space Technology (**MIDST**)
5. Nairobi Water Fund (**NWF**)
6. **Blue Deal** Upper Tana

3. Progress of Activities

- **Output 1**

Hydrological Monitoring Network Update in accordance with the Purpose of Observation

Activity 1-3: Clarification on the positions/purposes of each observation station from the viewpoint of flood and drought risk evaluation.

1. Status of Regular Gauging Stations

Status of Regular Gauging Stations in Tana Basin Area

	Total	Operational	Not Operational	Telemetering Station	Data Logger	Vandalized	Need Rehabilitation
Kerugoya	*13*	*13*	*0*	*7 (54%)*	*0*	*1*	*2 (15%)*
Muranga	*53*	*47*	*6*	*11 (21%)*	*19 (36%)*	*7*	*14 (26%)*
Meru	*16*	*13*	*3*	*3 (19%)*	*4 (25%)*	*0*	*0*
Sub-total	***82***	***73***	***9***	***21 (26%)***	***23 (28%)***	***8***	***16 (20%)***
Garissa	*5*	*3*	*2*	*1 (20%)*	*0*	*0*	*0*
Total	***87***	***76***	***11***	***22 (25%)***	***23 (26%)***	***8***	***16 (18%)***

It was realized Tana Basin Area observes 87 stations against recommended 26 stations in NWMP 2030.

Muranga has the largest number of stations as 53.

JICA Experts Team asked the reason to keep 87 stations to Tana Basin Office but so far, no clear answer is provided.

3. Progress of Activities

Including the future schedule

- **Output 1**

Hydrological Monitoring Network Update in accordance with the Purpose of Observation

Activity 1-4: Review of monitoring plan of Tana Catchment Area from the viewpoint of effective utilization of the observation results.

1. As a result of review of the current status of Regular Gauging Stations (RGS), there are no clear reasons for keeping the current number.
2. Therefore, monitoring network update is not able to be done with good reasons.

Way forward/Schedule

JICA Experts Team will look at those critical stations/areas with many water permits and less water availability such as: Maragua and Ragati.

NIPPON KOEI 13

3. Progress of Activities

- **Output 2**

Capacity Building on Hydrological **Monitoring**

Activity 2-1: Confirmation on operational status and analysis of issues on Observation Facilities and Data Transmission Facilities

1. Confirmation of the status of Data Logger provided by previous JICA Expert activities. Four data loggers were provided by previous JICA Expert Activities (2017-2019)

The status is as follows:

- One is installed at **4F10 Kathita** in Meru SRO, but the equipment was **stolen before May 2023**.
- One was installed at **4BE10 Tana Rukanga** in 2018, but it was **vandalized in June 2021**. The equipment was taken away. The station is left as it is (non-functional).
- One is **kept at Garissa SRO.**
- One is **kept at Muranga SRO.**

Checking the status of Data Logger provided by the previous JICA advisory activity. Status of the Data Logger yet to be installed.

Data Logger (Hioki) kept at Muranga SRO.

NIPPON KOEI 14

3. Progress of Activities

Activity 2-1: Confirmation on operational status and analysis of issues on Observation Facilities and Data Transmission Facilities

2. Analysis of issues on Observation Facilities and Data Transmission Facilities

(1) Telemetering Equipment

- Of the 22 Telemetering Stations in Tana Basin, JICA Experts Team visited five stations in October 2021.
- Three stations are well functioning with SEBA system, namely, 4DA11 Thiba, 4BB01 Ragati, and 4CC08 Thika.
- One station was vandalized with the door broken at 4BE10 Tana Rukanga.
- One station with ISODAQ system was not functioning at 4DD02 Thiba.

(2) Data Logger

- Of the 23 Data Loggers in Tana Basin, JICA Experts Team visited one station in June 2022, namely 4BE11 Maragua. This station is also telemeterized but monitoring by Data Logger and manual gauge reading is also being done.

NIPPON KOEI 15

3. Progress of Activities

(1) Telemetering Equipment

- Three stations are well functioning with SEBA system, namely, 4DA11 Thiba, 4BB01 Ragati, and 4CC08 Thika.

4DA11 Thiba

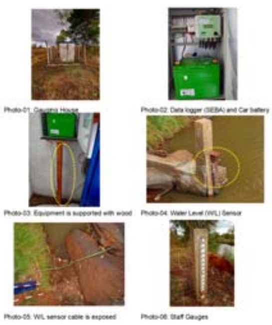
4BB01 Ragati

NIPPON KOEI 16

3. Progress of Activities

(1) Telemetering Equipment

- Three stations are well functioning with SEBA system, namely, 4DA11 Thiba, 4BB01 Ragati, and 4CC08 Thika.



4CC08 Thika

NIPPON KOEI 17

3. Progress of Activities

(1) Telemetering Equipment

- One station was vandalized with the door broken at 4BE10 Tana Rukanga.

Photo-01: Signboard of the Project
Photo-02: Gauging House is vandalized
Photo-03: Staff Gauges (in total 6 pcs)
Photo-04: Past Flood Level

4BE10 Tana Rukanga

NIPPON KOEI 18

3. Progress of Activities

(1) Telemetering Equipment

- One station with ISODAQ system was not functioning at 4DD02 Thiba.

Photo-01: Gauging House
Photo-02: Sedimentation of sand/mud due to past flood inside the gauging house
Photo-03: Data logger (ISODAQ). There is nest inside
Photo-04: Nest of bees inside of the gauging house
Photo-05: Water Level Sensor
Photo-06: Staff Gauges, one is stolen

4DD02 Thiba

NIPPON KOEI

3. Progress of Activities

(2) Data Logger

- Of the 23 Data Loggers in Tana Basin, JICA Experts Team visited one station in June 2022, namely 4BE11 Maragua. This station is also telemetered but monitoring by Data Logger and manual gauge reading is also being done.
- The installed Data Logger is called HOBO.
- The data retrieval using USB cable is easy and quick. It is recommended to install this system.

Photo-01: Gauge House
Photo-02: Structure for the water level gauge
Photo-03: Structure for the water level gauge (box)
Photo-04: Inside of the Box
Photo-05: Water level data logger (HOBO)
Photo-06: Data reading from the water level data logger to notebook PC though the coupler

4BE11 Maragua

NIPPON KOEI

3. Progress of Activities

Activity 2-1: Confirmation on operational status and analysis of issues on Observation Facilities and Data Transmission Facilities

2. Analysis of issues on Observation Facilities and Data Transmission Facilities

(1) Telemetering Equipment

- As a result of site visit, Telemetering Equipment of **SEBA is functioning very well**. It is recommended to install this system as it seems this system is **more reliable compared with other systems**.

(2) Data Logger

- Of the four Data Loggers provided by JICA two are installed but stolen/vandalized. It is **necessary to install two more** which are kept at Garissa and Muranga offices.
- JICA Experts Team visited one station in June 2022, namely 4BE11 Maragua. The **Data Logger HOBO is reliable, easy to handle.**

NIPPON KOEI

3. Progress of Activities

Including the future schedule

- **Output 2**

Capacity Building on Hydrological **Monitoring**

Activity 2-3: Training of Observation Facilities and Data Transmission Facilities

1. **A preliminary online lecture** was held in **January 2023** by Telemetering Expert Mr. Azuma. There were 20 participants, namely six from WRA headquarters, nine from Tana Basin Area, and five from JICA Experts Team.

Online lecture on January 12, 2023 by Mr. Azuma

2. **On site training** is scheduled to beheld **in November 2023 by Mr. Azuma.**

NIPPON KOEI

3. Progress of Activities

- **Output 2**

Capacity Building on Hydrological **Monitoring**

Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve

1. This work item is done through **on site** discharge measurement and river cross section survey (It is scheduled to conduct these activities for four times.).
2. In the original work plan this works were to be sublet and to be done by local company who was good at discharge measurement and river cross section survey.
3. However, WRA rejected the idea of JICA Experts Team, i.e., subletting and WRA mentioned they would do themselves.
4. Up to now, **as of October 2023**, **discharge measurement** and **river cross section survey** were jointly conducted by WRA and JICA Experts Team **three times**.
5. Target regular gauging stations for training are: **4DC03 Rupingazi** (Kerugoya Sub-Region), **4AC03 Sagana** (Muranga Sub-Region), and **4F10 Kathita** (Meru Sub-Region).

NIPPON KOEI

3. Progress of Activities

Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve

1. The **first** activities of discharge measurement and river cross section survey were conducted in **March to April 2022**.

Date 17 March 2022 09:00 a.m. Description: Checking the equipment at Kerugoya SRO	Date 18 March 2022 11:55 a.m. Description: Discharge Measurement at RGS (4DC03 Rupingazi)

Discharge measurement at 4DC03 Rupingazi

NIPPON KOEI

3. Progress of Activities

Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve

1. The **first** activities of discharge measurement and river cross section survey were conducted in **March to April 2022**.

Date 29 March 2022 00:41 p.m.
Description: Discharge measurement at RGS (4AC03 Sagana)

Date 29 March 2022 01:13 p.m.
Descrptipion: Cross section survey using leveling equipment at RGS (4AC03 Sagana)

Discharge measurement at 4AC03 Sagana

NIPPON KOEI
25

3. Progress of Activities

Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve

1. The **first** activities of discharge measurement and river cross section survey were conducted in **March to April 2022**.

Date 31 March 2022 00:37 p.m.
Description: Dischargeme Measurement at RGS (4F10 Katita)

Date 31 March 2022 00:46 p.m.
Description: Current meter (procured in the previous project) at RGS (4F10 Katita)

Discharge measurement at 4F10 Kathita

NIPPON KOEI
26

3. Progress of Activities

Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve

2. The **second** activities of discharge measurement and river cross section survey were conducted in **December 2022.**
3. The **third** activities were conducted in **May 2023**.

Date and time: 12:00, 23/05/2023
Location: RGS 4AC03 Sagana River
Description: Measuring flow velocity

Date and time: 12:00, 23/05/2023
Location: RGS 4AC03 Sagana River
Description: Measuring water level/flow velocity

Discharge measurement at 4AC03 Sagana

NIPPON KOEI
27

3. Progress of Activities

Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve

3. The **third** activities were conducted in **May 2023**.

Date and time: 12:00, 23/05/2023
Location: RGS 4AC03 Sagana River
Description: Measuring flow velocity

Date and time: 12:00, 23/05/2023
Location: RGS 4AC03 Sagana River
Description: Checking the measuring current meter point (0.6 x water depth)

Discharge measurement at 4AC03 Sagana

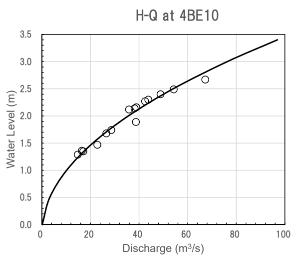
NIPPON KOEI
28

3. Progress of Activities

Including the future schedule

Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve

4. The **fourth** activities is scheduled to be conducted in **November 2023**.
5. After the four times measurement, H-Q Curve of each RGS will be prepared.



An example of H-Q curve which was prepared during the previous JICA Advisory Activities (2017-2019)

NIPPON KOEI
29

3. Progress of Activities

Including the future schedule

- **Output 3**

Capacity Building on **Arrangement and Storage** of Hydrological and Meteorological Data

Activity 3-1: Quality Improvement Guidance and Preparation of Quality Control Standard

1. During October 2023, the current status of quality control standard will be surveyed through interviews to Tana Basin Area Office.
2. Actual works will be executed in January to February 2024.

Activity 3-2: Confirmation on the Current Status and Improvement on Operation and Management of Database

1. During October 2023, the current status of the Database will be surveyed through interviews to Tana Basin Area Office.
2. Actual works will be executed in January to February 2024.

NIPPON KOEI
30

3. Progress of Activities

Including the future schedule

- **Output 4**

Capacity Building on **Analysis and Utilization** of Hydrological and Meteorological Data

Activity 4-1: Guidance on Basic Analysis: Implementation on Flow Regime Arrangement/Compilation and Probabilistic Analysis

Activity 4-2: Analysis Climate Change Affect

These items will be conducted during October 2023 together with confirmation of the current status of the data analysis conducted in Tana Basin Area Office and sub-basin offices. The scheduled items for guidance/capacity buildings are as follows:

Schedule of Guidance/Capacity Building (October 11 to 13, 2023)

(1) Probability analysis on hydrological data
(2) Preparation of a correlation diagram between rainfall and discharge
(3) Preparation of rating curve
(4) Procedures of analysis on the impact of the climate change
(5) Any other items which require capacity building

NIPPON KOEI 31

3. Progress of Activities

Including the future schedule

- **Output 4**

Capacity Building on **Analysis and Utilization** of Hydrological and Meteorological Data

Activity 4-3: Discussion and Compilation on the Function of WRA as well as Utilization of Monitoring Results aiming at Flood Damage Mitigation

→ This item will be discussed in Tana Basin Area Office by focusing on the items as tabulated below in October and November 2023.

Role	Who	What	When	How
Data Collection and Monitoring	WRA Hydrologists and Technical Staff	Continuous monitoring of rainfall, river flow, groundwater levels, and weather patterns.	Ongoing	Utilize advanced sensors, gauges, and weather forecasting tools. Analyze data in real-time to detect anomalies and predict flood or drought events.
Drought Early Warning System	WRA Technical Team	Activate early warning systems based on monitored data.	During drought events	Utilize historical and real-time data to issue alerts, advisories, and warnings to vulnerable communities. Coordinate with meteorological agencies.
Flood Preparedness	WRA Engineers and Emergency Response Team	Develop flood preparedness plans, including floodplain mapping and evacuation strategies.	Before and during the rainy season	Collaborate with local authorities to develop flood preparedness plans. Conduct drills, simulation exercises, and workshops for local communities.

NIPPON KOEI 32

3. Progress of Activities

Including the future schedule

- **Output 4**

Capacity Building on **Analysis and Utilization** of Hydrological and Meteorological Data

Activity 4-4: Discussion and Compilation on the Measures during Droughts as well as Utilization and Analysis of Monitoring Results

→ This item will be discussed in Tana Basin Area Office by focusing on the items as tabulated below in October and November 2023.

Roles	Who	What	When	How
Drought Management Plans	WRA Water Resource Planners	Develop and update drought management plans.	Before and during drought events	Engage with stakeholders to identify drought triggers and thresholds. Develop response strategies including water rationing and alternative water sources.
Post-Flood/Drought Assessment	WRA Engineers and Environmental Experts	Assess flood/drought impact on infrastructure, ecosystems, and communities.	After flood/drought events	Conduct damage assessments, analyze data on water levels, soil erosion, and infrastructure damage. Develop reports for decision-makers and recovery planning.
Community Engagement	WRA Community Outreach Team	Conduct awareness campaigns and workshops on flood/drought preparedness and conservation.	Before and during flood/drought events	Engage with local communities, schools, and NGOs to raise awareness. Distribute educational materials. Facilitate training on water conservation and sustainable practices.

NIPPON KOEI 33

3. Progress of Activities

Including the future schedule

- **Output 4**

Capacity Building on **Analysis and Utilization** of Hydrological and Meteorological Data

Activity 4-5: Publication and Notification to Related Organizations on the Hydrological and Meteorological Data

→ This item will be executed in the last field works of JICA Experts Team Activity, which is scheduled in August 2024. Items for publication should be discussed during the activities.

→ Publication and Notification will be held in a form of two times seminar, once in Nairobi and once in Embu. Detailed schedules are presented in the next slide.

NIPPON KOEI 34

3. Progress of Activities

Including the future schedule

Activity 4-5: Publication and Notification to Related Organizations on the Hydrological and Meteorological Data

Schedule of Publication and Notification

In Nairobi

1. Schedule:	In the end of August 2024 (One day)
2. Venue:	A Hotel in **Nairobi**
3. Purpose:	Dissemination of information sharing / disclosure methods to assumed users of monitoring data and analysis results
4. Contents:	1)Introduction of WRA's activities 2) Introduction of information sharing / disclosure methods by related organizations 3) Introduction of information sharing / disclosure method by WRA
5. Participants:	KMD, MWI, NGO, KenGen, other private companies, WRA regional office etc. (about 80 to 100 people)

NIPPON KOEI 35

3. Progress of Activities

Including the future schedule

Activity 4-5: Publication and Notification to Related Organizations on the Hydrological and Meteorological Data

Schedule of Publication and Notification

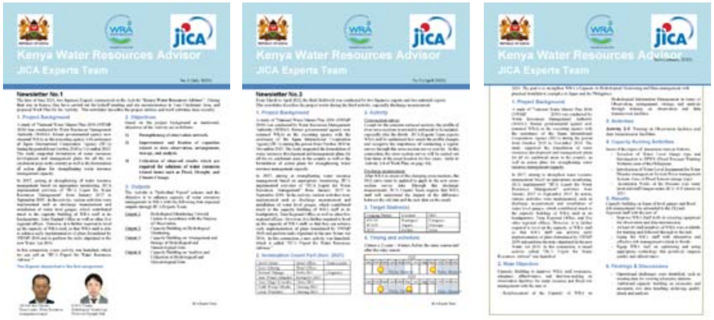
In Embu

1. Schedule:	In the end of August 2024 (One day)
2. Venue:	A Hotel in **Embu**
3. Purpose:	Dissemination of information sharing / disclosure methods to assumed users of monitoring data and analysis results
4. Contents:	1)Introduction of WRA's activities 2) Introduction of information sharing / disclosure methods by related organizations 3) Introduction of information sharing / disclosure method by WRA
5. Participants:	Local government, BWRCS , WRUAs, Large water user (Delmonte), TARDA, etc. (about 80 to 100 people)

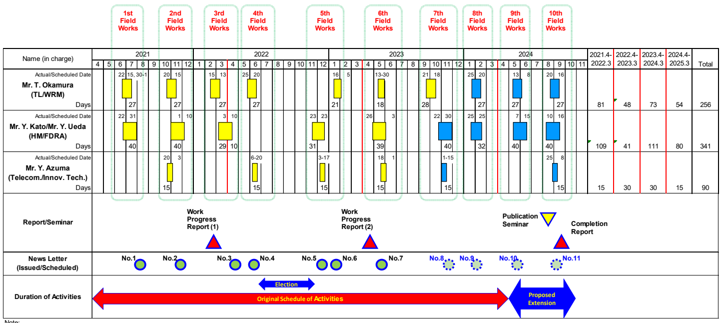
NIPPON KOEI 36

4. Other Activities

- Newsletter
  - As of the end of September 2023, JICA Expert Team issued seven newsletters. The below listed show some of them.



5. Assignment Schedule



Note:
TL/WRM: Team Leader/ Water Resources Management, **HM/FDRA**: Hydrological Monitoring/ Flood and Drought Risk Assessment
Telecom./Innov. Tech.: Telecommunication/ Innovation Technology

: Actual Assignment   : Scheduled Assignment

6. Items to be clarified with WRA (1/2)

1) **Activity 1-1:** Survey on recent flood and drought damages as well as countermeasures for such damages. (Ref. Slide #9): **Any other activities as countermeasures against flood and drought?**
2) **Activity 1-2:** Survey on support activities by other development partners. (Ref. Slide #11): **Any other development partners involved in water resources management?**
3) **Activity 1-3:** Clarification on the positions/purposes of each observation station from the viewpoint of flood and drought risk evaluation. (Ref. Slide #12): **The reason to keep 87 RGSs in Tana Basin Area Office against recommended 26 RGSs in NWMP 2030.**
4) **Activity 2-1:** Confirmation on operational status and analysis of issues on Observation Facilities and Data Transmission Facilities. (Ref Slide #14): **Schedule of installing remaining two sets of Data Logger (Hioki) provided by JICA in the previous JICA Experts Activities.**
5) **Activity 2-4:** Reinforcement of Capacity on Observation at site including preparation of H-Q Curve. (Ref. Slide # 23 to 29): **Kindly inform officially JICA of the intension of WRA to conduct Discharge Measurement and River Cross Section Survey by WRA itself without subletting such works which was scheduled/prepared by JICA.**

6. Items to be clarified with WRA (2/2)

6) **Activity 2-4:** Reinforcement of Capacity on Observation at site including preparation of H-Q Curve. (Ref. Slide # 23 to 29): **Kindly inform JICA Experts Team of the required equipment for discharge measurement in Tana Basin Area Office as well as in each Sub-Basin Offices.**
7) **Activity 3-1:** Quality Improvement Guidance and Preparation of Quality Control Standard. (Ref. Slide #30): **Does WRA have any Quality Control Standards for measured discharge data?**
8) **Activity 4-5:** Publication and Notification to Related Organizations on the Hydrological and Meteorological Data. (Ref Slide #35 to 36): **Any items which WRA intends to publish during the seminars in Nairobi and Embu in the end of August 2024?**

<End of Presentation>

MEETING ATTENDANCE FORM

SUBJECT: WRA STAFF CAPACITY DEVELOPMENT - BY JICA EXPERTS TEAM

DATE: 12TH OCTOBER 2023

TIME: 9:00AM

NO	NAME	INSTITUTION	DESIGNATION	STATION	GENDER	PHONE	EMAIL ADDRESS	REMARKS
1	Millicent Kareithi	WRA	Principal Community Engagement Officer	Embu	F			
2	Eugen Mwandoe	JICA	Telecommunication Expert	Nairobi	M			
3	Samuel Ndung'u	WRA	Surface Water Officer	Embu	M			
4	Billon Gitonga	WRA	ICT	Meru	M			
5	Mary Mwende Kilili	WRA	Attachee	Embu	F			
6	Pauline Nyamu	WRA	Surface Water Officer	Embu	F			
7	Wilson Githu	WRA	ICTO	Embu	M			
8	Samuel Maina	WRA	Water Resource Safety Officer	Embu	M			
9	Ruth Kilonzo	WRA	Human Resource Officer	Embu	F			
10	Cloy Adero	WRA	Senior Community Engagement Officer	Embu	F			
11	Mary Maina	WRA	Senior Assistant Office Administrator	Embu	F			
12	Silas Njiru	WRA	Senior Supply Chain Chain Management Assistant	Embu	M			
13	Nickson Amwoka	WRA	Senior Supply Chain Management Assistant	Embu	M			
14	Doreen Iluba	JICA	Administrator/Secretary	Nairobi	F			
15	Muriithi Mbogori	WRA	Principal Licencing Officer	Embu	M			
16	Jane Njuguna	WRA	Surface Water Officer	Kerugoya	F			
17	Okamura Takeshi	Nippon Koei Co, Ltd.	JICA Expert	Nairobi	M			
18	Morgan Onyango	WRA	ICT Assistant	Murang'a	M			
19	Denis Masika	JICA	Hydrologist	Nairobi	M			
20	Gilbert Chumo	JICA	Water Resource Specialist	Nairobi	M			
21	Yahya Aden	WRA	Hydrologist	Garissa	M			
22	Patricia Musau	WRA	Sub- Basin Area Coordinator	Kitui	F			
23	Simon Makasa	WRA	Licencing Officer	Kitui	M			

MEETING ATTENDANCE FORM

SUBJECT: WRA STAFF CAPACITY DEVELOPMENT - BY JICA EXPERTS TEAM

DATE: 13TH OCTOBER 2023

TIME: 9:00AM

NO	NAME	INSTITUTION	DESIGNATION	STATION	GENDER	PHONE	EMAIL ADDRESS	REMARKS
1	Millicent Kareithi	WRA	Principal Community Engagement Officer	Embu	F			
2	Eugen Mwandoe	JICA	Telecommunication Expert	Nairobi	M			
3	Samuel Ndung'u	WRA	Surface Water Officer	Embu	M			
4	Cloy Adero	WRA	Senior Community Engagement Officer	Embu	F			
5	Silas Njiru	WRA	Senior Supply Chain Chain Management Assistant	Embu	M			
6	Nickson Amwoka	WRA	Senior Supply Chain Management Assistant	Embu	M			
7	Mary Maina	WRA	Senior Assistant Office Administrator	Embu	F			
8	Ruth Kilonzo	WRA	Human Resource Officer	Embu	F			
9	Morgan Onyango	WRA	ICT Assistant	Murang'a	M			
10	Doreen Iluba	JICA	Administrator/Secretary	Nairobi	F			
11	Muriithi Mbogori	WRA	Principal Licencing Officer	Embu	M			
12	Jane Njuguna	WRA	Surface Water Officer	Kerugoya	F			
13	Okamura Takeshi	Nippon Koei Co, Ltd.	JICA Expert	Nairobi	M			
14	Samuel Maina	WRA	Water Resource Safety Officer	Embu	M			
15	Billon Gitonga	WRA	ICT	Meru	M			
16	Denis Masika	JICA	Hydrologist	Nairobi	M			
17	Pauline Nyamu	WRA	Surface Water Officer	Embu	F			
18	Patricia Musau	WRA	Sub- Basin Area Coordinator	Kitui	F			

Ms. Mary Maina
Snr Assistant Office Administrator- Embu

Mr. Samuel Ndung'u
Surface Water Officer - Embu

Ms. Cloy Adero
Snr Community Engagement Officer-Embu

Dr. Denis Masika
JICA Experts Team

Ms. Doreen Iluba
JICA Experts Team Secretary

Mr. T. Okamura
JICA Experts Team

Mr. Morgan Onyango
ICT - Murang'a

Ms. Ruth Kilonzo
HR Officer - Embu

Ms. Millicent Kareithi
Principal Community Engagement Officer- Embu

Mr. Silas Njiru
Snr Supply Chain Management Assistant-

Ms. Pauline Nyamu
Surface Water Officer- Embu

Ms. Jane Wanja
Surface Water Officer- Kerugoya

Mr. Billon Gitonga
ICT - Meru

Mr. Eugen Mwandoe
JICA Experts Team

Participants Photo
October 13, 2023
at Embu Regional Office

Report on Field Reconnaissance Survey of Proposed Telemetric Station Status

November 15, 2023
JICA Experts Team

1.0 Preamble

The JICA Expert Team consisting of Mr. Azuma, Mr. Ueda and Mr. Eugen left Nairobi on November 15, 2023 to Murang'a for the reconnaissance to establish and confirm the status of proposed pilot gauging station earmarked for capacity building training of WRA staff in the Tana Basin. Ms. Jane Wairimu, Surface Water Officer of WRA Sub-Regional Office, Murang'a has atteneded with the JICA Expert Team.

