4th Global DWAT (Dynamic Water resources Assessment Tool) Workshop

REPORT

Vientiane, Laos

3 to 4 November 2022

1. Opening

1.1 The 4th DWAT (Dynamic Water resources Assessment Tool) workshop, which was organized and financially supported by the Ministry of Environment of Korea, was held in Vientiane, Laos on November 3 and 4, 2022, jointly with the Korea Institute of Civil Engineering and Building Technology (KICT) and the World Meteorological Organization (WMO).

1.2 The opening of the meeting took place on November 3, 2022, at 13:30. The purpose of the workshop was to identify the outcomes of DWAT applications and to receive feedback from WMO regional experts on progress of improvement of the latest version of DWAT. In addition, potential improvements of DWAT were discussed and recommendations were documented during the workshop.

1.3 The director of Nakdong River Flood Control Office Hyo Seob Cho and Korean officials welcomed the participants to the workshop. Director Hyo Seob Cho suggested that DWAT can be used to help manage water resources, support policy experts, and identify current and future problems. He also highlighted that the dissemination of DWAT enabled the assessment of water resources and operations in the 192 WMO member states. He mentioned that the Republic of Korea has high expectation that this DWAT workshop would be a meaningful opportunity to upgrade the functions of DWAT.

1.4 Dr. Hyeonjun Kim, the developer of DWAT and vice-president of Research at KICT, welcomed the participants from to the 4th DWAT workshop and expressed his aspiration that the workshop would serve as an opportunity to share outcomes of DWAT applications, share DWAT experiences and discuss future directions.

1.5 Dr. Hwirin Kim, Head of Hydrology and Water Resources Division (HWR), WMO, expressed gratitude to Director of Nakdong River Flood Control Office Hyo Seob Cho, and Dr. Hyeonjun Kim, and welcomed the participants from Korea and other countries to the 4th DWAT workshop on behalf of Professor Petteri Taalas. Dr. Hwirin Kim showed gratitude for Korea's role in developing DWAT and supporting the workshop. She also proposed to provide an easier tutorial for DWAT so that it can be more widely used in the future. In this context, she expressed her expectations that this would help expand the use of DWAT to other various sub-regions of Asia, such as Central Asia and Cambodia and Laos. Lastly, she wished the 4th DWAT workshop a big success.

2. Introduction of participants and workshop program

2.1 Participants introduced themselves. 24 participants from 8 countries and 3 WMO officials attended the workshop physically. Some of the invited experts participated remotely. The list of participants is included in Appendix 1. Additionally, All presentations from this Workshop are available on the 4th DWAT Workshop website.

2.2 Dr. Manshin Han, of the Han River Flood Control Office, gave an introduction to the DWAT workshop. He explained the progress of the previous 3 workshops and introduced the program of the 4th DWAT workshop (See Appendix 2). Participants were looking forward to sharing their opinions on the various aspects of the advancement of DWAT. Dr Han also mentioned that, prior to the Workshop, the experts were provided the DWAT software and training materials (available on the DWAT website) and had a couple of technical sessions with the DWAT team to address questions and comments.

3. Management and assessment of water resources

3.1 Dr, Hwirin Kim gave a presentation on the need and requirements of water resources assessment. In addition, she introduced [Water Resources Assessment web portal](). She mentioned that this portal collects a large amount of guidance data and tools for water resources assessments and will be updated to share various relevant materials, know-hows, and case studies on water resources assessment.