The team had prior discussions with WRA officers in the basin and proposed the following stations for use in capacity building as pilot stations;-

- RGS 4AC03 River Sagana
- RGS 4BC02 River Tana at Sagana
- RGS 4BB01 River Ragati
- RGS 4BE01 River Maragua

Also identified were Automatic Weather Stations (AWS) at Muranga WRA Office, Automatic Weather Station near RGS 4AC03, and any other relevant ones within the study pilot sub-basin of Sagana- Gura Management Unit.

1.1 Telemetric Data Use for Formulation of Framework for WAP and F&D EWS

According to information gathered by JICA Experts Team, the above-mentioned stations are listed as telemetric and operational or need some intervention to be operational. There were also some stations with on-site operational data loggers installed and fitted with sensors that acquire data at very short intervals which would be useful for application as reference stations for telemetric capacity building training and formulation of training manuals for establishment of a framework for Water Allocation Planning (WAP) and a Flood and Drought Early Warning System (F&D EWS) template which WRA can replicate in basins.

2.0 Confirmation of Status of the Selected Station during the visit

The team was joined by Ms. Jane of Murang'a Sub-regional office and together paid a courtesy call to the Sub-Basin Area Coordinator, Mr. James Maina to appraise the office on the immediate and planned activities specific to capacity building in telemetric station data processing and outcome of the pilot study.

JICA Experts Team visited the following stations with the status established as enumerated below:-

2.1 RGS 4AC03 River Sagana

The water level at 11:55 a.m. was 1.19 m. The flow was receding according to observation of washed away vegetation in the banks of the river.

The concrete structure that anchored the second manual gauge was damaged during a gauging activity.

The Weather Station nearby was well kept, grass trimmed and it appeared to be orderly maintained. The team was informed that apart from weather parameter recordings, the station is also fitted with a sensor to monitor water level variations of the Sagana river thereby complementing the manual stations operated by WRA. The data from the station is transmitted directly to Meteorological Services in Nairobi.

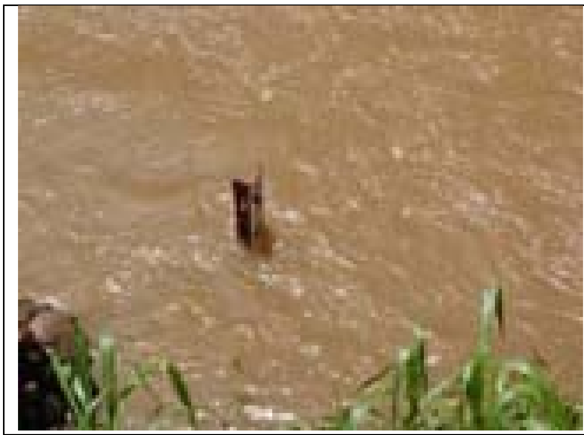


Photo 1: Staff gauge for manual reading	Photo-2: Automatic Weather Station (AWS)

2.2 RGS 4BB01 River Ragati

JICA Experts Team found the station vandalized, the data logger, sensors and all fixations were missing. However, the manual station under the bridge was not affected and the water level at 13:06 p.m. was about 1.10 m. The gauge is installed in the opposite side of the railway bridge abutment and difficult to read at the opposite end which was more accessible.

	
Photo-3: Vandalized gauging station	Photo-4: Staff gauge

2.3 RGS 4BC02 River Tana at Sagana

JICA Experts Team could not access the station. The site can only be accessed through the National Cereals and Produce Board because its fenced off from the establishment compound. However, by looking through the wire fence, the door seemed to be locked and intact.

The team could therefore not confirm the status of the instrumentation and sensors in the station housing. It was not confirmed whether the instrumentation is vandalized. The WRA official was requested to follow-up the matter at the sub-regional office to enable confirmation of the same.

The team has confirmed that the water level data has transmitted with the telemetry data at WRA H/Q on November 23, 2023.

	
Photo-5: RGS 4BC02	Photo-6: View through the fence

2.4 RGS 4BE01 River Maragua

The water level at 15:50 p.m. was 1.45 m. At site there are two telemetric stations. The team could only access the Hobo Data Logger station which Murang'a Sub-regional office had the key to open for data downloading. The second station said to be a SEBA station is maintained from the WRA head office. However, at site a manual station is installed under the bridge embankment.

The study intends to utilize observed data from the stations to complement observed levels and assist in filling gaps and also correlate the data sets at the station with other nearby ones.

	
Photo-7: Hobo Data Logger station	Photo-8: SEBA station

3. Conclusion and recommendations

Following on the above observations, the team noted that-

- The telemetric stations are well distributed in proposed pilot sub-basin for formulating a WAP process as well as template for early warning to address local flooding and drought conditions through combined utilization of real or near real time data from the AWS and river flow stations;
- The status of the data from the stations needs to be confirmed through collaboration with WRA and other partners operating in the basin;
- The issue of vandalism of stations is rampant and it is compromising integrity of telemetric network objective for real time data acquisition.

In this regard, it recommended as follows:-

a) Follow-up of placement of key issues should be addressed to ensure sub-regional offices are involved in the maintenance and data downloading of the telemetric station data.
b) Further, the Sub-regional office should liaise with the National Cereal and Produce Board (NC&PB) to access RGS 4BC02 and confirm its status and operationalize data acquisition.

c) The issue of vandalism needs to be addressed through collaboration with community and local administration.

4. Discussion with WRA HQ staff on countermeasures for the vandalism

Following on the Discussion with WRA HQ staff on countermeasures for the vandalism it was revealed that WRA is trying to protect the telemetry facilities as follows:

	
Photo-9: Embedded pipe for water level sensor inside of concrete structure	Photo-10: Digging for sensor cable from the water level sensor
	
Photo-11: Pipe for protection of the water level sensor cable	Photo-12: Protection with gabion

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Photo-11: Covered surface with concrete	

<End of Report>

JICA Water Resources Advisor
Activities Report on River Cross Section Survey and Discharge Measurement in Upper Tana

February 9, 2024
JICA Experts Team

1. Objectives:
   (1) To conduct river cross section survey and discharge measurement jointly with WRA staff at i) 4AC03 Sagana RGS, ii) 4DC03 Rupingazi RGS, and iii) 4F10 Kathita RGS.
2. Period: February 7 to 9, 2024
3. Participants

(From Nairobi):

(1) Mr. T. Okamura (JICA Expert, Team Leader/Water Resources Management)
(2) Mr. Y. Okada (JICA Expert, Hydrological Monitoring/ Flood and Drought Risk Assessment)
(3) Dr. Masika (JICA Expert Assistant for Hydrological Monitoring)
(4) Ms. Doreen Illuba (JICA Experts Team, Secretary)

On February 7, 2024 at 4AC03 Sagana RGS

(5) Ms. Jane Wairimu (Surface Water Officer, Muranga Sub-regional Office)

On February 8, 2024 at 4DC03 Rupingazi RGS

(6) Mr. Samuel Ndungu (Surface Water Officer, Tana Basin Office in Embu)
(7) Ms. Jane Njuguna (Surface Water Officer, Kerugoya Sub-regional Office)

On February 9, 2024 at 4F10 Kathita

(8) Mr. Alex Kimotho (Surface Water Officer, Meru Sub-regional Office)
(9) Mr. Gordon Omondi (Administrative Assistant, Meru Sub-regional Office)
(10) Ms. Millicent Muthoni (Intern to Meru Sub-regional Office, a student of KEWI)

4. Itinerary:

Date	Itinerary	Remarks
February 07, 2024 (Wed)	07:00-09:15 Move from Nairobi to Embu, WRA Tana Basin Office 09:45-10:15 Courtesy call Mr. Joram Njuguna (Water Quality Officer) of WRA Tana Basin Office, Explanation of the purpose of site Works 10:20-11:25 Move from Embu to Muranga Sub-regional Office (SRO) 11:40-12:25 Courtesy call to Sub-regional Manager, Preparation of Survey and Discharge Measurement Equipment including boat. 12:25-13:10 Move from Muranga SRO to Karatina 13:10-14:00 Lunch at Karatina 14:00-14:20 Move from Karatina to RGS 4AC03 Sagana 14:20-16:45 River Cross Section Survey and Discharge Measurement works at 4AC03 Sagana RGS 16:45-17:40 Move from 4AC03 Sagana RGS to Muranga 17:40-18:50 Move from Muranga to Embu Stay in Embu	Weather: Cloudy
February 08, 2024 (Thu)	08:30-09:15 Move from Embu to Kerugoya SRO 09:15-09:50 Meeting at SWO room 09:50-10:25 Move from Kerugoya SRO to RGS 4DC03 Rupingazi 10:25-13:30 River Cross Section Survey and Discharge Measurement works at 4DC03 Rupingazi RGS 13:30-13:40 Move from 4DC03 Rupingazi RGS to Embu	Weather: Sunny

	13:40-15:10 Lunch at Embu 15:10-17:10 Move from Embu to Meru Stay in Meru	
February 09, 2024 (Fri)	08:10-09:25 Move from Meru to RGS 4F17 Thingithu 09:25-09:45 Site observation of RGS 4F17 Thingithu 09:45-10:05 Move from RGS 4F17 Thingithu to RGS 4F10 Kathita 10:05-13:30 River Cross Section Survey and Discharge Measurement works at 4F10 Kathita RGS 13:30-14:50 Move from RGS 4F10 Kathita to Meru 15:15-16:15 Lunch at Meru 16:15-18:25 Move from Meru to Embu 18:25-20:50 Move from Embu to Nairobi	Weather: Sunny

5. Result and Findings

(1) Day 1: February 7, 2024 (Wed)

1) Report the purpose of the visit to the Tana Basin Office in Embu

The JICA Experts Team reported that it intended to undertake the fourth and last activity for river cross-section survey and discharge measurement. It was noted that the November mission failed due to very high flows caused by the El Nino rains.

a) JICA Experts Team reported the manager the review session of the four measurements would be held on February 14, 2024.

b) It was agreed that Mr. Ndungu was to join the team during the 4DC03 Rupingazi activity.

c) Mr. Joram (Water Quality Officer) requested the team to take water samples of one liter during the exercise.

2) Report the purpose of the visit to Muranga SRO

a) JICA Expert team reported this is the fourth time river cross-section survey and discharge measurement and informed the manager the review session of the four times measurement would be held on February 14, 2024.

b) SWO, Ms. Jane Wairimu Njoroge said the second gauge was broken when JICA Experts Team tried to conduct measurement in November 2023. It is suspected that water level in the bank was relatively high at the time and ground nearby the gauge thought have been unstable.

c) JICA Experts Team borrowed 1.Current meter, 2.Staff, 3.Level, 4.Tripod, 5.Tape measure, 6.Boat and 7.Pump from Muranga SRO. This is because other SROs don’t have equipment necessary for the survey and measurement.

d) JICA Experts Team asked the status of evaporation monitoring. SRO Ms. Jane Wairimu Njoroge said currently they don’t conduct evaporation monitoring because there are some holes in the evaporation pan.

3) The team set out in the afternoon to undertake river cross section survey and discharge measurement at RGS 4AC03 Sagana.

(2) Day 2：February 8, 2024 (Thu)

1) Report the purpose of the visit to Kerugoya SRO

   a) JICA Experts Team reported that this was the 4th time cross sectional survey and discharge measurement and informed the manager the review session of the four times measurement would be held on February 14, 2024.

   b) JICA Experts Team asked the status for the equipment necessary for cross section survey and measurement. Kerugoya SRO has a propeller-type current meter and an ADV current meter. The team took the proper-type meter to the site for measurement but it did not work correctly.

   c) JICA Expert team asked the status of evaporation monitoring. SRO Ms. Jane Njuguna, she said evaporation pan in Kerugoya works and she measure the evaporation every day.

2) River Cross Section Survey and Discharge Measurement at was undertaken at RGS 4DC03 Rupingazi in the morning session. Mr. Samuel Ndungu joined the team during the activity.

(3) Day 3：February 9, 2024 (Fri)

1) River Cross Section Survey and Discharge Measurement at RGS 4F10 Kathita

2) Report the purpose of the visit to Meru SRO

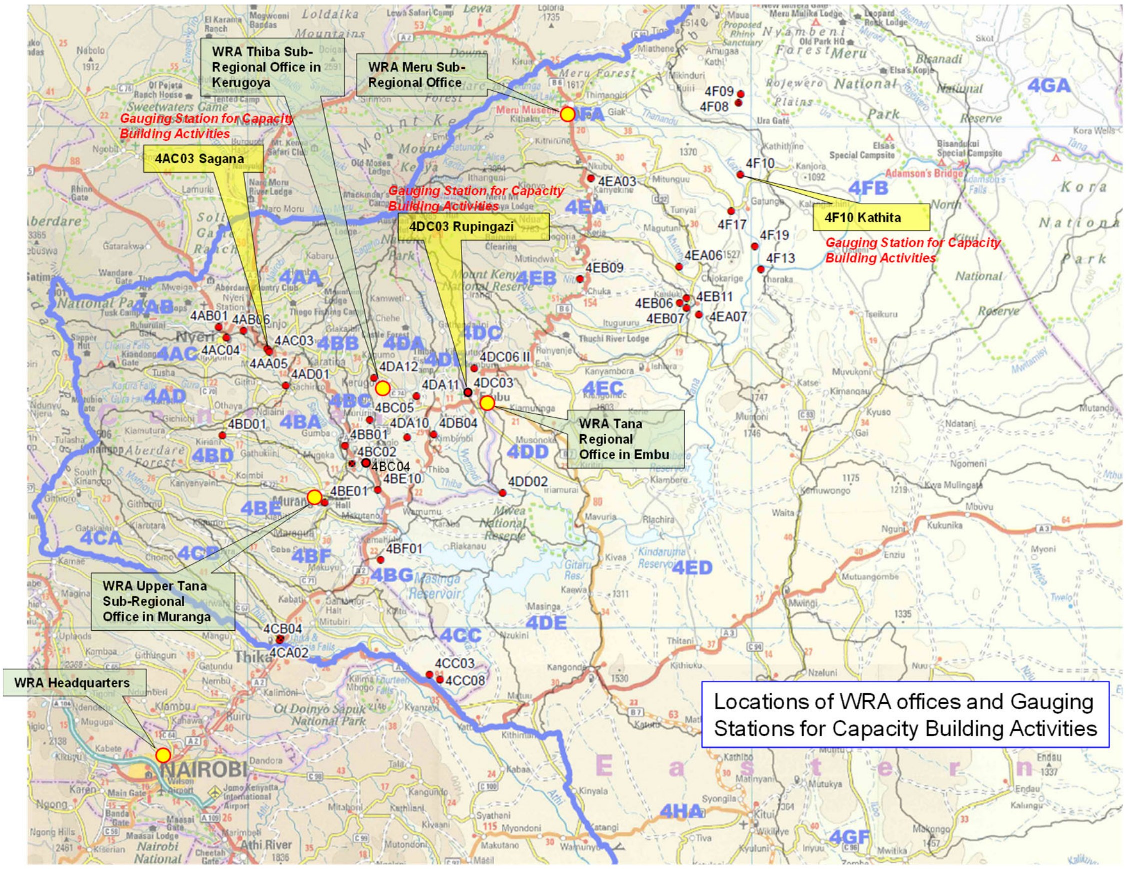
   a) JICA Experts Team reported that this was the 4th time cross-sectional survey and discharge measurement and informed the manager the review session of the four times measurements would be held on February 14, 2024.

   b) The Team leader raised the concern about the rehabilitation of the vandalized Hioki automatic water level recorder in May 2023 at Kathita. However, the office has not secured a budget for it though a request for the same had been placed to the Head Office.

   c) JICA Experts Team emphasized the need to optimize available resources for effective discharge measurement/monitoring.

   d) The JICA Experts Team reported that it intends to hold workshops at the end of August for water users, and water control and advise WRA on the way forward as well as popularizing WRA activities through publications. It was noted that the initial plan was to end the project in March 2024 but it has been extended to October 2024.

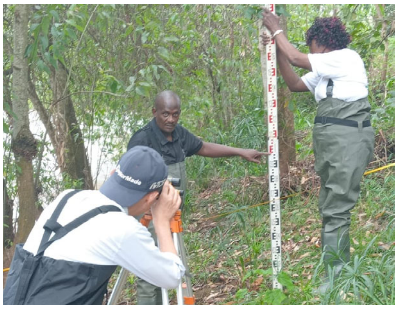
   e) JICA Experts Team asked the status of evaporation monitoring. SRO Mr. Alex M. Kimotho. He said although Meru office has the equipment of evaporation measurement, evaporation pan in Meru does not work currently, because there some hole in the pan.



Location of Gauging Stations for Capacity Building Activities

6. Photo of discussions, cross-section survey and discharge measurement
   (1) February 7, 2024 (Wednesday)
   Muranga SRO and 4AC03 Sagana regular gauging station
   From Muranga SRO, a Surface Water Officer, Ms. Jane Wairimu joined the survey and discharge measurement works.

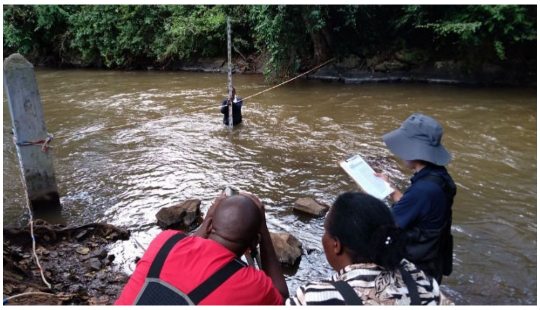
	
Courtesy call to Muranga Sub-regional Manager	Evaporation pan in Muranga SRO It was not used due to some holes in the pan.

	
Check of equipment including boat, life jacket, level, tripod, and current meter.	Current meter, tripod, level, and staff at Muranga Sub-regional office.
	
4AC03 Sagana RGS The second staff (concrete post) collapsed due to riverbank erosion. It should be reinstalled immediately. (view from upstream)	4AC03 Sagana RGS The collapsed second staff (concrete post) (view from downstream)
	
4AC03 Sagana RGS River cross-section survey with Ms. Jane Wairimu Njoroge (SWO of Muranga SRO)	4AC03 Sagana RGS Discharge measurement works
	
4AC03 Sagana RGS Discharge measurement works	4AC03 Sagana RGS The water level was 0.59 m.

	
4AC03 Sagana RGS Discharge measurement works	4AC03 Sagana RGS Discharge measurement works

(2) February 8, 2024 (Thursday)
Kerugoya SRO and 4DC03 Rupingazi regular gauging station
Mr. Samuel Ndungu (Surface water officer in Embu RO) and Ms. Jane Njuguna (Surface water officer in Kerugoya) attended the works.

	
Evaporation pan in Kerugoya SRO. It is used for evaporation measurement every day.	Current meter at Kerugoya SRO checked by JICA Experts Team, which has a mark of previous repairs. It seemed worked, however, a comparison of velocity with Muranga current meter at 4DC03 Rupingazi revealed that the current values were unnatural.
	
4DC03 Rupingazi RGS Preparation for river cross-section survey	4DC03 Rupingazi RGS

	
4DC03 Rupingazi RGS Setting up level for river cross-section survey.	4DC03 Rupingazi RGS River cross-section survey for the bench mark point.
	
4DC03 Rupingazi RGS JICA Experts Team support setting up of level.	4DC03 Rupingazi RGS Exercise for readig riverbed height by using level.
	
4DC03 Rupingazi RGS Exercise for readig riverbed height by using level.	4DC03 Rupingazi RGS Exercise for readig riverbed height by using level.
	
4DC03 Rupingazi RGS Exercise for readig riverbed height by using level.	4DC03 Rupingazi RGS Leveling works

	
4DC03 Rupingazi RGS Discharge measurement works.	4DC03 Rupingazi RGS Discharge measurement works.

(3) February 9, 2024 (Friday)
Meru SRO and 4F10 Kathita regular gauging station
Mr. Alex Kimotho (Surface water officer in Meru SRO), Mr. Gordon Omondi (Assistant Administrator), and Ms. Millicent Muthoni (Intern to Meru SRO, Kenya Water Institute) attended the works.

p 	
On the way to 4F10 Kathita RGS, dropped in at 4F17 Thingithu RGS to check the situation.	4F17 Thingithu RGS view from the left bank
	
4F10 Kathita RGS Tilted first gauge and the second gauge, of which gauge plate is about to be vandalized.	4F10 Kathita RGS Pre-check of river depth.

	
4F10 Kathita RGS As the deepest part was about 1.7 m, it was decided to use boat for river cross-section survey and discharge measurement.	4F10 Kathita RGS Prepared boat for survey and measurement works.
	
4F10 Kathita RGS Setting up of level for River Cross-section Survey	4F10 Kathita RGS River cross-section survey using boat.
	
4F10 Kathita RGS Discharge measurement using boat	4F10 Kathita RGS Discharge measurement using boat
	
Courtesy call to Meru Sub-regional manager	Checking of measurement pan for evaporation at Meru Sub-regional office Too many holes in the pan. It is required to repair for measurement.

<table>
<tr><td></td><td></td></tr>
<tr><td>A cup used for evaporation measurement at Meru SRO</td><td>A cup used for evaporation measurement at Meru SRO. WMO standard cup.</td></tr>
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<end of report>

A report on Review Session for Discharge Measurement and River Cross-Section Survey Results in Embu on February 14, 2024
JICA Experts Team

1. Date and Time: February 14, 2024, 10:00 to 16:00,
2. Venue: Water Resources Authority (WRA) Tana Basin Area Office in Embu
3. Participants: As per attached attendants list

   21 participants including JICA Experts Team, 12 participants from Tana basin Area office, 1 participant from Kerugoya Sub-Regional Office, 1 participant from Muranga Sub-Regional Office, 1 participant from Meru Sub-Regional Office.

4. Schedule:

   JICA Experts Team mobilized to Embu in the morning of February 14, 2024 for preparation of the review session. The programme is as per attached sheet. JICA Experts Team intended to mainly train the Surface Water Officers, but there were so many participants than expected including people in charge of ICT, Administrative Officer etc.

   The session was done through presentation of the material and exercise using MS Excel in each computer for calculation of discharge. The presentations aimed to enhance participants' proficiency in water resource management and optimizing preparation of rating curves through least square and graphical approaches, and on streamflow discharge calculation methods. During the session, rating curve training was conducted as a continuation of training in the previous activity which was held in October 2023.

   The expert team presented on measured discharge calculation, emphasizing streamflow as the volume rate of water flow, often expressed in cubic feet per second. Discharge is computed from velocity and water level measurements, with the conventional current-meter method commonly used. The midsection, two-point (0.2D and 0.8D), and six-tenths (0.6D) depth methods are explained for determining stream discharge. It was highlighted the importance of regular discharge measurements, a reliable stage-discharge relationship, and the need for additional capacity-building to enhance proficiency in these techniques.

   Presentation and demonstration on developing rating curves using two methods were tackled: the least square approach and graphical approach. The equation for the curves is $Q = c(h+a)^n$, with c, a, and n as variable values. The regression method is employed to create a best-fit curve, and optimization using Excel's solver add-in minimizes the error.

   Participants faced challenges comprehending software use, necessitating additional support. The need for careful fixing of variables in the equation was emphasized, ensuring accurate curve development. The presentation concluded with a comparison of estimated and measured data through curve plotting.

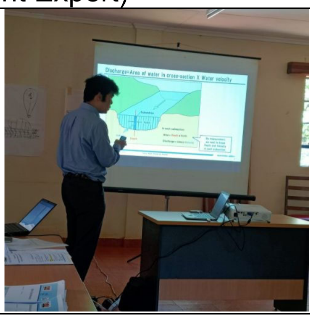
Specific needs were expressed by participants, enhancing their ability to apply hydrology techniques effectively such as Computers and Acoustic Doppler Current Profiler which can be utilized during floods.

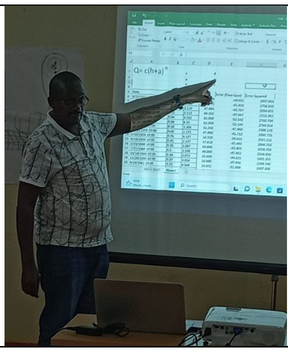
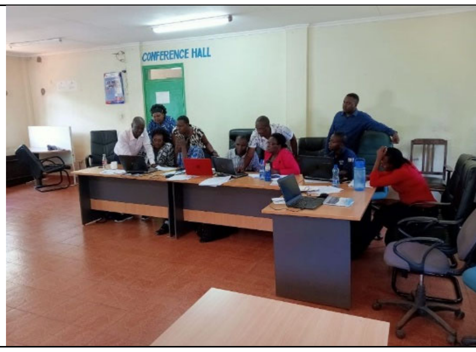
5. Training Feedback:

   The one-day seminar was fruitful, offering insights into rating curve development and streamflow discharge calculation. Google Forms facilitated feedback collection, providing advantages such as ease of use, efficient data organization, and convenient analysis (See attachment 4). The capacity-building exercise, utilizing hydrology techniques, successfully met participants' expectations. Challenges in software understanding and lack of computers were noted. Participants' requests for tablets and laptops underscore the potential for even greater success with improved technological support in future sessions.

6. Photos of Review Session Activities

   <February 14, 2024>

<table>
<tr><td></td><td></td></tr>
<tr><td>An introduction of the programme by Mr. Okamura (Team Leader/Water Resources Management Expert)</td><td>A lecture for method of discharge measurement by Mr. Okada (Hydrological Monitoring/FDRM Expert)</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Explanation on how to convert measured velocity to discharge by Mr. Okada (Hydrological Monitoring/FDRM Expert)</td><td>Situation for Calculation of Discharge Exercise using calculation sheet with MS Excel</td></tr>
</table>

	
Training session for rating curve by Dr. Masika(Hydrological Monitoring)	Situation of training session for rating curve
	
Situation of Discussions on required resources of discharge measurement and River Cross Section Survey by Mr. Okamura (Team Leader/Water Resources Management Expert)	Ms. Jane Njuguna Njoroge expressed her impressions, opinions, etc. on her participation in discharge measurements and their review session.

7. Attachment:
   (1) Programme of Review session for Discharge Measurement and River Cross Section Survey Results
   (2) Presentation Material
   (3) Attendants List
   (4) Results of Survey Questionnaire as of February 16, 2024

JICA WATER RESOURCES ADVISOR

PROGRAM OF

REVIEW SESSION FOR DISCHARGE MEASUREMENT AND RIVER CROSS SECTION SURVEY RESULTS
FEBRUARY 14, 2024

IN EMBU

(Rev.00)

Date	Schedule	Participants
FEBRUARY 14, 2024 (WEDNESDAY)		
10:00 – 10:30 AM	**Outlines of Discharge Measurement Activities** • Explanation of the purpose of activities • Outlines of survey and measurement activities	Participants- WRA Surface Water Officers of Embu, Muranga, Kerugoya, and Meru JICA Expert Team – T. Okamura
10:30 – 11:00 AM	**Method of Discharge Measurement** • Explanation of the measurement methos • Results of survey and measurement activities	Participants- WRA Surface Water Officers of Embu, Muranga, Kerugoya, and Meru JICA Expert Team – Y. Okada
11:00 - 11:20	**Tea Break**	All
11:20 - 12:50	**Explanation on Measured Discharge Calculation and Exercises** • Explanation on Calculation Sheet • Exercises using Calculation Sheet with MS Excel	Participants- WRA Surface Water Officers of Embu, Muranga, Kerugoya, and Meru JICA Expert Team – Y. Okada, Masika
13:00 - 14:00	**Lunch Break**	All
14:00 - 15:00 PM	**Presentation on the Discharge Calculation Results** • Muranga Sub-region (4AC03 Sagana) • Kerugoya Sub-region (A4DC03 Rupingazi) • Meru Sub-region (4F10 Kathita)	Participants- WRA Surface Water Officers of Embu, Muranga, Kerugoya, and Meru JICA Expert Team – Y. Okada, Masika
15:00-15:40	**Discussions on Required Resources of Discharge Measurement and River Cross Section Survey**	JICA team – T. Okamura, Eugene, Masika, Gilbert
15:40-16:00	**Closing Remarks from Tana Basin Area Coordinator**	Participants- WRA Surface Water Officers of Embu, Muranga, Kerugoya, and Meru JICA Expert Team

Note: All the participants should bring their own Laptop Computer with MS Excel for participating in the sessions.

JICA NIPPON KOEI

Water Resources Authority (WRA)

Kenya Water Resources Advisor

Review Session for
Discharge Measurement and River Cross Section Survey
Purpose and Outlines of Activities

February 14, 2024

JICA Experts Team Activities

1. Goal of activities

Strengthening of WRA's Capacity on Hydrological Data Management (Observation, Arrangement, Storage, Analysis, and Utilization)

2. Expected Outputs

- **Output 1**
  Hydrological Monitoring Network Update in accordance with the Purpose of Observation
- **Output 2**
  Capacity Building on Hydrological **Monitoring**
- **Output 3**
  Capacity Building on **Arrangement and Storage** of Hydrological and Meteorological Data
- **Output 4**
  Capacity Building on **Analysis and Utilization** of Hydrological and Meteorological Data

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JICA Experts Team Activities

- Output 2 Capacity Building on Hydrological Monitoring
  Activity 2-1: Confirmation on operational status and analysis of issues on Observation Facilities and Data Transmission Facilities
  Activity 2-2: Support on Preparation of Plan of Operation for Data Transmission Facilities
  Activity 2-3: Training of Observation Facilities and Data Transmission Facilities
  Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve





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JICA Experts Team Activities

Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve

In the original work plan of JICA, it was scheduled to sublet those works of:
- River Cross Section Survey and
- Discharge Measurement
to the contractor, of which details are as follows:

Item	Contents
Name of the Work	River cross section survey and Discharge measurement
Target location	4F10 Kathita, 4DC03 Rupingazi, and 4AC03 Sagana
Major technical specification (Draft)	• **Site reconnaissance, discussion with related organization** • **River cross section survey** 3 stations x 2 times/year (dry season 1 time + rainy season 1 time) x 2 times = 12 times in total • **Discharge measurement** 3 stations x 10 times/year at maximum (low flow 7 times + high flow 3 times) x 2 years = 60 times in total • **Preparation of report**
Work period	• Before and after the rainy season of 2022 (2 times in February and in June) • Before and after the rainy season of 2023 (2 times in February and in June)

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JICA Experts Team Activities

Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve

Candidate sub-contractors

Sublet works	Method of selection	Candidate contractor
River cross section survey and discharge measurement	Selection based on cost	• RAMANI Geosystem • GEOSCOPE SURVEYING AND COMPUTING SERVICES LIMITED • NARIANA ENTERPRISES LIMITED • Afrique Heritage Agencies Ltd.

Against JICA Experts Team's proposal, WRA decided not to hire sub-contractor, but to do the works by WRA them selves.

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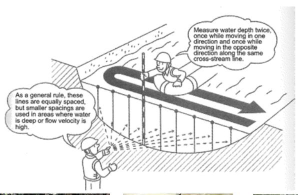
JICA Experts Team Activities

- Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve
  - River Cross Section Survey
    - Setting up level and reading the staff along the river.







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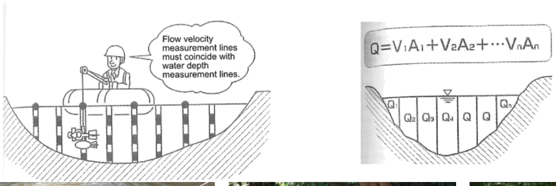
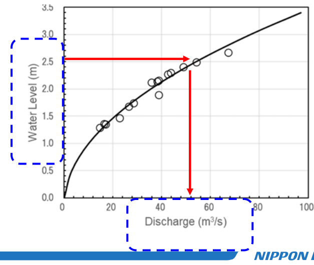
JICA Experts Team Activities

- Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve
  - Discharge Measurement
    - By summing up measured velocity multiplied by each sectional area, river discharge can be calculated.



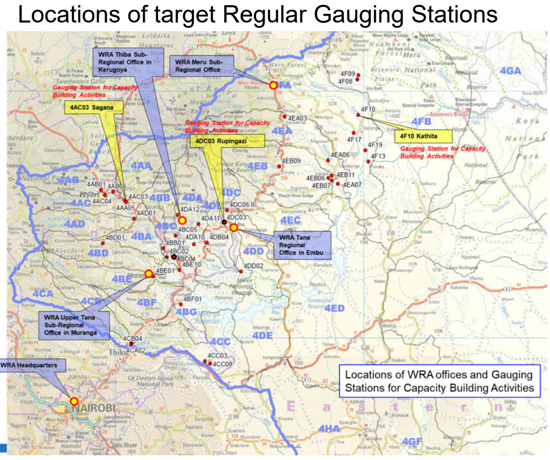
JICA Experts Team Activities

- Activity 2-4: Reinforcement of Capacity on Observation at site including preparation of H-Q Curve
  - Preparation of H-Q Curve
    - With accumulation of H, Q data, H-Q curve is prepared.
    - If the water level is observed, by converting the water level (H) to discharge (Q) using H-Q curve, the discharge can be estimated.



JICA Experts Team Activities

- Locations of target Regular Gauging Stations



JICA Experts Team Activities

- Number of times for river cross section survey and discharge measurement
  - 1st activities: March 2022
  - 2nd activities: December 2022
  - 3rd activities: May 2023
  - 4th activities: February 2024
    - February 7 (Wednesday) at 4AC03 Sagana
    - February 8 (Thursday) at 4DC03 Rupingazi
    - February 9 (Friday) at 4F10 Kathita

JICA Experts Team Activities

- **Today's program**
  - 10:00 – 10:30 AM (T. Okamura)
    - Outlines of Discharge Measurement Activities
      - Explanation of the purpose of activities
      - Outlines of survey and measurement activities
  - 10:30 – 11:00 AM (Y. Okada, Masika)
    - Method of Discharge Measurement
      - Explanation of the measurement methos
      - Results of survey and measurement activities
  - Tea Break
  - 11:20 – 12:50 PM (Y. Okada, Masika, WRA SWOs)
    - Explanation on Measured Discharge Calculation and Exercise
      - Explanation of Calculation Sheet
      - Exercise using Calculation Sheet with MS Excel
  - Lunch Break
  - 14:00 – 15:00 PM (WRA Surface Water Officers)
    - Presentation on the Discharge Calculation Results
  - 15:00 – 15:40 PM (WRA and JICA Experts Team)
    - Discussions on Required Resources
  - 15:40 – 16:00 PM (Tana Basin Area Coordinator)
    - Closing Remarks

End of Presentation

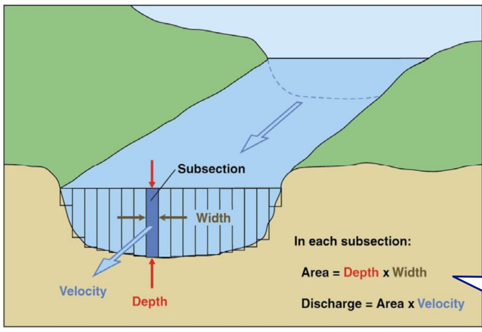
NIPPON KOEI

REPUBLIC OF KENYA

Method of Discharge Measurement

Wednesday, 14 February 2024

Discharge=Area of water in cross-section X Water velocity



By measurement, we need to know Depth and Velocity in each subsection.

Source: USGS

Wednesday, 14 February 2024

Procedure of discharge measurement

1. Record the readings of water level at staff gauges
2. Check flow conditions as discharge measurement method depend on flow conditions
3. Decide measurement method from four types
4. Preparation of required equipment and setting
5. Measure water levels and flow velocities
6. Record the readings of water level at staff gauges
7. Record of the results and data analyses

Wading measurement

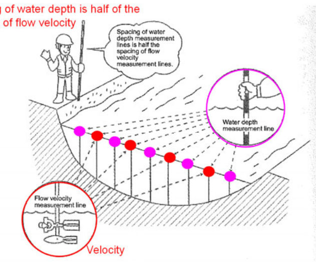
- Low flow (1): Wading measurement using current meter
- Low flow (2): Observation by boat using current meter
- Medium flow: Observation by boat using current meter
- High flow (flood) : Observation by float

Wednesday, 14 February 2024

Basic spacing of CS survey of Discharge Measurement

Water surface width (m)	Spacing between water depth measurement lines (m)	Spacing between flow velocity measurement lines (m)
Less than 10	10~15% of water surface width	10~15% of water surface width
10 ~ 20	1	2
20 ~ 40	2	4
40 ~ 60	3	6
60 ~ 80	4	8
80 ~ 100	5	10
100 ~ 150	6	12
150 ~ 200	10	20
More than 200	15	30

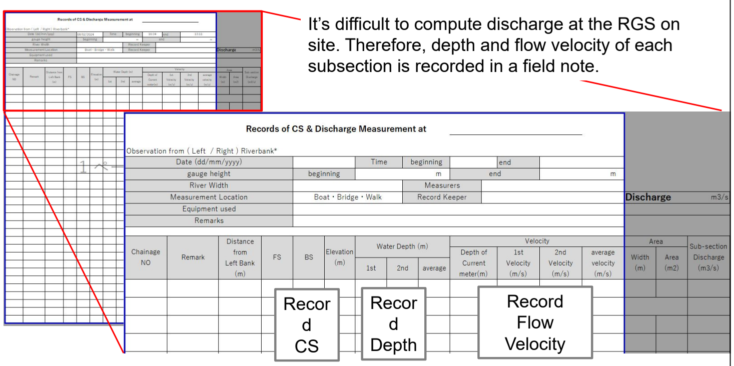
Spacing of water depth is half of the spacing of flow velocity



Wednesday, 14 February 2024

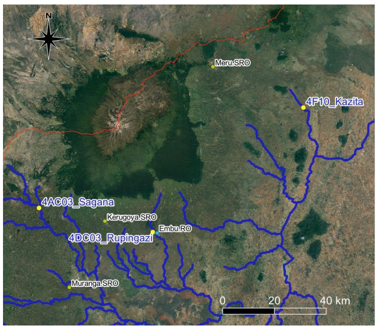
Field Note

It's difficult to compute discharge at the RGS on site. Therefore, depth and flow velocity of each subsection is recorded in a field note.



Wednesday, 14 February 2024

Target Gauging Station/Timing



Gauging Station	Location
4AC03	Sagana
4DC03	Rupingazi
4F10	Kathita

Timing (2 times x 2 year = 4 times)

Year	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Year 2022		●										●
Year 2023					●						✕	
Year 2024		●										

Wednesday, 14 February 2024

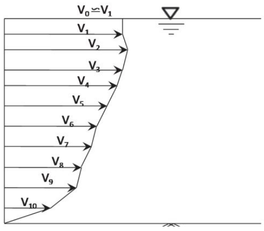
6

Basic Spacing of CS survey of Discharge measurement

Water surface width (m)	Spacing between water depth measurement lines (m)	Spacing between flow velocity measurement lines (m)
Less than 10	10~15% of water surface width	10~15% of surface w
10 ~ 20	1	2
20 ~ 40	2	4
40 ~ 60	3	6
60 ~ 80	4	8
80 ~ 100	5	10
100 ~ 150	6	12
150 ~ 200	10	20
More than 200	15	30

Rupingazi

Sagana、Kathita

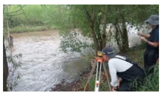


2point method: (Normal Method)
Measure the flow velocity at 20% and 80% of the water depth.

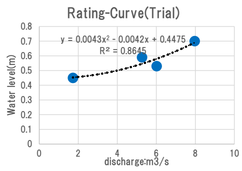
1point method: (Applied at shallow area)
Measure the flow velocity at 60% of the water depth.

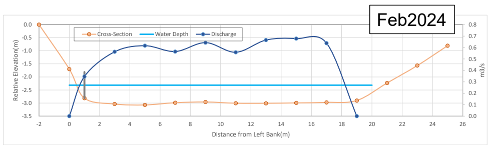
Wednesday, 14 February 2024

4AC03 Sagana River: Discharge Measurement Status



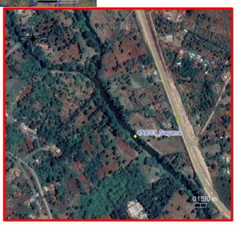
Date	Gauge height (m)	Discharge (m3/s
29-Mar-2022	0.45	1.73
19-Dec-2022	0.53	6.02
23-May-2023	0.7	7.97
7-Feb-2024	0.59	5.27





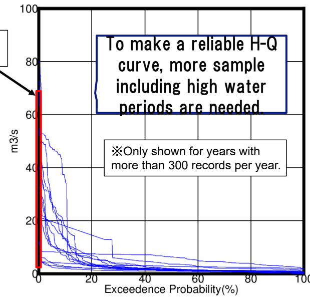
Wednesday, 14 February 2024

4AC03 Sagana River: Status of Existing Data



Daily discharge record available from 1947 to 2019(with numerous missing period

Annual Maximum:
4.5m3/s(2018) ~ 80.2m3/s(1965)



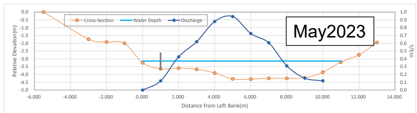
Flow Duration Curve

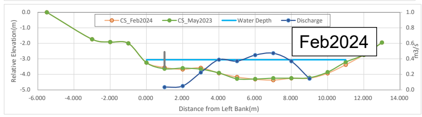
Wednesday, 14 February 2024

4DC03 Rupingazi : Discharge Measurement Status

Date	Gauge height (m)	Discharge (m3/s	Remarks
18-Mar-2022	0.31	0.425	
9-Dec-2022	0.47	2.34	1st Measurement 2.40 m3/s 2nd measurement 2.28 m3/s
23-May-2023	0.5	4.62	1st measurement 4.64 m3/s 2nd measurement 4.60 m3/s
8-Feb-2024	0.5	[redacted] ※ 2.5	1st measurement [redacted] m3/s 2nd measurement [redacted] m3/s

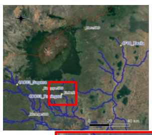
※will become clear after exercise

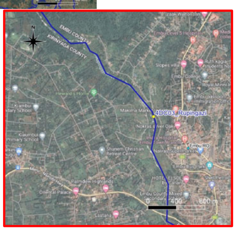




Wednesday, 14 February 2024

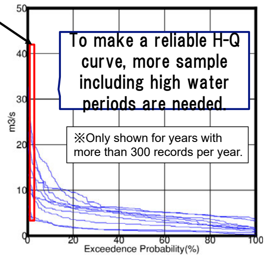
4DC03 Rupingazi : Existing Data Status





Daily discharge record available from 1969 to 2022(with numerous missing period)

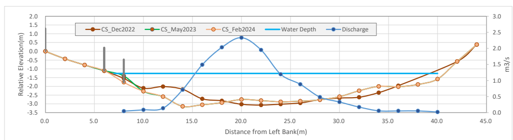
Annual Maximum:
4.8m3/s(1979) ~ 32.7m3/s(1973)



Wednesday, 14 February 2024

4F10 Kathita: Discharge measurement status

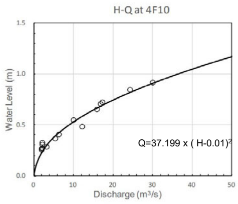
Date	Gauge height (m)	Discharge (m3/s	Remarks
14-Dec-2022	0.6	—	No discharge measurments
30-Mar-2022	(Confirming)	5.85	Averaged discharge (5.80m3/s and 5.89m3/s)
18-May-2023	(Confirming)	10.67	Averaged discharge (10.36 m3/s and 10.98m3/s)
9-Feb-2024	0.51	12.04	Measure 1times



Wednesday, 14 February 2024

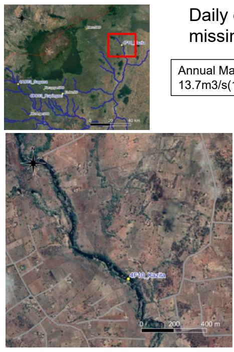
4F10 Kathita H-Q curve during previous JICA Project

Date	Gauge height (m)	Discharge (m3/s	Remarks
14-Dec-2022	0.6	—	No discharge measurments
30-Mar-2022	(Confirming)	5.85	Averaged discharge (5.80m3/s and 5.89m3/s)
18-May-2023	(Confirming)	10.67	Averaged discharge (10.36 m3/s and 10.98m3/s)
9-Feb-2024	0.51	12.04	Measure 1times



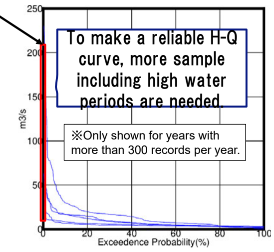
Source : Water Resource Advisor Project 2019(JICA)

4F10 Kathita Existing Data Status



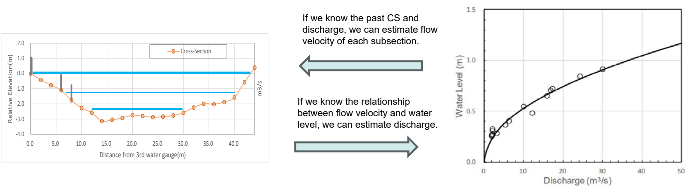
Daily discharge record available from 1959 to 2013(with numerous missing period)

Annual Maximum:
13.7m3/s(1973) ~ 230m3/s(2013)



Conclusion so far and way forward

- JICA expert team conducted 4 times discharge measurement during March 2022 to Feb 2024.
- However, to make a reliable H-Q curve, more sample including high water periods are needed.
- If existing H-Q and Cross-Section data is available, we'd like to make the use of them for the future Hydrological Data Management.