<Screenshot from WMO Water Resources Assessment web portal>

3.2 Dr. Cheolhee Jang from KICT gave an overview of DWAT and its development. In addition, he explained various functions of DWAT including applications on rice paddies and snowmelt and asked the participants for their interests on DWAT and active participation in expressing their opinions. Dr. Hwirin Kim noted that the quality of the data is often poor in most regions, and it is challenging to ensure the quality of the input data when using DWAT. Dr Hyo Seob Cho said the typhoon committee is developing a standardized hydrological data quality control system which will be available from next year. He said that the system is expected to create synergy with DWAT since it will be provided online and offline. Moreover, Dr. Hwirin Kim also mentioned that
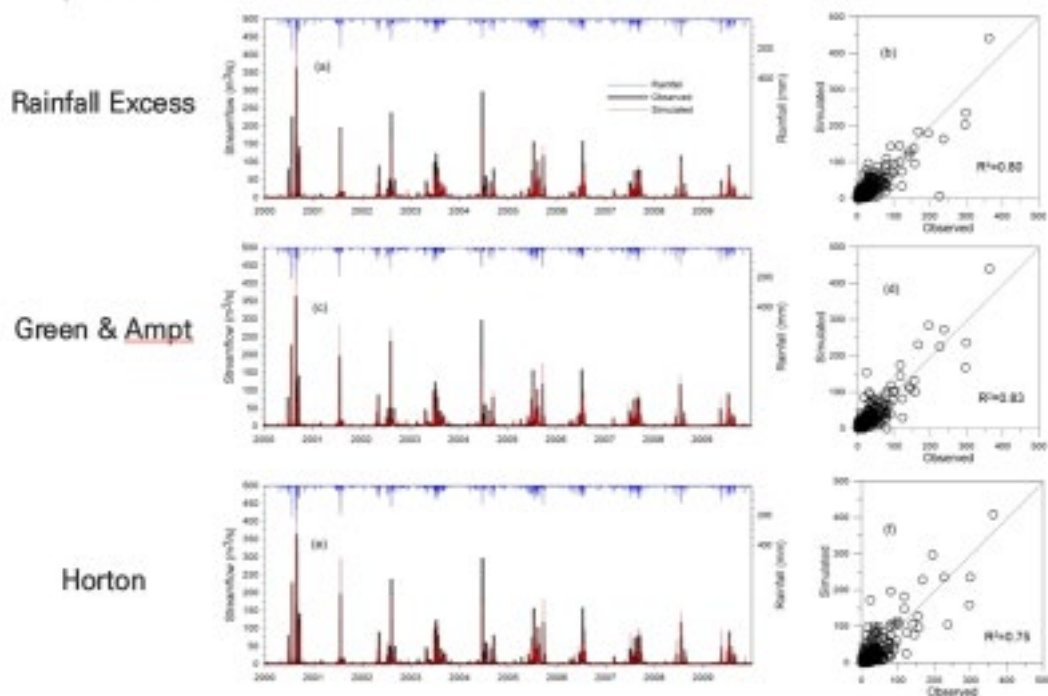
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it is necessary to consider using the data on unmeasured basins provided by NOAA and GOOGLE to carry out simulations on those areas.

3.3 Dr. Deokhwan Kim from KICT introduced various cases of DWAT application in drought and flood analysis in regions of Korea. His presentation was divided into two parts; how DWAT is applied in drought and flood analysis. Firstly, for the drought study, he presented the comparison of infiltration methodologies, using the SCE-UA method-an automatic calibration technique-for Boryeong Dam basin in Korea. Good results were identified for Rainfall Excess and Green&Ampt in this case.

<Comparison of simulated streamflow based on infiltration methodology>
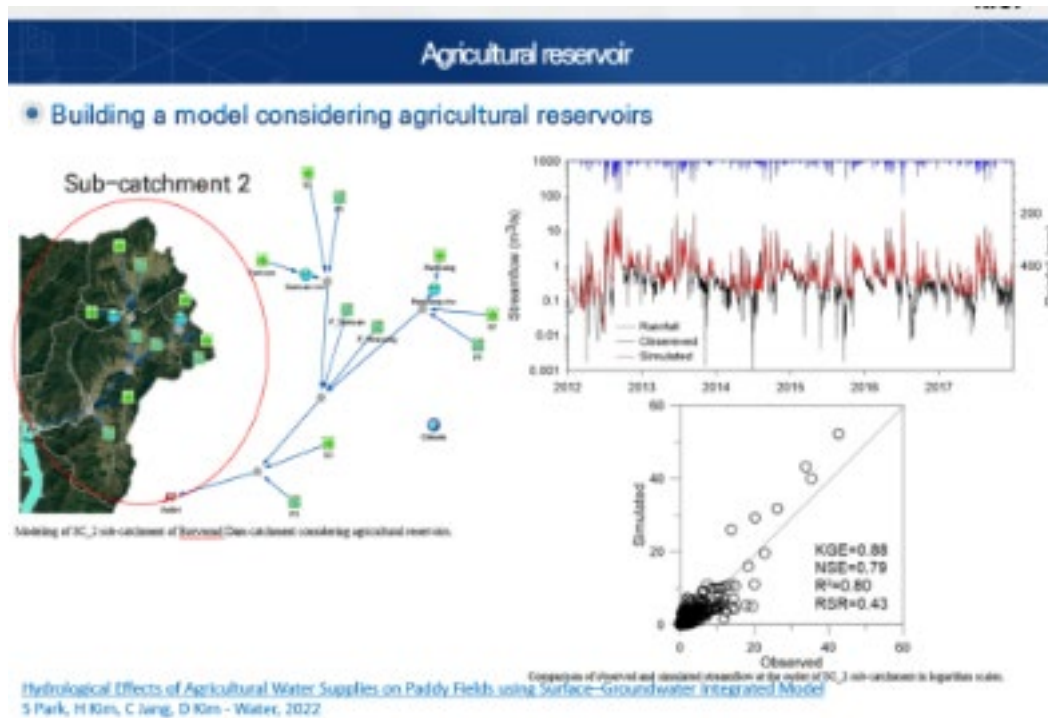
The second drought study looked at the effects of groundwater pumping on hydrological response, and the third case showed results of reflecting agricultural reservoirs for irrigation.