NIPPON KOEI

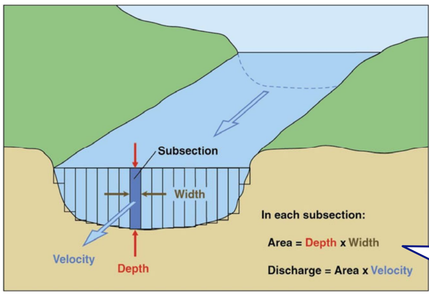
REPUBLIC OF KENYA

WRA WATER RESOURCES AUTHORITY *Accounting for every Drop!*

JICA

Explanation on Measured Discharge Calculation and Exercises

Discharge=Area of water in cross-section X Water velocity

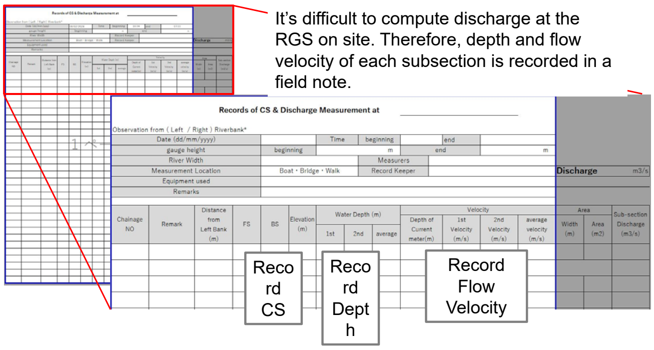


Source: USGS

By measurement, we need to know Depth and Velocity in each subsection.

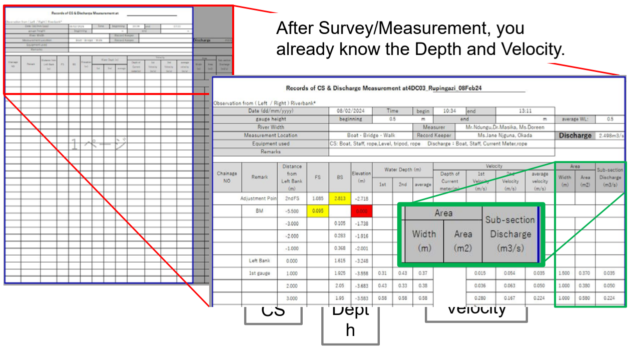
Field Note (Before Survey/Measurement)

It's difficult to compute discharge at the RGS on site. Therefore, depth and flow velocity of each subsection is recorded in a field note.

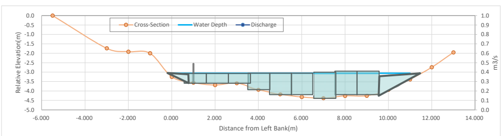


Field Note (After Survey/Measurement)

After Survey/Measurement, you already know the Depth and Velocity.



Let's Compute Discharge!



4DC03 Rupingazi

Explanation of Measured Discharge Calculation and Exercises

By
Denis Masika

at
WRA Regional Office
Embu

14/02/2024

Measured Discharge Calculation

- Streamflow discharge - volume rate of flow of water that includes any substances dissolved or suspended in the water.
- Discharge is usually expressed in units of cubic feet per second (cms or ft^3/sec)
- Stream discharge is computed indirectly from velocity and water level (stage) measurements
- If the mean water velocity normal to the direction of flow (*V*) and the cross-sectional area (*A*) of water flow is known, then the discharge (*Q*) can be computed as $Q=VA$.

Measured Discharge Calculation cont..

- The discharge rating is a relationship between the stage and discharge or between stage, discharge, slope, rate of change of state, or other factors
- Developing a stage-discharge relationship for a stream requires a set of observed flow (discharge) measurements.
- Discharge measurements are made at each gaging station to determine the discharge rating for that site.
- Discharge measurements are initially made are made frequently over a wide range in stages.
- Periodic measurements are then made (usually monthly) to validate the rating or to identify any changes in the rating caused by changes in the stream channel or stream bed

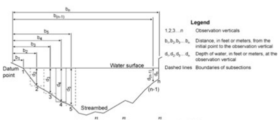
Determining discharge using current meters

- The conventional current-meter method is the most commonly used approach in determining discharge. It measures the stream velocity
- The method is based on determining the mean streamflow velocity and flow cross-sectional area;
  - The product of these variables determines the stream discharge.
- The hydrographer measures stream depth and velocity at selected intervals across a stream's cross-section.
- Methods used: wading, or supported by a cableway, bridge, or a boat.
- Depth and position measurements are made with simple surveying or sounding equipment.

Determining Discharge Using Current Meters cont…

Midsection Method

- WRA uses the midsection method of computing stream discharge using current meter velocity measurements
- The stream cross-section is divided into rectangular subsections
- At the center of each of these subsections (called a *vertical*), a depth and velocity measurement is made, and the distance from a datum point on the shore is determined.
- The total discharge can be determined using the procedure outlines



$$Q = \sum_i^n q_i = \sum_i^n v_i a_i = \sum_i^n v_i (w_i d_i)$$

where

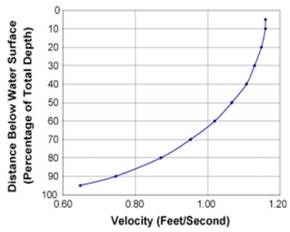
Q = total stream discharge
q_i = discharge in subsection i
v_i = mean flow velocity normal to subsection i
a_i = crossectional area of subsection i
w_i = width of subsection i

$$= \begin{cases} \frac{b_2 - b_1}{2} & \text{if } i = 1; \\ \frac{b_{i+1} - b_{i-1}}{2} & \text{if } 2 \le i \le n-1; \\ \frac{b_n - b_{n-1}}{2} & \text{if } i = n \end{cases}$$

d_i = depth of subsection i
b_i = distance from shoreline datum to center of subsection i
n = number of subsections dividing the stream crossection

Vertical Velocity Curve Method

- A series of velocity observations are made at points distributed between the water surface and the streambed. Normally observations are taken at 0.1 depth increments between 0.1 and 0.9 of the total depth.
- Observations are always taken at 0.2, 0.6 and 0.8 of the depth to facilitate comparison with other velocity methods.
- The vertical velocity methodology is based on plotting the vertical velocities versus the depth.



Vertical Velocity Curve Method

Two-Point Method (0.2D and 0.8D)

- It uses velocity observations at 0.2 and 0.8 of the depth below the surface.
- The average of these two observations is the mean velocity in the vertical.
- The methodology gives accurate and consistent results. The two-point method results are typically within 1 percent of the true mean vertical velocity.

Discharge measurement at Kathita 4F10

Chainage	Velocity 0.8	Velocity 0.2	Average Velocity	Depth	Width	Q
11	0		0	0.355	1	0
13	0.103	0.114	0.1085	0.765	2	0.166005
15	0.138	0.21	0.174	0.955	2	0.33234
17	0.106	0.226	0.166	1.205	2	0.40006
19	0.228	0.22	0.224	1.255	2	0.56224
21	0.408	0.341	0.3745	1.255	2	0.939995
23	0.539	0.487	0.513	1.275	2	1.30815
25	0.873	0.754	0.8135	1.405	2	2.285935
27	0.704	0.763	0.7335	1.425	2	2.090475
29	0.601	0.529	0.565	1.345	2	1.51985
31	0.441	0.431	0.436	1.145	2	0.99844
33	0.268	0.181	0.2245	0.765	2	0.343485
35	0.038	0.028	0.033	0.565	2	0.03729
37	0	0	0	0.205	1	0
						10.98427

Vertical Velocity Curve Method

Six-Tenths(0.6D) Depth Method

- This approach presumes that a velocity observation made in the vertical at 0.6 of the depth below the surface is the mean vertical velocity.
- Observational data and mathematical models have shown that the 0.6 depth produces reliable results.

Discharge measurement at Ruingazi 4DC03

Chainage	Depth	Width	Velocity	Area	Discharge
11.6	0.5	0.5	0.179	0.25	0.04475
10.6	0.52	1	0.399	0.52	0.20748
9.6	0.55	1	0.331	0.55	0.18205
8.6	0.82	1	0.275	0.82	0.2255
7.6	0.85	1	0.64	0.85	0.544
6.6	1.2	1	0.831	1.2	0.9972
5.6	1.2	1	0.884	1.2	1.0608
4.6	1.2	1	0.785	1.2	0.942
3.6	1.2	1	0.624	1.2	0.7488
2.6	1.2	1	0.713	1.2	0.8556
1.6	0.4	0.75	0.081	0.3	0.0243
1.1		0.25	0	0	0
			0.479	0.774	5.832

End

Thank you for listening

DEMONSTRATION OF RATING CURVE DEVELOPMENT

JICA WATER ADVISOR TEAM

presented to

WATER RESOURCES AUTHORITY

TANA BASIN REGIONAL OFFICE

14th February, 2024

Developing a rating curve exercise in Excel

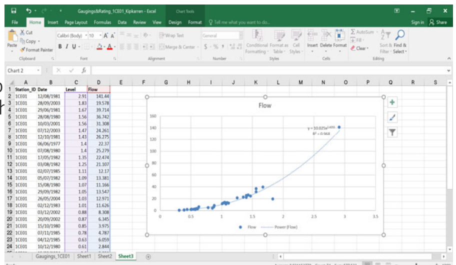
- Rating curves can be developed using 2 methods
  - Least square approach
  - Graphical approach
- Generally, the equation takes the form

$Q= c(h+a)^n$

Where c, a, n are variable. They are randomly assumed values

Developing rating curve by regression method

Use the regression method to develop a best fit curve with equation, R^2

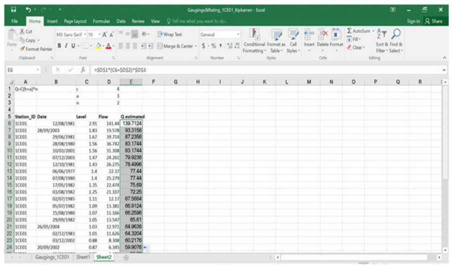


Developing rating curve by rating equation method

- use the randomly assumed values to estimate the discharge $Q_{estimated}$ (m^3/s)
- use the equation

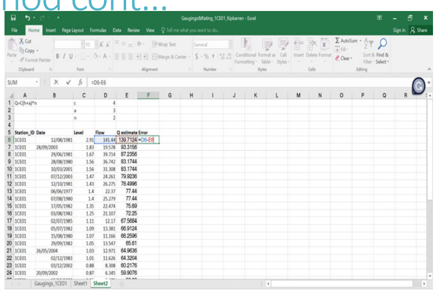
$Q= c(h+a)^n$ to determine the discharge

NB: c, a, n are constant values in the equation; use the '$' sign before a letter to fix the column and before the number to fix the row e.g. D1



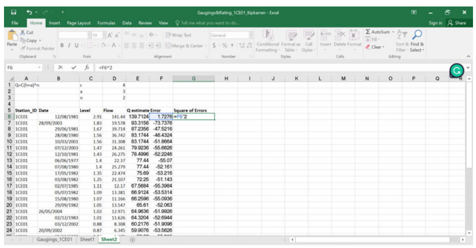
Developing rating curve by rating equation method cont…

Determine the error by subtracting the estimated discharge from the measured discharge



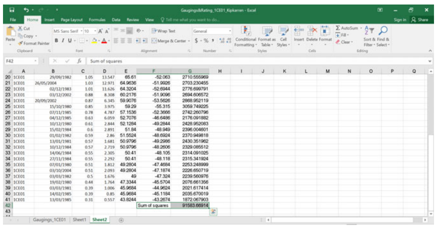
Developing rating curve by rating equation method cont…

Determine the square of errors



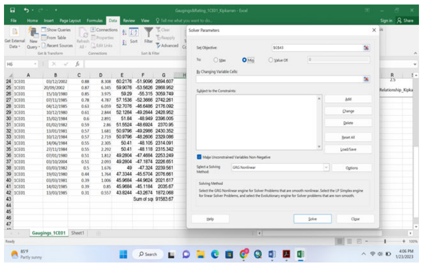
Developing rating curve by rating equation method cont…

Determine the sum of square of errors



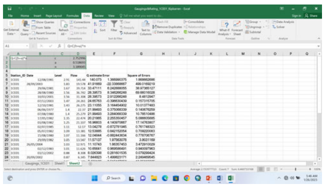
Developing rating curve by rating equation method cont…

- Use an optimization function in excel to minimize the error i.e. solver addin in excel
- Go to solver under the Data icon, select the 'Set objective' dialogue to minimize the total error i.e. sum of square error
- Select the 'Min'
- Choose the parameter to be manipulated to be 'c, a, n' in the "by changing variable cell"
- Enter OK to get the first iteration. Check the error



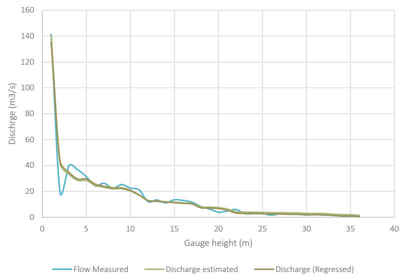
Developing rating curve by rating equation method cont…

- Use the same data values until there is no changes with minimum error (optimization process)
- Then use the optimised values of c,a,n to derive the equation e.g.
- Q=2.753(H+0.519)^3.2



Comparison of measured vs estimated rating curves

- Check how best the estimated values are compared to the measured data by plotting the curves



End

Thank you for listening

NIPPON KOEI

REPUBLIC OF KENYA

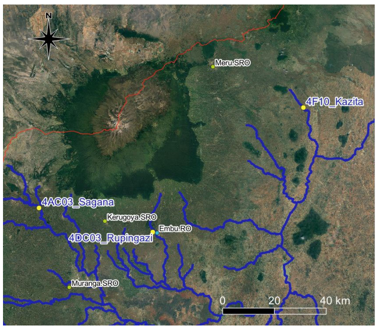
WRA WATER RESOURCES AUTHORITY *Accounting for every Drop!*

JICA

Presentation on Discharge Calculation Results

Wednesday, 14 February 2024

Target Gauging Station/Timing



Gauging Station	Location
4AC03	Sagana
4DC03	Rupingazi
4F10	Kathita

Timing (2 times x 2 year = 4 times)

Year 2022											
Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
		●									●
Year 2023											
Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
				●						~~○~~	
Year 2024											
Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
	●										

Wednesday, 14 February 2024

This time's discharge measurement Schedule

date		Activities
7-Feb	Wed	Move from Nairobi -> Embu RO > Muranga SRO -> 4AC03 Sagana River
		Discharge Measurement@4AC03_Sagana river (Muranaga SRO)
		Move from 4AC03 Sagana river -> Muranga SRO -> Hotel in Embu
8-Feb	Thu	Move from hotel in Embu > Kerugoya SRO > 4DC03 Rupingazi
		Discharge measurement @ 4DC03_Rupingazai (Kerugoya SRO)
		Move from 4DC03 Rupingazi -> Kerugoya SRO -> Meru SRO -> Hotel in Meru
9-Feb	Fri	Move from hotel in Meru -> Meru SRO -> 4F10 Kathia river
		Discharge Measurement@4F10_Kathita river (Meru SRO)
		Move from 4F10 ->Meru SRO -> Muranga SRO -> Nairobi

※ In Muranga SRO, JICA Expert team borrowed ①Current Meter, ②Staff, ③Level,④ Tripod, ⑤Tape Meausre, ⑥Boat, and ⑦Pump

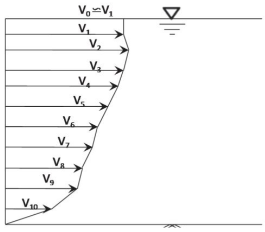
Wednesday, 14 February 2024

Basic Spacing of CS survey of Discharge measurement

Water surface width (m)	Spacing between water depth measurement lines (m)	Spacing between flow velocity measurement lines (m)
Less than 10	10~15% of water surface width	10~15% of surface w
10 ~ 20	1	2
20 ~ 40	2	4
40 ~ 60	3	6
60 ~ 80	4	8
80 ~ 100	5	10
100 ~ 150	6	12
150 ~ 200	10	20
More than 200	15	30

Rupingazi

Sagana、Kathita

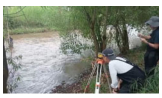


2point method: (Normal Method)
Measure the flow velocity at 20% and 80% of the water depth.

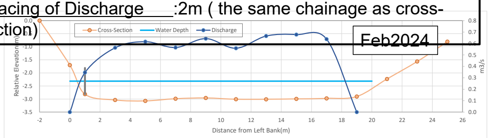
1point method: (Applied at shallow area[less than 1m])
Measure the flow velocity at 60% of the water depth.

Wednesday, 14 February 2024

4AC03 Sagana River: Discharge Measurement Status



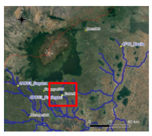
Date/Time :about15:00-17:00 07Feb 2024 (except travel time)
Member: Ms. Jane Njoroge and JICA expert team (5 people)
Spacing of Cross-Section:2m
Spacing of Discharge :2m (the same chainage as cross-section)

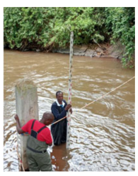


Date	Gauge height (m)	Discharge (m3/s	Remarks
29-Mar-2022	0.45	1.73	
19-Dec-2022	0.53	6.02	1st measurement 6.80 m3/s 2nd measurement 5.61 m3/s
23-May-2023	0.7	7.97	1st measurement 11.37 m3/s 2nd measurement 7.97 m3/s
7-Feb-2024	0.59	5.27	1st measurement 5.60 m3/s 2nd measurement 4.79 m3/s

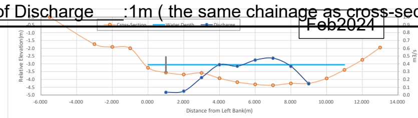
Wednesday, 14 February 2024

4DC03 Rupingazi : Discharge Measurement Status





Date/Time :10:34-13:11 08Feb 2024 (except travel time)
Member: Mr.Samuel Ndungu, Ms. Jane Njuguna, and JICA expert team (6 people)
with the help of local people
Spacing of Cross-Section:1m
Spacing of Discharge :1m (the same chainage as cross-section)

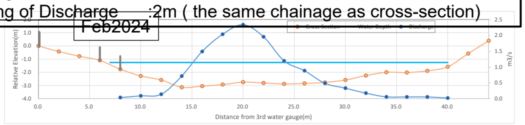


Date	Gauge height (m)	Discharge (m3/s	Remarks
18-Mar-2022	0.31	0.425	
9-Dec-2022	0.47	2.34	1st Measurement 2.40 m3/s 2nd measurement 2.28 m3/s
23-May-2023	0.5	4.62	1st measurement 4.64 m3/s 2nd measurement 4.60 m3/s
8-Feb-2024	0.5	2.5	1st measurement 2.50 m3/s 2nd measurement 2.49 m3/s

Wednesday, 14 February 2024

4F10 Kathita Discharge Measurement status

Date/Time : About 10:00-13:30 09Feb 2024 (except travel time)
Member: Mr.Alex M.Kimoto, Mr. Gorden, Ms.Milicent and JICA expert team (7 people)
with the help of local people
Spacing of Cross-Section:2m
Spacing of Discharge :2m (the same chainage as cross-section)



Date	Gauge height (m)	Discharge (m3/s	Remarks
14-Dec-2022	0.6	—	No discharge measurments
30-Mar-2022	(Confirming)	5.85	Averaged discharge (5.80m3/s and 5.89m3/s)
18-May-2023	(Confirming)	10.67	Averaged discharge (10.36 m3/s and 10.98m3/s)
9-Feb-2024	0.51	12.04	Measure 1times

JICA

NIPPON KOEI

Water Resources Authority (WRA)

Kenya Water Resources Advisor

Review Session for

Discharge Measurement and River Cross Section Survey

Required Resources for Activities

February 14, 2024

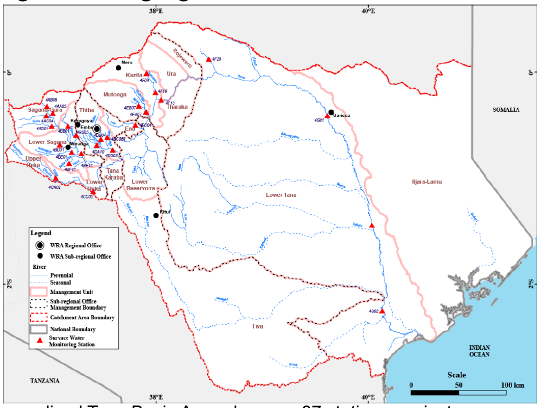
1. Regular Gauging Stations under Tana Basin Area

Status of Regular Gauging Stations in Tana Basin Area

	Total	Operational	Not Operational	Telemeteri ng Station	Data Logger	Vandali zed	Need Rehabilitation
Kerugoya	*13*	*13*	*0*	*7 (54%)*	*0*	*1*	*2 (15%)*
Muranga	*53*	*47*	*6*	*11 (21%)*	*19 (36%)*	*7*	*14 (26%)*
Meru	*16*	*13*	*3*	*3 (19%)*	*4 (25%)*	*0*	*0*
Sub-total	***82***	***73***	***9***	***21 (26%)***	***23 (28%)***	***8***	***16 (20%)***
Garissa	*5*	*3*	*2*	*1 (20%)*	*0*	*0*	*0*
Total	***87***	***76***	***11***	***22 (25%)***	***23 (26%)***	***8***	***16 (18%)***

It was realized Tana Basin Area observes 87 stations against recommended 26 stations in NWMP 2030.
Muranga has the largest number of stations as 53.

1. Regular Gauging Stations under Tana Basin Area



It was realized Tana Basin Area observes 87 stations against recommended 26 stations in NWMP 2030.

1. Regular Gauging Stations under Tana Basin Area

Of the 87 stations in Tana Basin Area
Category wise number of stations are as follows:

Type of Gauging Station	Criteria of Installation	Equipment	Numbers of RGSs in Tana Basin Area
National (N)	Stations of national importance Data gives an overview of the national water resources status Located at rivers and water bodies of national importance Monitors water from several management units Monitors water resources that would indicate the extreme impact on national water resources To be fully automated	Gauge plates Automatic water level recorder Data logger	1
Management Unit (MU)	Located at the outlet of each management unit Gives WR status for a specific management unit (Water Quality and Quantity) Has long-term data available To be fully automated	Gauging station Automatic water level recorder Data logger	8
Intra Management Unit (IMU)	Located at the outlet of each sub-management unit Gives WR status for a specific management sub-catchment (Water Quality and Quantity) Used for water allocation and demand management Assesses the critical catchment yields	Gauge plates	24
Special (S)	Monitors water resources status for selected water bodies, e.g., Wastewater sewers Established for specialized studies Established where there are disputes	Gauge plates	46
Otheres			8
	Total		87

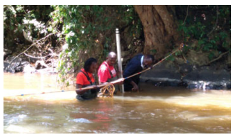
2. Required numbers of staff for activities

1. **For River Cross Section Survey**
   (1) For small and shallow stream less than 1.2 m depth: 2-3 people
      1) Level reader: 1-2
      2) Staff holder: 1
   (2) For large and deep stream more than 1.2 m depth (using boat): 4-5 people
      1) Level reader: 1-2
      2) Staff holder: 1
      3) Boat controller: 2
2. **For Discharge Measurement**
   (1) For small and shallow stream less than 1.2 m depth: 3 people
      1) Discharge recorder: 1
      2) Staff holder: 1
      3) Current meter reader: 1
   (2) For large and deep stream more than 1.2 m depth (using boat): 4 people
      1) Discharge recorder: 1
      2) Staff and Current meter reader: 1
      3) Boat controller: 2

For both of River Cross Section Survey and Discharge Measurement
a) For small and shallow stream less than 1.2 m depth: minimum 3 people
b) For large and deep stream more than 1.2 m depth (using boat): minimum 5 people

2. Required numbers of staff for activities

1. For small and shallow stream less than 1.2 m depth: minimum 3 people



2. For large and deep stream more than 1.2 m depth: minimum 5 people using boat


2. Required times for activities

1. **Go to the site and back to the office: 1 to 2 hours**
2. **Setup and tidying up: 0.5 hours**
3. **River Cross Section Survey: 1 hour**
4. **Discharge Measurement: 1 hour**

Total time for activities 3.5 to 4.5 hours (4 hours in average) per regular gauging station

→ This required time can be shortened through quick setup, survey, measurement and tidying up.

→ This required time can be shortened through skill development on survey and measurement.

3. Required resources and total time for activities

By assuming minimum one time survey and measurement per year,
In case of covering:
National Station (1 location), it is half day (4 hours) with 5 people.

In case of covering
National and Management Unit Stations (1+8 = 9 locations), required time is 4 hours x 9 locations = 36 hours, i.e., 4.5 days with 5 people.

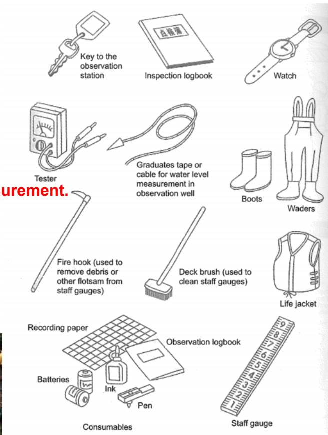
In case of covering
National, Management Unit, and Intra Management Unit Stations (1+8+24 = 33 locations), required time is 4 hours x 33 locations = 132 hours, i.e., 16.5 days with 5 people.

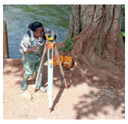
In case of covering
All the stations, required time is 4 hours x 87 locations = 348 hours, i.e., 43.5 days (2 months) with 5 people.

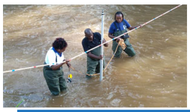
4. Required equipment for activities

1. **Level + Tripod**
2. **Staff**
3. **Rope marked in every meter**
4. **Current meter**
5. **Wading suit**
6. **Measurement tape**
7. **Field note**
8. **Boat as necessary**

Check if you have sufficient equipment for measurement.








End of Presentation

ATTENDANCE SHEET FOR REVIEW SESSION ON DISCHARGE MEASUREMENT AND
RIVER CROSS SECTION SURVEY ON 14TH FEB 2024 AT EMBU REGIONAL OFFICE

NO	NAME	INSTITUTION	DESIGNATION	STATION	PHONE	EMAIL ADDRESS
1	Jackline Mutinda	WRA	Principal Hydrologist/Regional Technical Manager	Embu		
2	Wilson Githu	WRA	ICT Officer	Embu		
3	Eric Muthaura	WRA	Snr.Records Management Assistant	Embu		
4	Jack Donald Ganga	WRA	Attachee	Embu		
5	Raphael Waruingi	WRA	Intern	Embu		
6	Silas Njiru Kamanja	WRA	Snr.Supply Chain Management Assisant	Embu		
7	Nickson Amwoka	WRA	Supply Chain Management Assistant	Embu		
8	Ruth W. Kilonzo	WRA	Snr. Human Resource Officer	Embu		
9	Mercy Vera Odidid	WRA	Snr. Administrative Officer	Embu		
10	Samwel Ndung'u	WRA	Hydrologist	Embu		
11	Alex Kimotho	WRA	Hydrologist	Meru		
12	Jane Njuguna	WRA	Hydrologist	Kerugoya		
13	Jane Njoroge	WRA	Hydrologist	Murang'a		
14	Mary Maina	WRA	Office Assistant	Embu		
15	Doreen Iluba	JICA	Secretary	Nairobi		
16	Gilbert Maiyo	JICA	Water Resource Engineer	Nairobi		
17	Denis Masika	JICA	Hydrologist	Nairobi		
18	Okamura Takeshi	JICA	Team Leader, Water Resources Management Expert	Nairobi		
19	Okada Yuki	JICA	Hydrological Monitoring/ Flood and Drought Risk Management Expert	Nairobi		
20	Muturi Simon	World Waternet	Project Manager	Nairobi		
21	Gicuku Nyaga	WRA	Snr	Embu		

REVIEW SESSION FOR DISCHARGE MEASUREMENT AND RIVER CROSS SECTION SURVEY

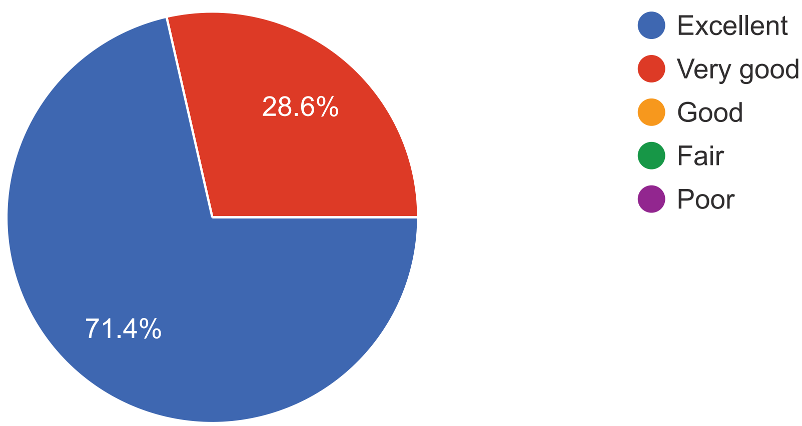
7 responses

Publish analytics

1. How would you rate the overall quality of the seminar?

Copy

7 responses



2. Did the seminar meet your expectations?

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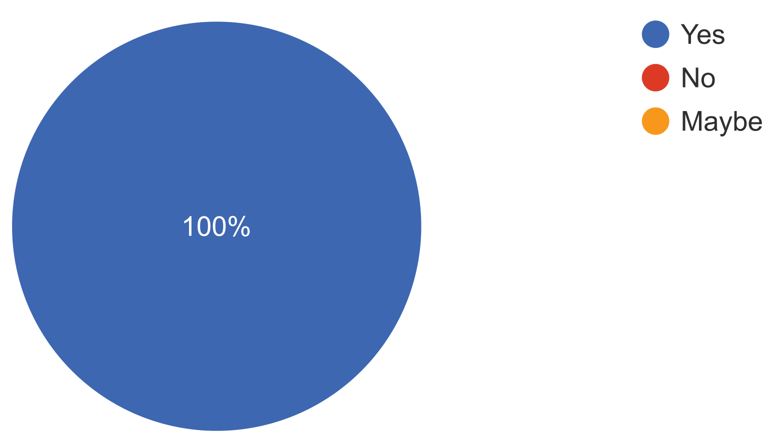
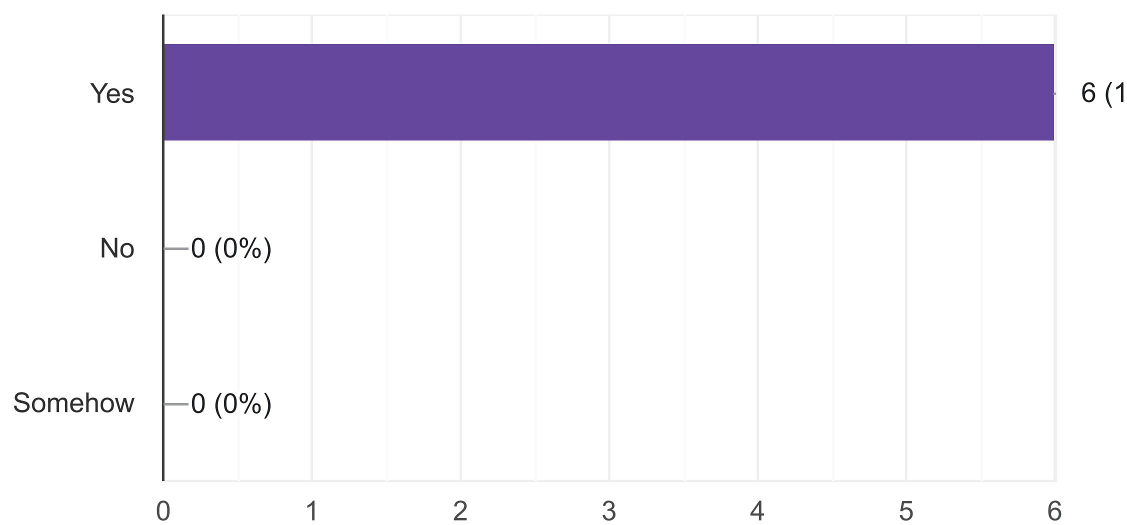
7 responses



3. Were the speakers knowledgeable and engaging?

Copy

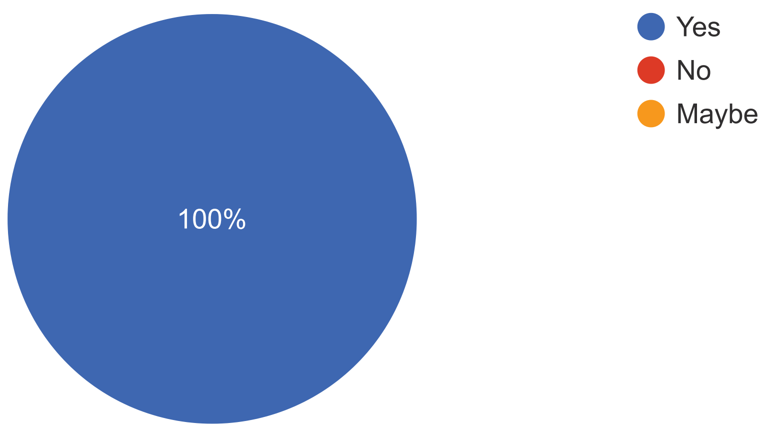
6 responses



4. Did you find the practical demonstrations and examples used useful in enhancing your understanding of the concepts taught?

Copy

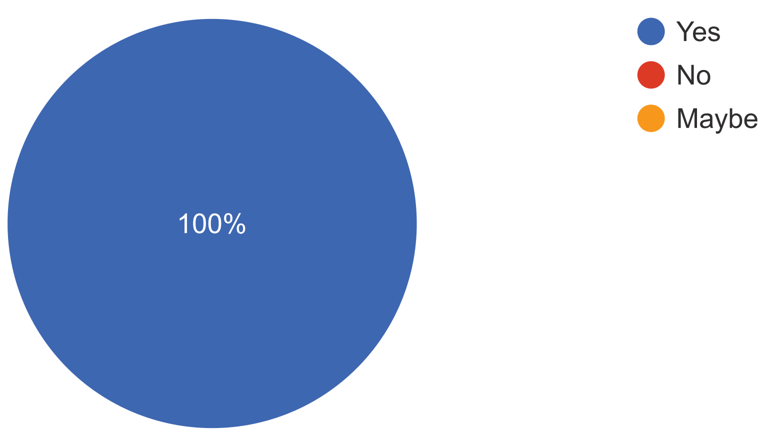
7 responses



5. Did you find the training material practical, intuitive, and helpful?

Copy

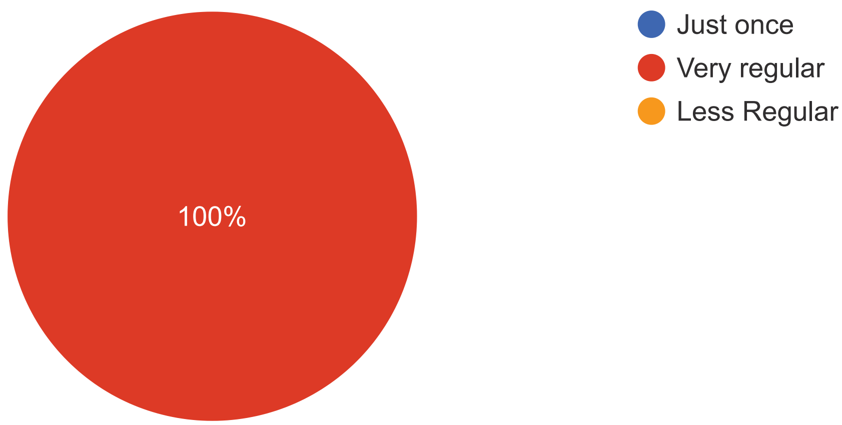
7 responses



6. How regular do you think such trainings should be provided?

Copy

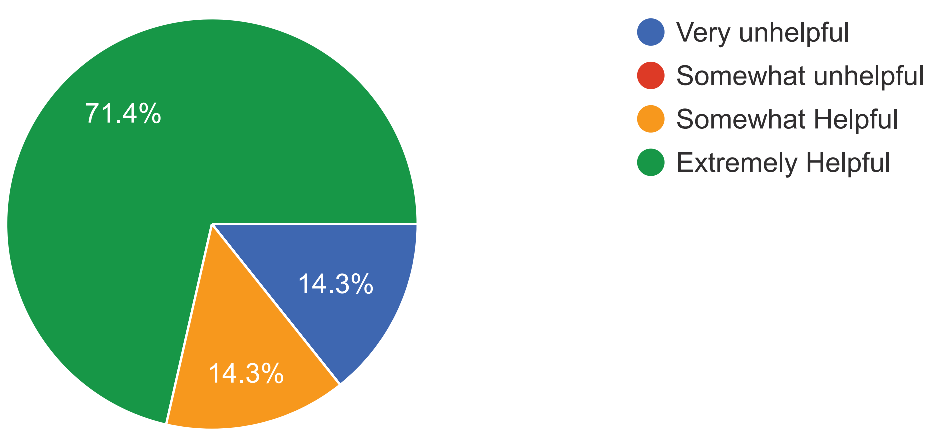
7 responses



7. Did you find the training helpful?

Copy

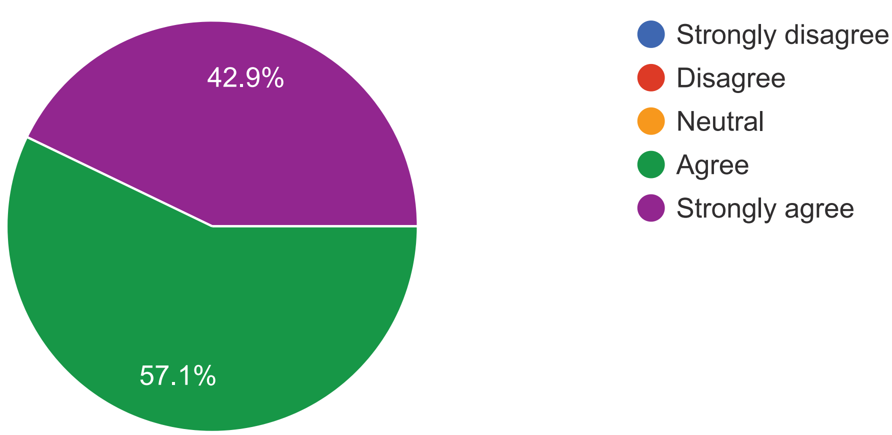
7 responses



8. The training program was well organized and easy to follow?

Copy

7 responses



9. Which session(s) did you find most beneficial or informative?

7 responses

Rating curved

Measurements methods

All sessions we're beneficial

Discharge calculations and it's important

Discharge measurement calculation using the template provided/River closs-section profiling

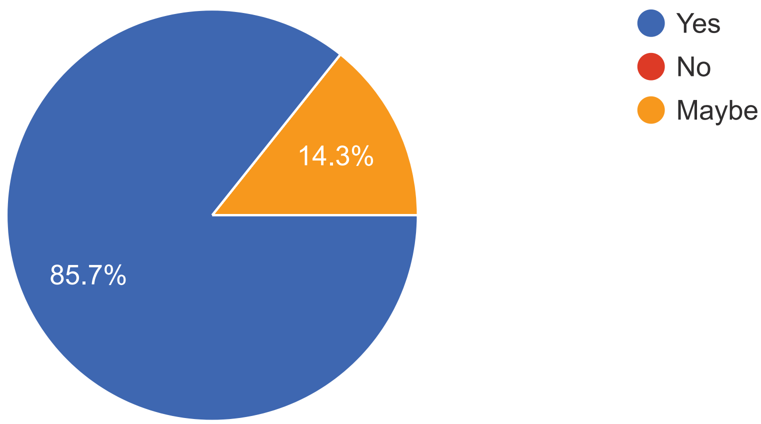
use of solver to calculate the river discharge.

All especially rating equation session

10. Did you find the seminar content relevant to your interests or field of work/study?

Copy

7 responses



11. Do you have any additional comments or suggestions for improving future seminars?

6 responses

No

More field work

It was a good session with great educator to learner interaction

Its unfortunate you are coming to the end of the current programme. wish you can continue with more programmes.

more days and practical's for the leaners

seminars should be longer to give more time for practical exercises

A report on Training Session for Frequency Analysis of Rainfall and Discharge in Embu on June 10, 2024

JICA Experts Team

1. Date and Time: June 10, 2024, 10:00 to 16:00
2. Venue: Water Resources Authority (WRA) Tana Basin Area Office in Embu
3. Participants: As per attached attendants list

   20 participants including JICA Experts Team, 13 participants from Tana basin Area office, 1 participant from Kerugoya Sub-Regional Office, 1 participant from Muranga Sub-Regional Office, 1 participant from Meru Sub-Regional Office.

NO	NAME	INSTITUTION	DESIGNATION	STATION
1	Doreen Iluba	JICA	Secretary	Nairobi
2	Samuel Ndung'u	WRA	Senior Hydrologist	Embu
3	Yahya Aden	WRA	Hydrologist	Murang'a
4	Mercy Mbaya	WRA	Hydrologist	Meru
5	Jane Njunguna	WRA	Hydrologist	Kerugoya
6	Raphael Waruingi	WRA	Geologist Intern	Embu
7	Brian Kisaka	WRA	Civil Engineering Intern	Embu
8	Gitari Shareen	WRA	Attachee	Embu
9	Mugambi Evon	WRA	Hydrology Attachee	Embu
10	Josephat Nzuva	WRA	Biochemistry Attachee	Embu
11	Roy Ngari	WRA	Environmental Science & Technology Attachee	Embu
12	Derrick Kimotho	WRA	ICT Attachee	Embu
13	Joseph Tsuma	WRA	Biochemistry Attachee	Embu
14	Esekon Diana	WRA	Biochemistry Attachee	Embu
15	Okamura Takeshi	JICA	JICA Expert	Nairobi
16	Sophia Mwihaki	WRA	Records management Assistant	Embu
17	Diana Nyaguthii	WRA	Project Management Attachee	Embu
18	Jack Donald Ganga	WRA	Water Quality & Pollution Control Intern	Embu
19	Yuki Okada	JICA	JICA EXpert	Nairobi
20	Denis Masika	JICA	Hydrologist	Nairobi

4. Schedule:

   JICA Experts Team mobilized to Embu in the morning of June 10, 2024 for preparation of the training session. The programme is as per attached sheet. JICA Experts Team intended to mainly train the Surface Water Officers, but there were so many participants than expected including people in charge of civil engineering intern, environmental science & technology, etc.

   The session was done through presentation of the material and exercise using MS Excel in each computer for calculation of discharge. The presentation was aimed to introduce that frequency analysis is used for evaluation of magnitude of Flood of April 2024, etc., and consideration of climate change adaptation.