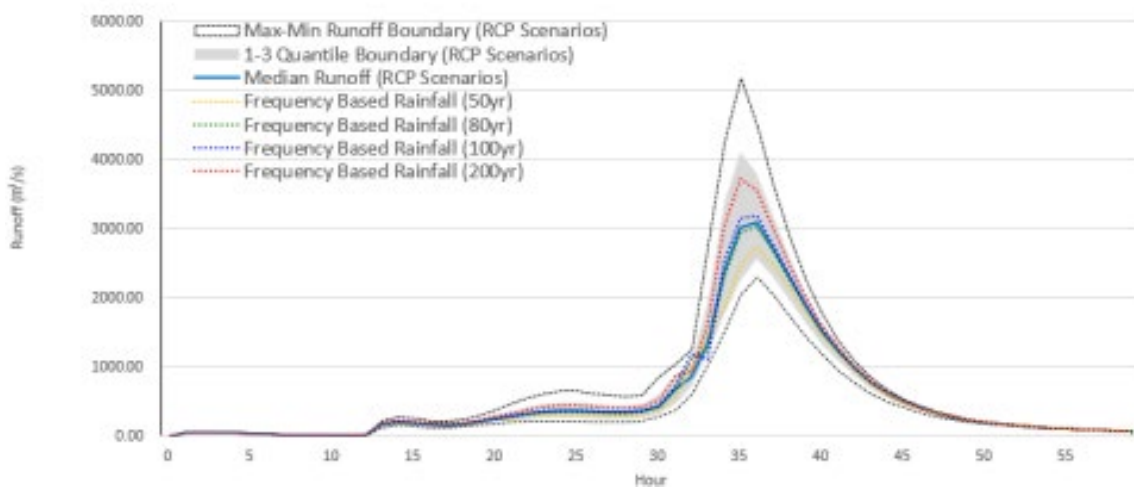<Results from model considering agricultural reservoirs>

For flood analysis, he presented a case where climate change scenario is applied. A model was built for Suncheon Dongcheon basin and an analysis was conducted for flood runoff according to climate change scenario. Design flood according to climate change was presented through this.

<Design flood according to climate change scenario>

3.4 Dr. Hyo Seob Cho asked if there were any cases of DWAT that considered snowmelt, and Dr. Hyeonjun Kim answered that there is no case of applying snowmelt since the impact of snowmelt is not significant in Korea. Dr. Yuri Simonov explained that there was a case from the 2nd DWAT workshop where snowmelt had been applied, though the result was not successful. He mentioned that the snowmelt mechanism of DWAT is in the process of improvement. Dr. Marcelo Uriburu asked why the Horton equation for infiltration from the DWAT cases presented by Dr. Deokhwan Kim did not consider declining constant for the calibration. Dr. Cheolhee Jang, the developer of DWAT, explained that the Horton equations applied to DWAT do not consider declining constant. Dr. Hyeonjun Kim added that the depth of the soil layer was considered for calibration in this case. Dr. Hwirin Kim from WMO Secretariat asked if DWAT could be used for flood prediction. Dr. Hyeonjun Kim answered that DWAT can also be used for real-time flood prediction as the simulation intervals range from one minute to one day. In addition, he suggested that radar data could be used to calculate the downstream flow of Hantan River since there are restrictions on the use of data from North Korea.

3.5 Dr. Hwirin Kim asked whether it is necessary to distinguish between simulations of flooding and non-flooding season since initial conditions such as soil moisture should be applied differently from continuous simulations in flood prediction. Dr. Hyeonjun Kim answered that the physical mechanisms for initial conditions such as soil moisture and groundwater level in flood prediction are not much different from continuous simulations, and that wet conditions and rising level of groundwater should be considered. He also emphasized that infiltration parameters may seem physically the same in flood prediction and continuous simulations, but there should be different hydrological approach taken to time simulations and day simulations. In addition, Dr. Hwirin Kim mentioned that there were poor results from the large basins in Russia and asked about solutions for larger basins as there are many larger basins

compared to basins of Korea in other regions such as Central Asia. Dr. Deokhwan Kim explained that the problem was not caused by DWAT, but GIS in the preprocessing, and that there will be no issue with DWAT 2.0 as it will provide a different preprocessing method. In addition, Dr. Marcelo asked how the climate change scenario was applied to DWAT in the case presented by Dr. Deokhwan Kim. Dr. Deokhwan Kim explained that the climate change scenario is provided on a daily basis and was downscaled before it was applied.