During the session, training of frequency analysis was conducted using MS Excel. First, the trainees learned how to calculate the return period from Plotting Position using the annual maximum value. Then they learned the relationship between target discharge and return period using Weibull distribution and Gumbel distribution, etc.

During the discussion time, participants recognized that frequency analysis is highly dependent on the results of daily monitoring, and that daily monitoring, quality control, and data storage are extremely important.

Photos of Training Session Activities

<June 10, 2024>

	
Presentation for April 2024 flood, example of usage of frequency analysis, by Mr. Okada (Hydrological Monitoring/FDRM Expert)	Explanation for method of calculating frequency analysis by Dr. Masika (Hydrological Monitoring)
	
Situation of Exercise for frequency analysis(1)	Situation of Exercise for frequency analysis(2)
	
Situation on discussions for necessity of daily monitoring, quality check, and data storage	Group photo of participants

5. Attachment:
   (1) Programme of Training session for Frequency Analysis of Rainfall and Discharge
   (2) Presentation Material

Kenya WATER RESOURCES ADVISORS PROJECT

PROGRAM OF

TRAINING SESSION FOR FREQUENCY ANALYSIS OF RAINFALL and DISCHARGE

June 10, 2024

IN EMBU

Date	Schedule	Participants
JUNE 1O, 2024 (MONDAY)		
10:00 – 11:00 AM	**Rainfall Pattern, Hydrological cycle characteristics, and projected climate change impacts around Upper Tana Basin** • Presentation using satellite-based rainfall dataset and reviewing related articles.	Participants- WRA Surface Water Officers of Embu, Muranga, Kerugoya, and Meru JICA Expert Team Y.OKada
11:00 – 11:15 AM	**Tea Break**	All
11:15 – 11:45 AM	**Method of Computing Frequency Analysis** • Explanation of the Calculation Sheet	Participants- WRA Surface Water Officers of Embu, Muranga, Kerugoya, and Meru JICA Expert Team Y.Okada, Masika
11:45 – 1:00 PM	**Exercise of Computing Frequency Analysis for Rainfall** • Exercises using Calculation Sheet with MS Excel	All
1:00 - 2:00 PM	**Lunch Break**	All
2:00-3:15 PM	**Exercise of Computing Frequency Analysis for high flow and low flow**	All
3:15 -3:20 PM	**Short Break**	All
3:20-3:50 PM	**Discussion for** • Discharge Measurement • Mitigation Measures for Extreme Events (Flood and Drought) , etc.	Participants- WRA Surface Water Officers of Embu, Muranga, Kerugoya, and Meru JICA Expert Team T. Okamura
3:50- 4:00 PM	**Closing Remarks from Tana Basin Area Coordinator**	All

Note: All the participants should bring their Laptops with MS Excel to participate in the sessions.

Kenya Water Resources Advisors Project

Training Session for Frequency Analysis of Rainfall and flow

Rainfall Pattern, Hydrological cycle characteristics, and projected climate change impacts around Tana Basin

1. Outline of April 2024 Flood
2. Mechanism of Rainfall
3. Climate variability around Eastern Africa
4. Future climate risk

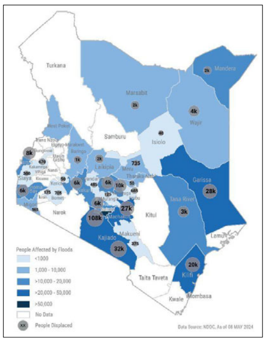
Yuki OKADA
Hydrological Monitoring/
Flood and Drought Risk Assessment

1

1.Outline of April 2024 Flood

2

1.Outline of April 2024 Flood/Damage Situation of April Flood（as of 10 May 2024）



Source: OCHA

Source: Kenya Red Cross

3

1.Outline of April 2024 Flood/ Main Flood Event

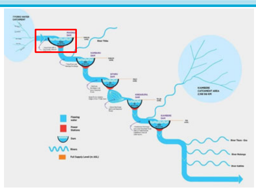
Heavy Flood Advisory was issued on 9th April

It is assumed main flood event occurred during 4-9, 11-16, 27-29th April

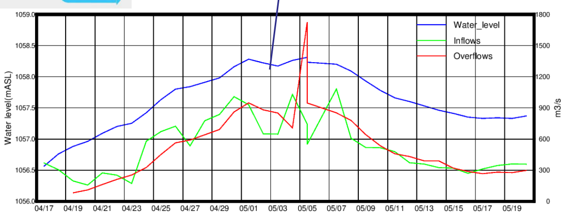
NO	DATE	TITLE	AREA	DAMAGE
43	4th April 2024	Mwea Residents Left Homeless After River Thiba Broke Its	Mwea- Kirinyaga County	Houses destroyed and swept away, hectares of crops washed away
44	8th April 2024	KeNHA closes Nairobi-Garissa Road due to flooding at Mororo	Mororo- Tana River	Road impassable due to flooding
45	9th April 2024	Hundreds stranded as floods wreak havoc along Garissa-	Tula and Arer area Bangale sub-county in Tana River	Road network cut off and transport paralyzed due to flooding
46	9th April 2024	51 passengers narrowly escape death as bus is swept by floods	Lager Areli- Garissa County	Death related risks
47	11th April 2024	Kenya: Heavy Rains and Flooding Update - Flash Update	Marsabit, Turkana, Tana River, Garissa, Kirinyaga, Muranga, Kiambu,	3000 households displaced, 339 livestock killed, unknown acres of croplands lost
48	12th April 2024	Red Cross: At least 323 households affected by heavy	Thiba in Mwea West Kirinyaga County	323 households displaced
49	15th April 2024	Two killed as floods wreak havoc in Tana River	Tana North	Loss of lives, families displaced
50	16th April 2024	Over 100 Families Flee Homes As Floods Rock Kirinyaga	Ngurubani in Mwea Kirinyaga County	Over 100 families displaced
51	27th April 2024	Garissa faces supplies shortage as floods cut off roads network	Garissa-Madogo Highway	Supply shortage of basic commodities
52	28th April 2024	23 People Missing As Boat Capsizes In Tana River	Madogo - Tana River	23 people missing,
53	29th April 2024	Hundreds displaced in Garissa and Mororo, Tana River as floods	Garissa and Tana River Counties	Houses sub-merged &Families displaced, road network destroyed, property destroyed
54	29th April 2024	Floods Continue To Wreak Havoc In Garissa	Bulla punda, Kamor, Sheikh, vumbi, Windsor, Bulla nyuki - in Garissa	Houses submerged and families displaced

4

1.Outline of April 2024 Flood/ 7 Forks Dams/Masinga

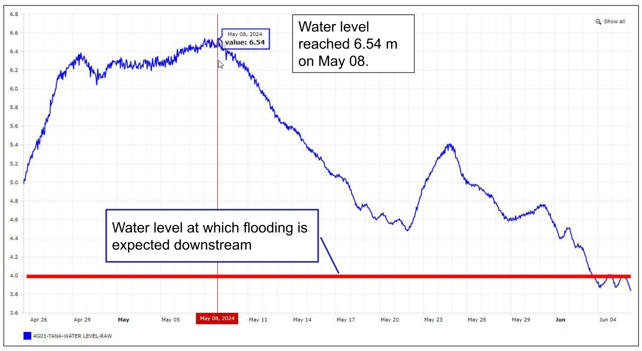


KenGen sounds warning as Masinga Dam water levels hit record high. Masinga Dam. The water level at the dam was recorded at 1,058.28 metres above sea level on May 1, 2024, against a full supply level of 1,056.50 metres.



5

1.Outline of April 2024 Flood/ Water level of 4G01 Garissa

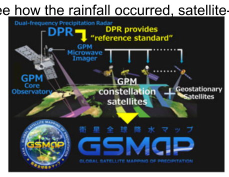


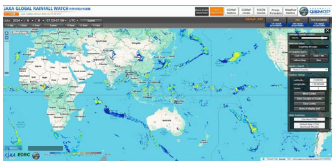
Source: MIKE INFO, WRA

6

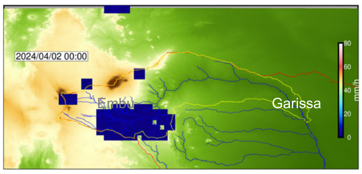
1.Outline of April 2024 Flood/ Rainfall analysis using GSMaP

To see how the rainfall occurred, satellite-based rainfall data was visualized.



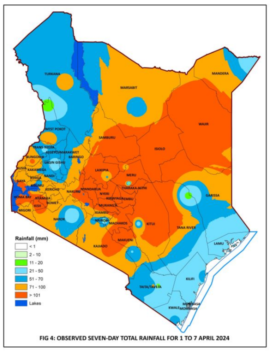


Description of rainfall data	
Variable	Rain Rate (mm/hr)
Domain	60N-60S
Grid Resolution	0.1 degree latitude/longitude
Temporal Resolution	1 hour
Availability	1998-01-01T00:00 ~

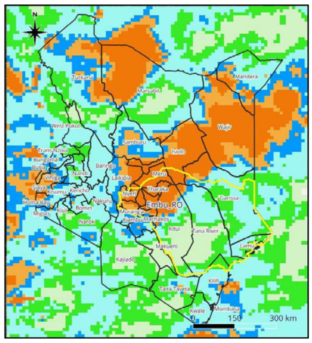


7

1.Outline of April 2024 Flood/ Estimated Rainfall Distribution for 1 to 7 April 2024



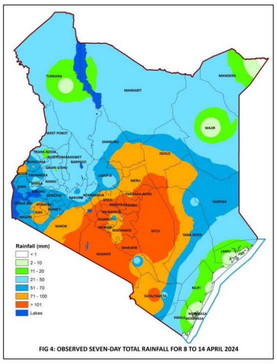
Source: KMD (spatially interpolate rain-gauge data)



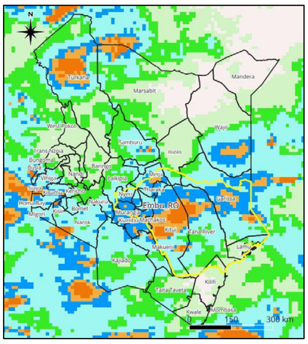
Source: JICA Expert team based on GSMaP_MVK

8

1.Outline of April 2024 Flood/ Estimated Rainfall Distribution for 8 to 14 April 2024



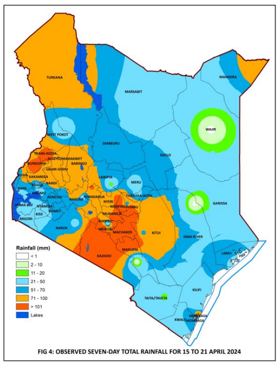
Source: KMD



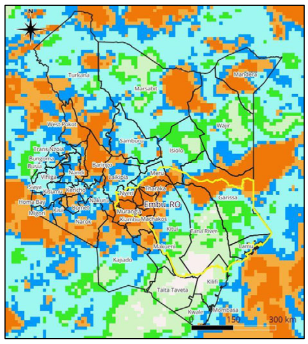
Source: JICA Expert team based on GSMaP_MVK

9

1.Outline of April 2024 Flood/ Estimated Rainfall Distribution for 15 to 21 April 2024



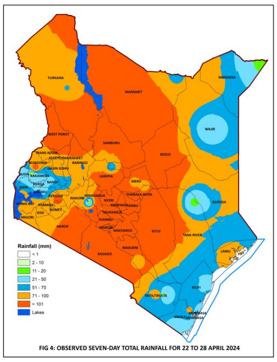
Source: KMD



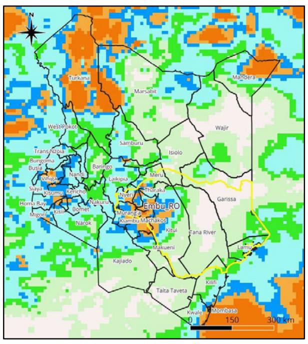
Source: JICA Expert team based on GSMaP_MVK

10

1.Outline of April 2024 Flood/ Estimated Rainfall Distribution for 22 to 28 April 2024



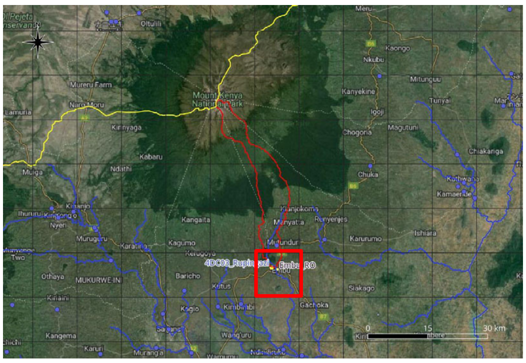
Source: KMD



Source: JICA Expert team based on GSMaP_MVK

11

1.Outline of April 2024 Flood/ Frequency Analysis using GSMaP rainfall around Embu Regional Office



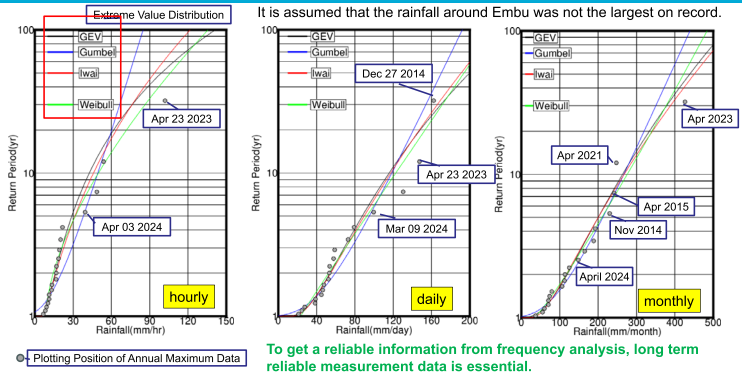
To evaluate the scale of April 2024 rain compared to previous rains, **Frequency Analysis** ※ was carried out.

※ Detailed methods will be presented in the next session.

12

1.Outline of April 2024 Flood/ Frequency Analysis using GSMaP rainfall around Embu Regional Office

It is assumed that the rainfall around Embu was not the largest on record.



To get a reliable information from frequency analysis, long term reliable measurement data is essential.

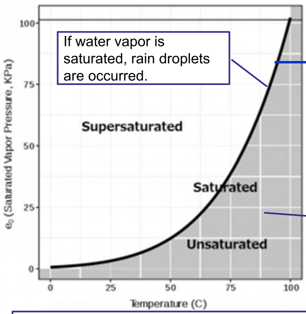
※ Detailed methods will be presented in the next session.

13

2. Mechanism of Rainfall formation

14

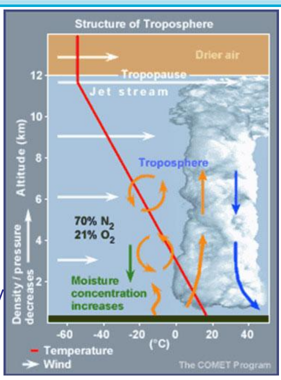
2.Mechanism of Rainfall formation



If water vapor is saturated, rain droplets are occurred.

Relative Humidity =100%

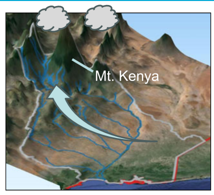
The hotter the air mass, the less rainfall and the more water vapor it can store.



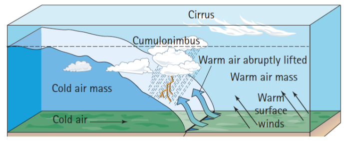
In the troposphere, the higher the altitude, the lower the temperature.
⇒ rain is more likely to occur If there is an **upward current with** much moisture.

15

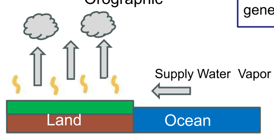
2.Mechanism of Rainfall formation /Examples of upward current



Orographic

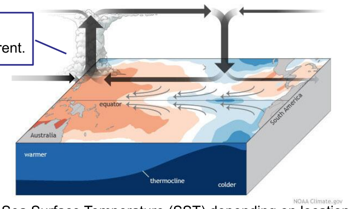


Boundaries between air masses with different properties



Difference between specific heat
(Land warms more easily)

Wind convergence generates upward current.



Differences in Sea Surface Temperature (SST) depending on location

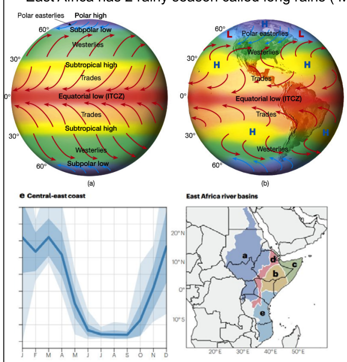
16

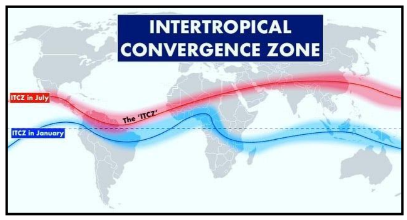
3. Climate Variability around Eastern Africa

17

3.Climate variability around Eastern Africa

East Africa has 2 rainy season called long rains (March, April, May) and short rains (October, November, December)





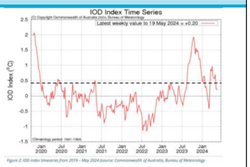
ITCZ moves
north during vernal equinox -summer solstice autumn equinox,
south during autumn equinox -winter solstice vernal equinox.

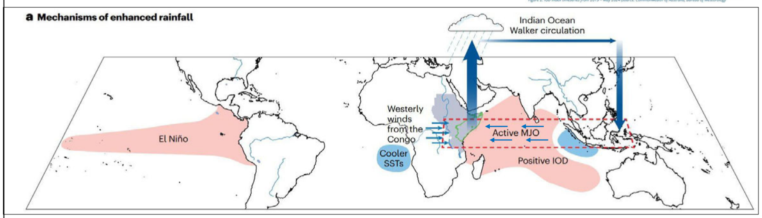
18

3.Climate variability around Eastern Africa/El Niño, La Niña and IOD

El Nino' s impact on Eastern Africa is mediated Indian Ocean Dipole(IOD).

The positive IOD (signifying an SST anomaly difference of at least +0.4°C for at least three months between the warmer west and cooler east) is linked with wetter **short rains** over Eastern Africa.

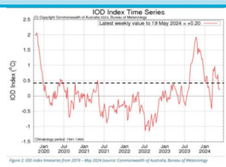


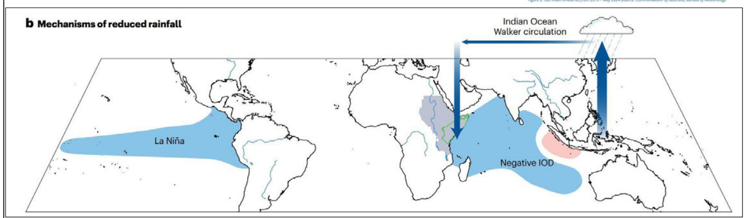


Source: Palmer et al., 2023

3.Climate variability around Eastern Africa/El Niño, La Niña and IOD

In contrast, the negative IOD (defined by a sustained negative SST difference at least 0.4℃) is associated with weaker **short rains.**

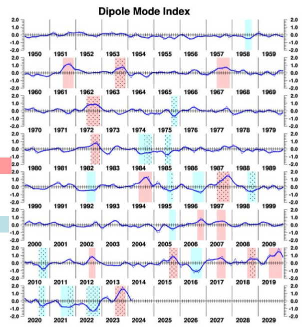


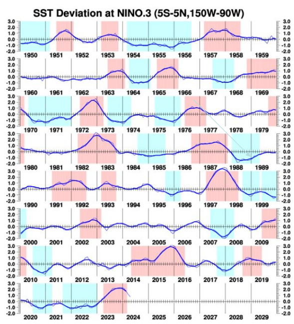


Source: Palmer et al., 2023

3.Climate variability around Eastern Africa / Index of IOD and El Nino

- Positive / Negative IOD occur later in the year.
- Positive/negative IOD tends to co - occur with El Nino/La Niña.

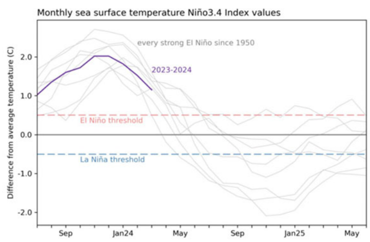




Source: JMA

3.Climate variability around Eastern Africa /April 2024 rain and After August 2024

- Some article says April 2024 rain was Jq2Snst2jsmfshji xjfxtsfqwfnsx3
- NOAA CPC indicate the El Nino condition is rapidly fading
- The probability of La Nina will increase to over 80 % from September, then continue at least the end of the year.



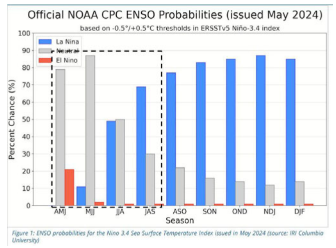
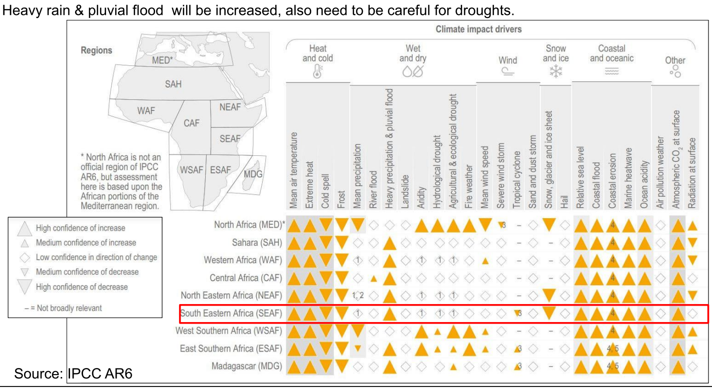


Figure 1: ENSO probabilities for the Nino 3.4 Sea Surface Temperature Index issued in May 2024 (source: IRI Columbia University)

4. Future Climate Risk

4.Future Climate Risk/ Projected change in climate impact drivers in Africa

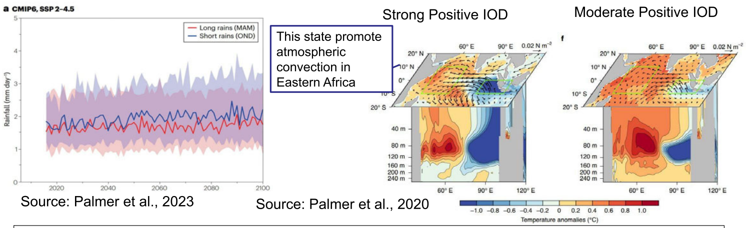
Heavy rain & pluvial flood will be increased, also need to be careful for droughts.



Source: IPCC AR6

4.Future Climate Risk/ Future Climate of Eastern Africa

Long Rains	No significant changes are projected for frequency and amplitude.
Short Rains	Projected to increase with global warming.
El Niño and La Niña IOD	No significant change are projected. On the other hand, an increased occurrence of **extreme** El Niño, La Niña and Positive IOD events is projected.



Source: Palmer et al., 2023

Source: Palmer et al., 2020

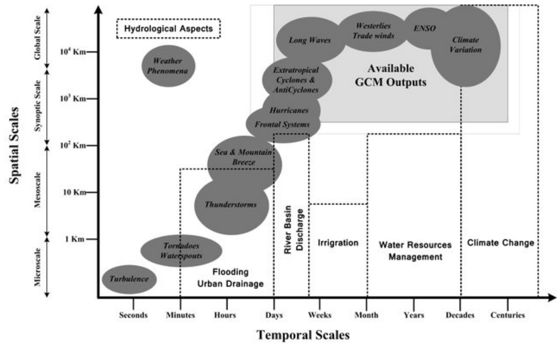
Increasing the chance of extreme rains is associated with a higher risk of flooding and the potential for groundwater recharge in Eastern Africa.

25

4.Future Climate Risk/ Climate Change Adaptation

For flood damage mitigation and water resources management of future climate, hydrological cycle analysis should be carried out for climate change adaptation.

However, to do this, high-resolution climate model output is necessary due to the relationship between horizontal-scale and timescale for rainfall related events.



Source: Nese and Grenci (2011)

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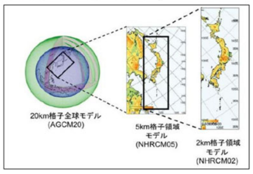
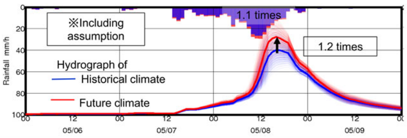
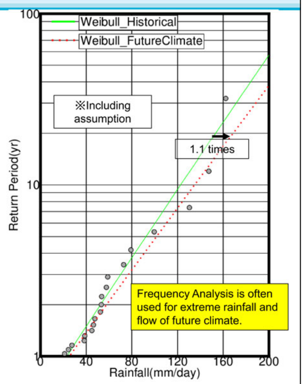
4.Future Climate Risk/Climate Change Adaptation

Japanese government analyzed downscaled climate model data(2-5km grid) and evaluated that extreme rain will be 1.1 times greater and its peak flow rate will be 1.2 times greater in the future climate (damage will be double as much as it is now).







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Summary

◆ April 2024 Flood

Some article says April 2024 rain was Jq8 nst2jsmfshji xjfxtsfqwfnsx3

◆ Mechanism of Rainfall

Upward current (+ Convergence) is the main factor of rainfall.

◆ Climate Variability

El Niño, La Nina and IOD influence the climate and rainfall variability of Eastern Africa.

◆ Future Climate

- No significant changes are projected for long rains, on the other hand short rains are projected to increase.
- In addition, **extreme** El Nino, La Nina and Positive IOD events is projected to increase.
- Increasing the chance of extreme rains is associated with a higher risk of flooding and the potential for groundwater recharge.

◆Hydrological cycle analysis for future climate adaptation

- Hydrological cycle analysis should be carried out.
- Frequency Analysis is often used for extreme rainfall and flow of future climate.
- To get a reliable information from frequency analysis for historical climate, long term reliable measurement data is essential.

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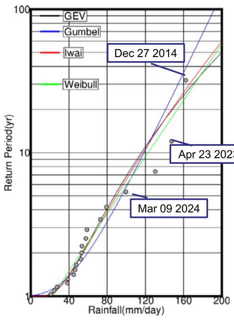
The procedure of annual maximum series (AMS) modelling for frequency analysis

1. Extract annual maximum data from long term measurement data
2. Estimate parameter (Scale parameter, location parameter, shape parameter, etc.) of extreme value distribution
3. Compare with Plotting Position
4. Select the best distribution, which has the closest tendency to Plotting Position.
5. Evaluate frequency analysis



1

Gumbel Distribution

$$F(x) = \exp\left[-\exp\left(-\frac{x-c}{a}\right)\right]$$

a: Scale Parameter
C: location Parameter

$$b_0 = \frac{1}{N}\sum_{j=1}^{N} x_{(j)} \qquad b_1 = \frac{1}{N(N-1)}\sum_{j=1}^{N}(j-1)x_{(j)}$$

j: order of order statistics(j = 1～N)
N: the number of order statistics

$$\lambda_1 = \beta_0 \qquad \lambda_2 = 2\beta_1 - \beta_0$$

$$\begin{cases} a = \lambda_2 / \ln 2 \\ c = \lambda_1 - 0.5772a \end{cases}$$

2

Weibull Distribution

$$F(x) = 1 - \exp\left[-\left(\frac{x-c}{a}\right)^k\right] \qquad (k \neq 0)$$

a: Scale Parameter
C: location Parameter
K: shape parameer

$$b_0 = \frac{1}{N}\sum_{j=1}^{N} x_{(j)} \qquad b_1 = \frac{1}{N(N-1)}\sum_{j=1}^{N}(j-1)x_{(j)} \qquad b_2 = \frac{1}{N(N-1)(N-2)}\sum_{j=1}^{N}(j-1)(j-2)x_{(j)}$$

$$\lambda_1 = \beta_0 \qquad \lambda_2 = 2\beta_1 - \beta_0 \qquad \lambda_3 = 6\beta_2 - 6\beta_1 + \beta_0$$

$$\begin{cases} k = 285.3\tau^6 - 658.6\tau^5 + 622.8\tau^4 - 317.2\tau^3 + 98.52\tau^2 - 21.256\tau + 3.5160 \\ a = \dfrac{\lambda_2}{(1-2^{-1/k}) \cdot \Gamma(1+1/k)} \\ c = \lambda_1 - a \cdot \Gamma(1+1/k) \end{cases}$$

where $\tau = \lambda_3 / \lambda_2$

Where Γ = Gumma Function

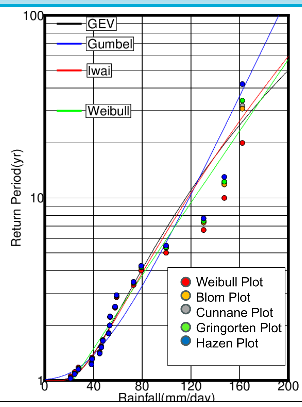
3

Plotting Position

$$F[x_{(i)}] = \frac{i - \alpha}{N + 1 - 2\alpha}$$

i: order of order statistics(i = 1～N)
N: the number of order statistics

公式名	Weibull	Blom	Cunnane	Gringorten	Hazen
α	0	0.375	0.40	0.44	0.5



4

Frequency analysis

JICA WATER ADVISOR TEAM

Presented to

WATER RESOURCES AUTHORITY
TANA BASIN REGIONAL OFFICE
10th June, 2024

FREQUENCY ANALYSIS

- Frequency analysis describes how often an event is likely to occur
- Runoff is a random variable thus the concept of frequency applies to runoff characteristics and rainfall characteristics
- The peak of the discharge hydrograph is an important design variable in hydrology e.g 100-yr peak discharge in their design work
- The frequency concept for runoff can be viewed in terms of either the *return period* or the *exceedance probability*
- Statistical frequency analysis is a commonly used procedure for the analysis of flood data at a gaged location

Frequency Analysis cont.

- Statistical theory is applied to analyze how often an event (flooding or low flows and drought) is likely to occur.
  - This technique is a statistical examination of the frequency–magnitude relationship
- The analysis attempts to place a probability on the likelihood of a certain event occurring.
- It is mainly concerned with the low-frequency, high-magnitude events (e.g. a large flood or a very low river flow).
- Flow duration curves **vs** frequency analysis.
  - **Flow duration curves** tell us the percentage of time that a flow is above or below a certain level. This is average data and describes the overall flow regime
  - **Flood frequency analysis** is concerned only with peak flows: the probability of a certain flood recurring.
  - **Low flow frequency analysis** is concerned purely with the lowest flows and the probability of them recurring

Flow Duration Curves

- **Flow Duration Curve (FDC)** - gives the percentage of time during which any selected discharge may be equaled or exceeded over a historical period.
- FDC represents the relationship between the magnitude and frequency of (daily, weekly, monthly, etc) streamflow for a particular river basin
- FDC provides a simple, yet comprehensive, graphical view of the overall historical variability associated with streamflow in a river basin
- FDC combines in one curve the flow characteristics of a stream throughout the range of discharge, without regard to the sequence of occurrence.
- If the period upon which the curve is based represents the long-term flow of a stream, the curve may be used to predict the distribution of future flows for water-supply, pollution studies, etc.

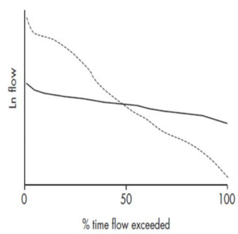
NB: FDC applies only to the period for which data were used to develop the curve or to the period to which the curve is adjusted

Characteristics of FDC

- Daily mean flow data is most commonly used: the average flow for each day
  - (**Note**: This is not the same as a mean daily flow, which is the average of a series of daily flows)
- To derive a flow duration curve the daily mean flow data are required for a long period of time
- The shape of the flow-duration curve gives a good indication of a catchment's characteristic response to its average rainfall history
  - An initially steeply sloped curve results from a very variable discharge, usually from small catchments with little storage where the stream flow reflects directly the rainfall pattern.
  - FDC with a very flat slope indicates little variation in flow regime, the result of the damping effects of large storages
- In the low-flow region:
  - an intermittent stream would exhibit periods of no flow,
  - a very flat curve indicates that moderate flows are sustained throughout the year due to natural or artificial streamflow regulation, or due to a large groundwater capacity that sustains the base flow to the stream

Interpreting a flow duration curve

- The shape of a flow duration curve can tell a lot about the hydrological regime of a catchment
- **Dotted line** - there is a large difference between the highest and lowest flow values, whereas, for the solid line, there is far less variation.
  - The catchment has far more variation. During dry periods it has a very low flow, but responds to rainfall events with a high flow. This is characteristic of impermeable upland catchments or streamflow in dryland areas
- **Solid line** -the catchment never has particularly low flows or particularly high flows.
  - This type of hydrological response is found in catchments where there is a high baseflow (groundwater-derived) and high infiltration rates during storm events.

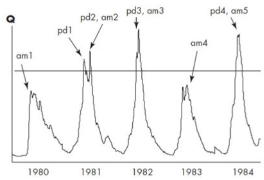


Statistics derived from a flow duration curve

- The flow value that is exceeded 95 percent of the time (*Q*95).
  - A useful statistic for low-flow analysis.
- The flow value that is exceeded 80 percent of the time (*Q80*).
  - A useful statistic for normal flow analysis
- The flow value that is exceeded 50 percent of the time (*Q*50).
  - This is the median flow value that indicates the flood flow criteria.
- The flow value that is exceeded 10 percent of the time (*Q*10).
  - A useful statistic for analysis of high flows and flooding.

FLOOD FREQUENCY ANALYSIS

- Flood frequency analysis is concerned with peak flows.
- There are two different ways that a peak flow can be defined:
  - the single maximum peak within a year of record giving an **annual maximum series**;
  - any flow above a certain threshold value, giving a **partial duration series**.



Flood frequency analysis cont.

Challenges when using either data series in flood frequency analysis

- Annual maximum may miss a large storm event where it occurs more than once during a year but it does provide a continuous series of data that are relatively easy to process.
- The setting of a threshold storm is critical in the analysis of the partial duration series - requires considerable experience to get right
- If the data series is longer than ten years then the annual maxima can be used; for very short periods of record the partial duration series can be used
- The first step in carrying out flood frequency analysis is to obtain the data series (in this case annual maxima). The annual maximum series should be for as long as the data record allows.
  - The greater the length of the record the more certainty can be attached to the prediction of the average recurrence interval.
- **Assumption:** The peak flows in flood frequency analysis are independent of each other

Flood frequency analysis cont.

- It is important to grasp the significance of the non-normal distribution for two reasons:
  - Common statistical techniques that require normally distributed data (e.g. t-tests etc.) cannot be applied in flood frequency analysis.
  - It shows what you might expect: small events are more common than large floods, but very large flood events do occur; i.e. a high magnitude, low-frequency relationship.
- NB: Most hydrological datasets are not normally distributed (i.e. it is not a classic bell-shaped curve).

Flood frequency analysis cont.

- Terms used in flood frequency analysis
  - Probability of excedence: *P*(*X*). This is the probability that a flow (*Q*) is greater than, or equal to a value *X*. The probability is normally expressed as a unitary percentage (i.e. on a scale between 0 and 1).
  - The relative frequency: *F*(*X*). The probability of the flow (*Q*) being less than a value *X*. This is also expressed as a unitary percentage.
  - The average recurrence interval: *T*(*X*) or return period is a statistical term meaning the chance of excedence once every *T*-years over a long record. This should not be interpreted as meaning that is exactly how many years are likely between certain size floods.
- NB: These terms are interrelated mathematically

Methods to determine flood frequency analyses

Plotting position formula - Weibull formula

- The first step is to rank the annual maximum series data from low to high.

  Assumption: Each data point (i.e. the maximum flood event for a particular year) is independent of any others (year the flood occurred in becomes irrelevant).

- Step Two: Calculate the Probability *F*(*X*) term using

$$F(X) = \frac{r}{N+1}$$

  - *r* is the rank of an individual flood event (*X*) within the data series and
  - *N* is the total number of data points (i.e. the number of years of record)

Methods to determine flood frequency analyses cont.

- In applying this formula:
  - The value of *F*(*X*) can never reach 1 (i.e. it is asymptotic towards the value 1).
  - If you rank your data from high to low (i.e. the other way around) then you will be calculating the *P*(*X*) value rather than *F*(*X*). This is easily rectified by using the formula linking the two

NB

  - The Weibull formula is simple to use and effective but is not always the best description of an annual maximum series data.
  - The probabilities derived from the Weibull formulae give a good description of the flood frequency within the measured stream record but do not provide enough data when you need to extrapolate beyond a known time series

Methods for fitting hydrological distributions

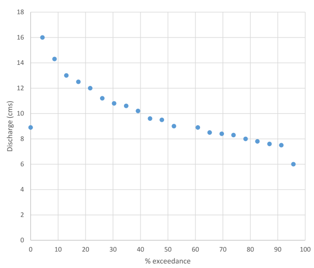
Frequently used distributions in hydrology

- Gumbel distribution
- Log-Pearson Type III
- Log-normal

- The choice of distribution is often based on:
  - personal preference
  - distribution that best fits flow regimes for a particular region

Worked example

Plotting position	Discharge (cumecs)	P =m/n+1	Return period T=1/P
1	16	0.043	23
2	14.3	0.087	11.5
3	13	0.13	7.67
4	12.5	0.174	5.75
5	12	0.217	4.6
6	11.2	0.261	3.83
7	10.8	0.304	3.29
8	10.6	0.348	2.88
9	10.2	0.391	2.56
10	9.6	0.435	2.3
11	9.5	0.478	2.09
12	9	0.522	1.92
13	8.9		
14	8.9	0.609	1.64
15	8.5	0.652	1.53
16	8.4	0.696	1.44
17	8.3	0.739	1.35
18	8	0.783	1.28
19	7.8	0.826	1.21
20	7.6	0.87	1.15
21	7.5	0.913	1.1
22	6	0.957	1.05



LOW FLOW FREQUENCY ANALYSIS

- Low Flow Frequency Analysis (LFFA) is a stochastic approach for characterizing low flow events.
- The aim is to quantify the likelihood that the flow at a particular site will persist below a particular level over a particular duration.
- LFFA is typically utilized where a single statistic or index e.g. Q95 is insufficient to describe the low flow regime.
- LFFA provides a means to quantify the flow-duration-frequency behaviour of the site of interest.
- Individual low flows events can be delineated by considering periods where the flow falls below a threshold level.
- Normally, a D-day average discharge per year is considered.
- Low flow characteristics provide threshold values for different water-based activities and is required for such water resource management issues e.g. water allocation for water supply, irrigation etc.

Low flow frequency analysis cont.

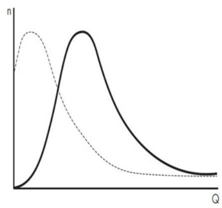
- Annual minimum series is derived from a time series for low flows

Challenge:

  - Which annual year should be used when you have to assume that the annual minimum flows are independent of each other analysis of when low flows occur needs to be carried

NB: There is a finite limit on how low a flow can be setting the difference between flood frequency and low flow frequency analysis

- In theory, a flood can be of infinite size, whereas it is not possible for a low flow to be less than zero (negative flows should not exist in freshwater hydrology).
- This places a limit on the shape of a probability distribution, effectively truncating it on the left-hand side



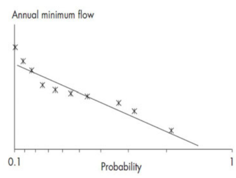
Low flow frequency analysis cont.

- Statistical techniques described for flood frequency analysis assume a full log-normal distribution and cannot be easily applied for low flows.

NB:

  - Probabilities calculated from the Weibull formula are plotted against the annual minimum flow values.
  - The data fit a straight line, but if we extrapolate the line further it would intersect the x-axis at a value of approximately 0.95.

- Implication - there is a 5 percent chance of having a flow less than zero (i.e. a negative flow).
- The way around
  - Fit an exponential rather than a straight line to the data. This is easy to do by eye but complicated mathematically.



Limitations of frequency analysis

- The estimation technique is only as good as the streamflow records that it is derived from. Where the records are short or of dubious quality very little of worth can be achieved through frequency analysis.
- Do not extrapolate average recurrence intervals beyond twice the length of your data set since very large floods can create problems for flow gauges and therefore this extreme data may be of dubious quality
- The assumption is made that each storm or low flow event is independent of another used in the data set. This is relatively easy to guard against in annual maximum (or minimum) series, but more difficult for a peak threshold series.
- There is an inherent assumption made that the hydrological regime remains static during the complete period of record. This may not be true where land use, or climate change, has occurred in the catchment

Hands on exercise

END

Thank you for listening

Kenya WATER RESOURCES ADVISORS PROJECT

PROGRAM OF

TRAINING SESSION FOR FREQUENCY ANALYSIS OF RAINFALL and DISCHARGE

June 10, 2024

IN EMBU

Date	Schedule	Participants
JUNE 1O, 2024 (MONDAY)		
10:00 – 11:00 AM	**Rainfall Pattern, Hydrological cycle characteristics, and projected climate change impacts around Upper Tana Basin** • Presentation using satellite-based rainfall dataset and reviewing related articles.	Participants- WRA Surface Water Officers of Embu, Muranga, Kerugoya, and Meru JICA Expert Team Y.OKada
11:00 – 11:15 AM	**Tea Break**	All
11:15 – 11:45 AM	**Method of Computing Frequency Analysis** • Explanation of the Calculation Sheet	Participants- WRA Surface Water Officers of Embu, Muranga, Kerugoya, and Meru JICA Expert Team Y.Okada, Masika
11:45 – 1:00 PM	**Exercise of Computing Frequency Analysis for Rainfall** • Exercises using Calculation Sheet with MS Excel	All
1:00 - 2:00 PM	**Lunch Break**	All
2:00-3:15 PM	**Exercise of Computing Frequency Analysis for high flow and low flow**	All
3:15 -3:20 PM	**Short Break**	All
3:20-3:50 PM	**Discussion for** • Discharge Measurement • Mitigation Measures for Extreme Events (Flood and Drought) , etc.	Participants- WRA Surface Water Officers of Embu, Muranga, Kerugoya, and Meru JICA Expert Team T. Okamura
3:50- 4:00 PM	**Closing Remarks from Tana Basin Area Coordinator**	All

Note: All the participants should bring their Laptops with MS Excel to participate in the sessions.

Kenya Water Resources Advisors Project

Training Session for Frequency Analysis of Rainfall and flow

Rainfall Pattern, Hydrological cycle characteristics, and projected climate change impacts around Tana Basin

1. Outline of April 2024 Flood
2. Mechanism of Rainfall
3. Climate variability around Eastern Africa
4. Future climate risk

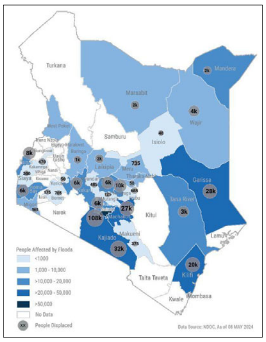
Yuki OKADA
Hydrological Monitoring/
Flood and Drought Risk Assessment

1

1.Outline of April 2024 Flood

2

1.Outline of April 2024 Flood/Damage Situation of April Flood（as of 10 May 2024）



Source: OCHA

Source: Kenya Red Cross

1.Outline of April 2024 Flood/ Main Flood Event

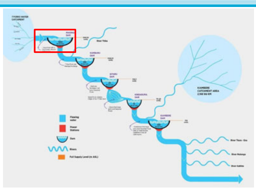
Heavy Flood Advisory was issued on 9th April

It is assumed main flood event occurred during 4-9, 11-16, 27-29th April

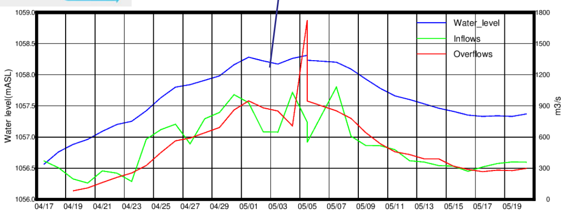
NO	DATE	TITLE	AREA	DAMAGE
43	4th April 2024	Mwea Residents Left Homeless After River Thiba Broke Its	Mwea- Kirinyaga County	Houses destroyed and swept away, hectares of crops washed away
44	8th April 2024	KeNHA closes Nairobi-Garissa Road due to flooding at Mororo	Mororo- Tana River	Road impassable due to flooding
45	9th April 2024	Hundreds stranded as floods wreak havoc along Garissa-	Tula and Arer area Bangale sub-county in Tana River	Road network cut off and transport paralyzed due to flooding
46	9th April 2024	51 passengers narrowly escape death as bus is swept by floods	Lager Areli- Garissa County	Death related risks
47	11th April 2024	Kenya: Heavy Rains and Flooding Update - Flash Update	Marsabit, Turkana, Tana River, Garissa, Kirinyaga, Muranga, Kiambu,	3000 households displaced, 339 livestock killed, unknown acres of croplands lost
48	12th April 2024	Red Cross: At least 323 households affected by heavy	Thiba in Mwea West Kirinyaga County	323 households displaced
49	15th April 2024	Two killed as floods wreak havoc in Tana River	Tana North	Loss of lives, families displaced
50	16th April 2024	Over 100 Families Flee Homes As Floods Rock Kirinyaga	Ngurubani in Mwea Kirinyaga County	Over 100 families displaced
51	27th April 2024	Garissa faces supplies shortage as floods cut off roads network	Garissa-Madogo Highway	Supply shortage of basic commodities
52	28th April 2024	23 People Missing As Boat Capsizes In Tana River	Madogo - Tana River	23 people missing,
53	29th April 2024	Hundreds displaced in Garissa and Mororo, Tana River as floods	Garissa and Tana River Counties	Houses sub-merged &Families displaced, road network destroyed, property destroyed
54	29th April 2024	Floods Continue To Wreak Havoc In Garissa	Bulla punda, Kamor, Sheikh, vumbi, Windsor, Bulla nyuki - in Garissa	Houses submerged and families displaced

4

1.Outline of April 2024 Flood/ 7 Forks Dams/Masinga



KenGen sounds warning as Masinga Dam water levels hit record high. Masinga Dam. The water level at the dam was recorded at 1,058.28 metres above sea level on May 1, 2024, against a full supply level of 1,056.50 metres.



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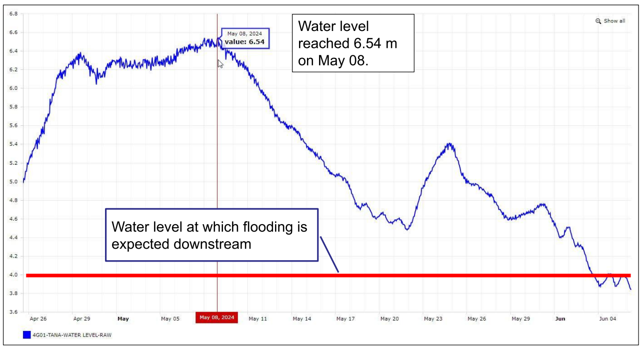
1.Outline of April 2024 Flood/ Water level of 4G01 Garissa

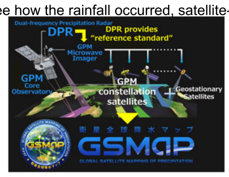


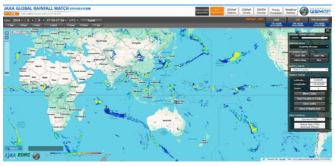
Source: MIKE INFO, WRA

6

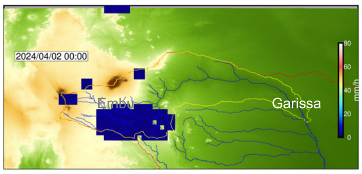
1.Outline of April 2024 Flood/ Rainfall analysis using GSMaP

To see how the rainfall occurred, satellite-based rainfall data was visualized.



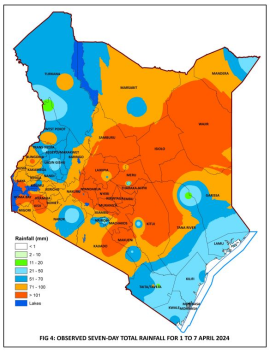


Description of rainfall data	
Variable	Rain Rate (mm/hr)
Domain	60N-60S
Grid Resolution	0.1 degree latitude/longitude
Temporal Resolution	1 hour
Availability	1998-01-01T00:00 ~

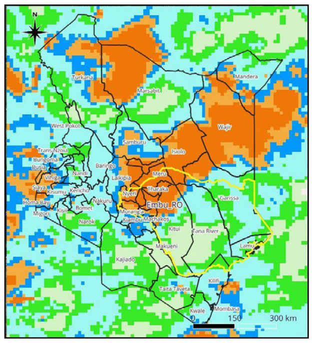


7

1.Outline of April 2024 Flood/ Estimated Rainfall Distribution for 1 to 7 April 2024



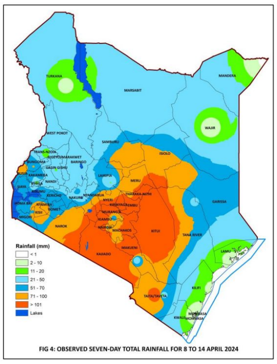
Source: KMD (spatially interpolate rain-gauge data)



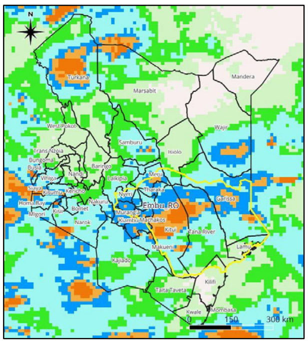
Source: JICA Expert team based on GSMaP_MVK

8

1.Outline of April 2024 Flood/ Estimated Rainfall Distribution for 8 to 14 April 2024



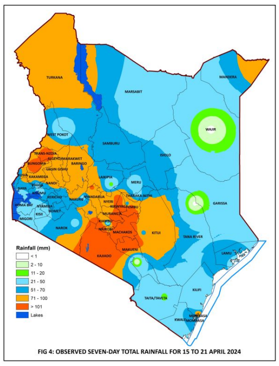
Source: KMD



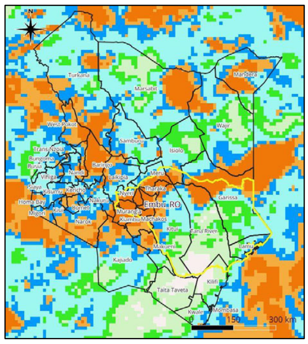
Source: JICA Expert team based on GSMaP_MVK

9

1.Outline of April 2024 Flood/ Estimated Rainfall Distribution for 15 to 21 April 2024



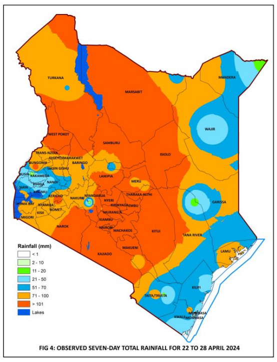
Source: KMD



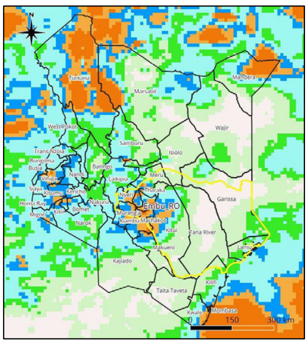
Source: JICA Expert team based on GSMaP_MVK

10

1.Outline of April 2024 Flood/ Estimated Rainfall Distribution for 22 to 28 April 2024



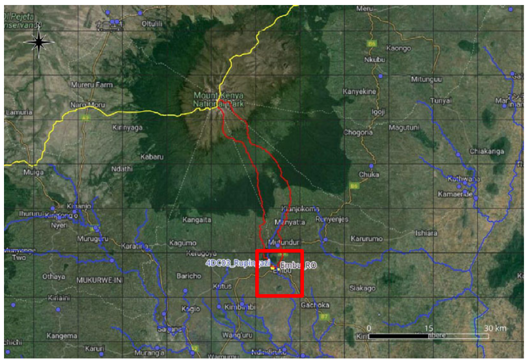
Source: KMD



Source: JICA Expert team based on GSMaP_MVK

11

1.Outline of April 2024 Flood/ Frequency Analysis using GSMaP rainfall around Embu Regional Office



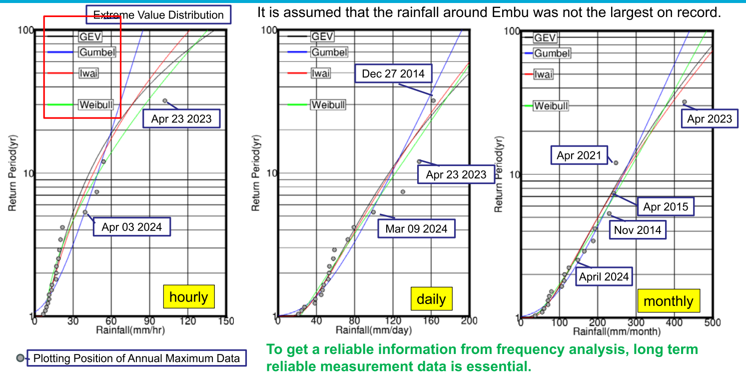
To evaluate the scale of April 2024 rain compared to previous rains, **Frequency Analysis** ※ was carried out.

※ Detailed methods will be presented in the next session.

12

1.Outline of April 2024 Flood/ Frequency Analysis using GSMaP rainfall around Embu Regional Office

It is assumed that the rainfall around Embu was not the largest on record.



To get a reliable information from frequency analysis, long term reliable measurement data is essential.

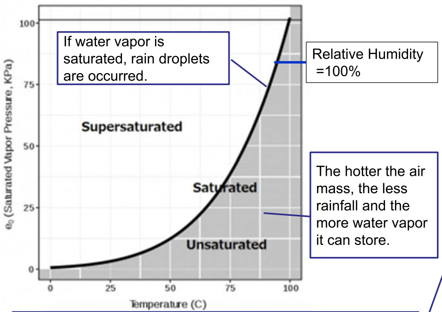
※ Detailed methods will be presented in the next session.

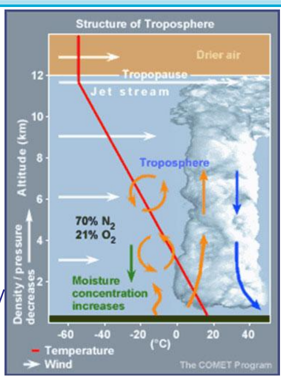
13

2. Mechanism of Rainfall formation

14

2.Mechanism of Rainfall formation





In the troposphere, the higher the altitude, the lower the temperature.
⇒ rain is more likely to occur If there is an **upward current with** much moisture.

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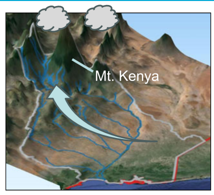
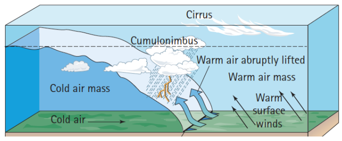
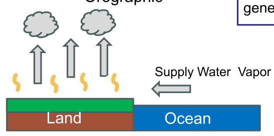
2.Mechanism of Rainfall formation /Examples of upward current



Orographic

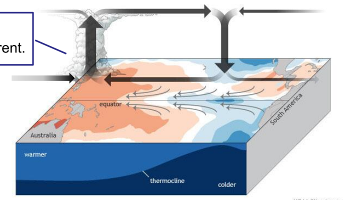


Boundaries between air masses with different properties



Difference between specific heat
(Land warms more easily)

Wind convergence generates upward current.



Differences in Sea Surface Temperature (SST) depending on location

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3. Climate Variability around Eastern Africa

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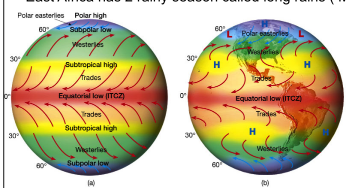
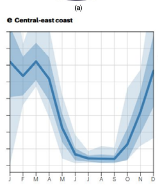
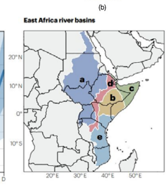
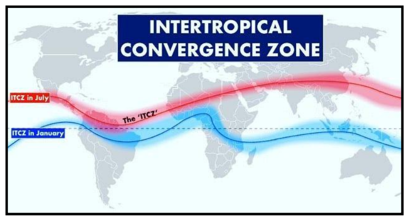
3.Climate variability around Eastern Africa

East Africa has 2 rainy season called long rains (March, April, May) and short rains (October, November, December)









ITCZ moves
north during vernal equinox -summer solstice autumn equinox,
south during autumn equinox -winter solstice vernal equinox.

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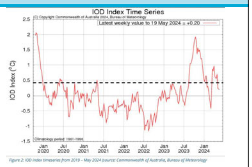
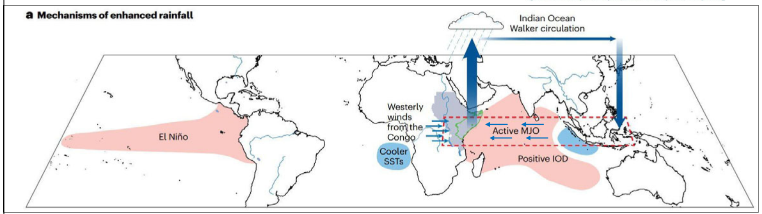
3.Climate variability around Eastern Africa/El Niño, La Niña and IOD

El Nino' s impact on Eastern Africa is mediated Indian Ocean Dipole(IOD).

The positive IOD (signifying an SST anomaly difference of at least +0.4° C for at least three months between the warmer west and cooler east) is linked with wetter **short rains** over Eastern Africa.





Source: Palmer et al., 2023

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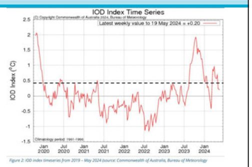
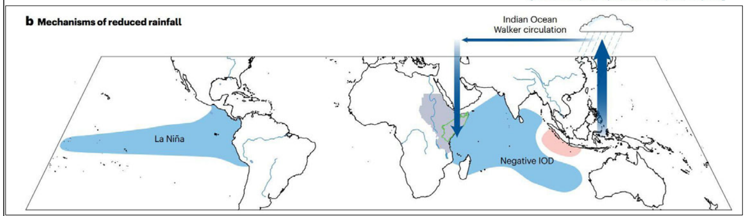
3.Climate variability around Eastern Africa/El Niño, La Niña and IOD

In contrast, the negative IOD (defined by a sustained negative SST difference at least 0.4℃) is associated with weaker **short rains.**





Source: Palmer et al., 2023

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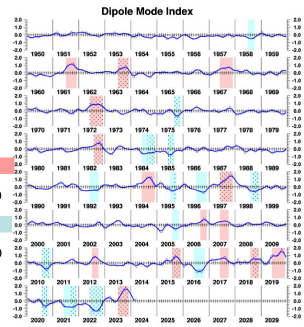
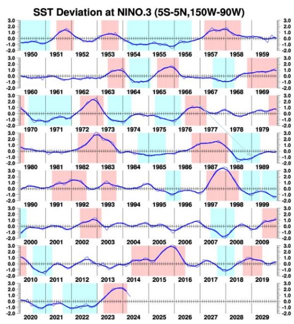
3.Climate variability around Eastern Africa / Index of IOD and El Nino

- Positive / Negative IOD occur later in the year.
- Positive/negative IOD tends to co - occur with El Nino/La Niña.

P IOD

N IOD





El Nino

La Niña

Source: JMA

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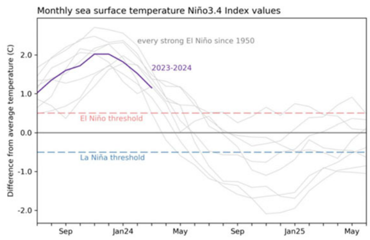
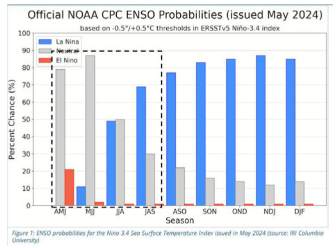
3.Climate variability around Eastern Africa /April 2024 rain and After August 2024

- Some article says April 2024 rain was Jq2Snst2jsmfshji xjfxtsfqwfnsx3
- NOAA CPC indicate the El Nino condition is rapidly fading
- The probability of La Nina will increase to over 80 % from September, then continue at least the end of the year.





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4. Future Climate Risk

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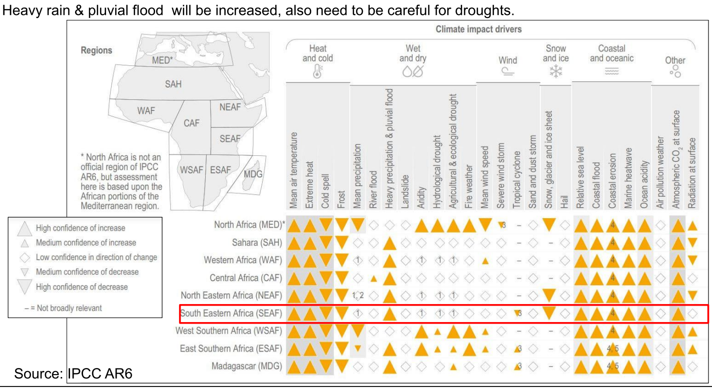
4.Future Climate Risk/ Projected change in climate impact drivers in Africa

Heavy rain & pluvial flood will be increased, also need to be careful for droughts.



Source: IPCC AR6

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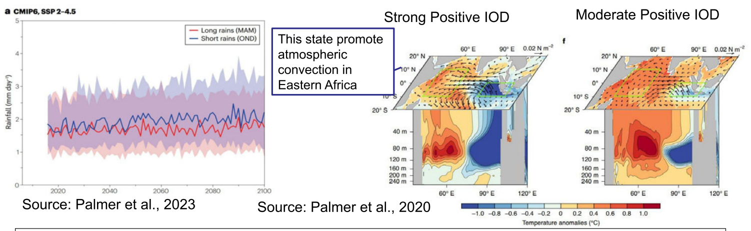
4.Future Climate Risk/ Future Climate of Eastern Africa

Long Rains	No significant changes are projected for frequency and amplitude.
Short Rains	Projected to increase with global warming.
El Niño and La Niña IOD	No significant change are projected. On the other hand, an increased occurrence of **extreme** El Niño, La Niña and Positive IOD events is projected.



Source: Palmer et al., 2023 Source: Palmer et al., 2020

Increasing the chance of extreme rains is associated with a higher risk of flooding and the potential for groundwater recharge in Eastern Africa.

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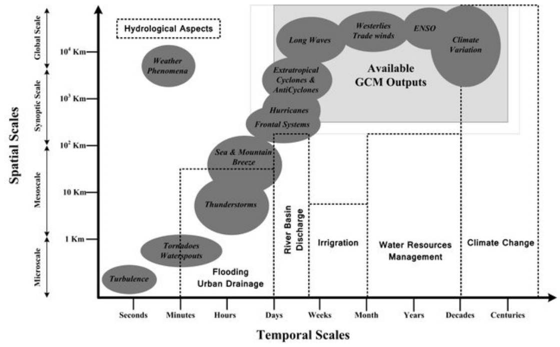
4.Future Climate Risk/ Climate Change Adaptation

For flood damage mitigation and water resources management of future climate, hydrological cycle analysis should be carried out for climate change adaptation.

However, to do this, high-resolution climate model output is necessary due to the relationship between horizontal-scale and timescale for rainfall related events.



Source: Nese and Grenci (2011)

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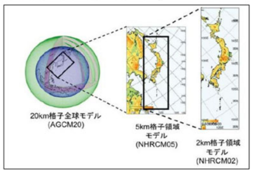
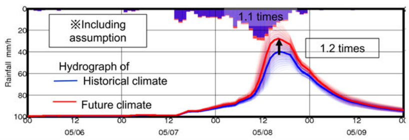
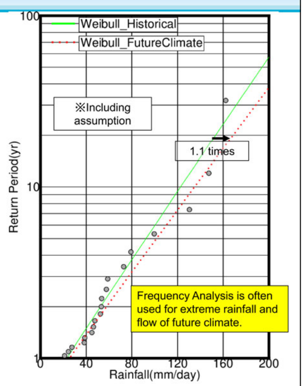
4.Future Climate Risk/Climate Change Adaptation

Japanese government analyzed downscaled climate model data(2-5km grid) and evaluated that extreme rain will be **1.1** times greater and its peak flow rate will be **1.2** times greater in the future climate (damage will be **double** as much as it is now).







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Summary

◆ <u>April 2024 Flood</u>
Some article says April 2024 rain was Jq2Srst2jsmfshji xjfxtsfqwfnsx3

◆ <u>Mechanism of Rainfall</u>
Upward current (+ Convergence) is the main factor of rainfall.

◆ Climate Variability
El Niño, La Nina and IOD influence the climate and rainfall variability of Eastern Africa.

◆ <u>Future Climate</u>
- No significant changes are projected for long rains, on the other hand short rains are projected to increase.
- In addition, **extreme** El Nino, La Nina and Positive IOD events is projected to increase.
- Increasing the chance of extreme rains is associated with a higher risk of flooding and the potential for groundwater recharge.

◆<u>Hydrological cycle analysis for future climate adaptation</u>
- Hydrological cycle analysis should be carried out.
- Frequency Analysis is often used for extreme rainfall and flow of future climate.
- To get a reliable information from frequency analysis for historical climate, long term reliable measurement data is essential.

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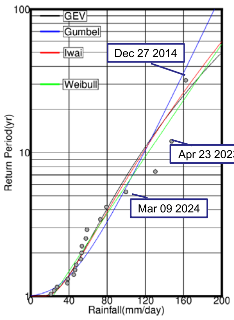
The procedure of annual maximum series（AMS）modelling for frequency analysis

1. Extract annual maximum data from long term measurement data
2. Estimate parameter (Scale parameter, location parameter, shape parameter, etc.) of extreme value distribution
3. Compare with Plotting Position
4. Select the best distribution, which has the closest tendency to Plotting Position.
5. Evaluate frequency analysis



1

Gumbel Distribution

$$F(x) = \exp\left[-\exp\left(-\frac{x-c}{a}\right)\right]$$

a： Scale Parameter
C: location Parameter

$$b_0 = \frac{1}{N}\sum_{j=1}^{N} x_{(j)} \qquad b_1 = \frac{1}{N(N-1)}\sum_{j=1}^{N}(j-1)x_{(j)}$$

j: order of order statistics(j = 1～N)
N: the number of order statistics

$$\lambda_1 = \beta_0 \qquad \lambda_2 = 2\beta_1 - \beta_0$$

$$\begin{cases} a = \lambda_2/\ln 2 \\ c = \lambda_1 - 0.5772a \end{cases}$$

2

Weibull Distribution

$$F(x) = 1 - \exp\left[-\left(\frac{x-c}{a}\right)^k\right] \qquad (k \neq 0)$$

a： Scale Parameter
C: location Parameter
K: shape parameer

$$b_0 = \frac{1}{N}\sum_{j=1}^{N} x_{(j)} \qquad b_1 = \frac{1}{N(N-1)}\sum_{j=1}^{N}(j-1)x_{(j)} \qquad b_2 = \frac{1}{N(N-1)(N-2)}\sum_{j=1}^{N}(j-1)(j-2)x_{(j)}$$

$$\lambda_1 = \beta_0 \qquad \lambda_2 = 2\beta_1 - \beta_0 \qquad \lambda_3 = 6\beta_2 - 6\beta_1 + \beta_0$$

$$\begin{cases} k = 285.3\tau^6 - 658.6\tau^5 + 622.8\tau^4 - 317.2\tau^3 + 98.52\tau^2 - 21.256\tau + 3.5160 \\ a = \dfrac{\lambda_2}{(1-2^{-1/k})\cdot\Gamma(1+1/k)} \\ c = \lambda_1 - a\cdot\Gamma(1+1/k) \end{cases}$$

where $\tau = \lambda_3/\lambda_2$

Where Γ = Gumma Function

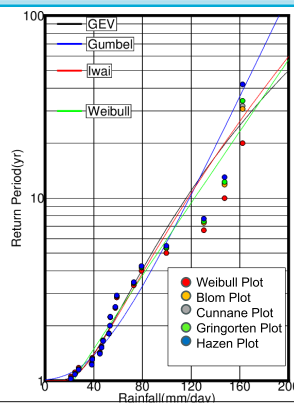
3

Plotting Position

$$F[x_{(i)}] = \frac{i-\alpha}{N+1-2\alpha}$$

i: order of order statistics(i = 1～N)
N: the number of order statistics

公式名	Weibull	Blom	Cunnane	Gringorten	Hazen
α	0	0.375	0.40	0.44	0.5



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