3.6 Dr. Jungsool Park from Han River Flood Control Office introduced new approach and strategies for water resources management in Korea. He explained observation techniques and dam operation strategies for response to flood during peak season and flow management during off-peak season. He also explained new strategies for water resources management, including the use of artificial intelligence and digital twins. Dr. Hyeonjun Kim said it is necessary to compare such strategies with Google's AI system for flood prediction. Dr. Hwirin Kim mentioned that not only Google but also Microsoft is working on flood prediction using AI which is quite noteworthy.

<Screenshot from the presentation of Dr. Jungsool Park from Han River Flood Control Office of Ministry of Environment>

4. Presentations on the results from DWAT applications

4.1 The purpose of the workshop is to evaluate the performance of the model and analyze its applicability to water resources assessment by comparing observation data with the results of DWAT v1.3 applications on local basins in each country by experts. Experts presented the results and their experiences of using the DWAT program in the following paragraphs. All presentations from the workshop are available on the DWAT website.

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4.2 Dr. Erasmo Rodríguez (Colombia) presented the results of the DWAT application to Chuza River basin in Colombia. SCE-UA method, a new automatic calibration technique added in DWAT v1.3, was used to calibrate the parameters for simulation of the daily flow. The overall results were satisfactory, but there were limitations in simulation of low flow. He explained that his team is working on using sub-daily data to solve this problem. He suggested that it would be worthwhile to include options of visual definition on warm-up, calibration, and validation periods to facilitate modeling and training support. In addition, he proposed to add a feature that enables the user to select the objective function according to the modeling purpose, and to add objective function and calibration techniques.

<Chuza River basin in Colombia>

4.3 Mr. Sysamouth (Laos) presented a summary of the results of DWAT application to Nam Lik basin in Laos. He analyzed the local climate status and prepared input data to apply DWAT in the local region. He carried out simulation on Nam Lik basin, using the constructed input data. The performance was somewhat disappointing with the calibration factor of 0.275. Dr. Hyeonjun Kim advised that better results could be drawn if the basin was subdivided into multiple regions for simulation rather than simulating the large basin at once. Mr.

Sysamouth noted the ease of using the DWAT and the well-documented guidelines, suggesting that the usability of the model could be further improved by allowing direct calibration at the basin exit node.

<Simulations on Nam Lik basin in Laos>

4.4 Dr. Marcelo (Argentina) tested the value of DWAT as a tool for water resources assessment and management. He evaluated the performance of DWAT in the previous workshop. Using the DWAT based on the results from the last workshop, he presented the results of evaluation of changes in energy generation according to climate change at the hydroelectric dam located at the exit of Burrumayo River basin in northwestern Argentina. DWAT was used to simulate flow based on climate change scenarios. Dr. Marcelo said that the rest of the process didn't use DWAT, and he plans to conduct research using hydraulic structure module of DWAT for the next time.

<Results from DWAT calibration and climate change>

4.5 Dr. Yuri Simonov (Russia) introduced Central Asia Hydrometeorology Modernization Project (CAHMP) and mentioned that Central Asian Flood Early Warning System (CAFEWS) has been in place as part of this project since January 2020. He said that one of the activities under the CAFEWS project is the implementation of DWAT at National Meteorological and Hydrological Services (NMHS) of Central Asian countries. He explained that the project is ongoing, and there were training programs for regional workshops in those countries in September and October 2022 and materials for DWAT training were prepared. He mentioned that a final report on requirements for DWAT implementation will be prepared in November, and a final report on training activities and implementation of DWAT in NHMS of each country in Central Asia will be prepared in 2023. At the regional workshop in September, there

were presentations on the introduction of DWAT and theories that support the model, and case studies on Russian basins. He also explained that there were discussions on the selection of pilot basins for each country and requirements for hydrometeorological and supplementary materials during the workshop.

<Regional workshop in Central Asia>

He also presented the preliminary implementation results for Oba River basin in Kazakhstan and Naryn River basin in Kyrgyzstan and mentioned that the model is being constructed for basins in Uzekistan. He said all Central Asian countries expressed their willingness to participate in the implementation of DWAT for pilot basins. He said additional work is needed to automate DWAT and link with the flow of the hydrometeorological input data (real-time observation data and NWP) in order to streamline the use of DWAT for operational hydrological services for consumers. In addition, he said there could be synergy created if DWAT is linked with existing web systems in the region.

< Pilot basin in Kazakhstan (Oba River basin) and simulation results>

Dr. Hyeonjun Kim and Dr. Hwirin Kim expressed gratitude for efforts to spread DWAT applications in Central Asia. Dr. Hwirin Kim suggested uploading

training materials and reports to WMO's water resources assessment website, and Dr. Yuri gave positive response to this idea. Dr. Sung Kim mentioned that snowmelt should be reflected to improve the flow simulation results of DWAT applications in Kazakhstan and Kyrgyzstan. Dr. Hyeonjun Kim agreed with the need for a mechanism for snowmelt simulation and said that he would make efforts to support applications in Central Asia.
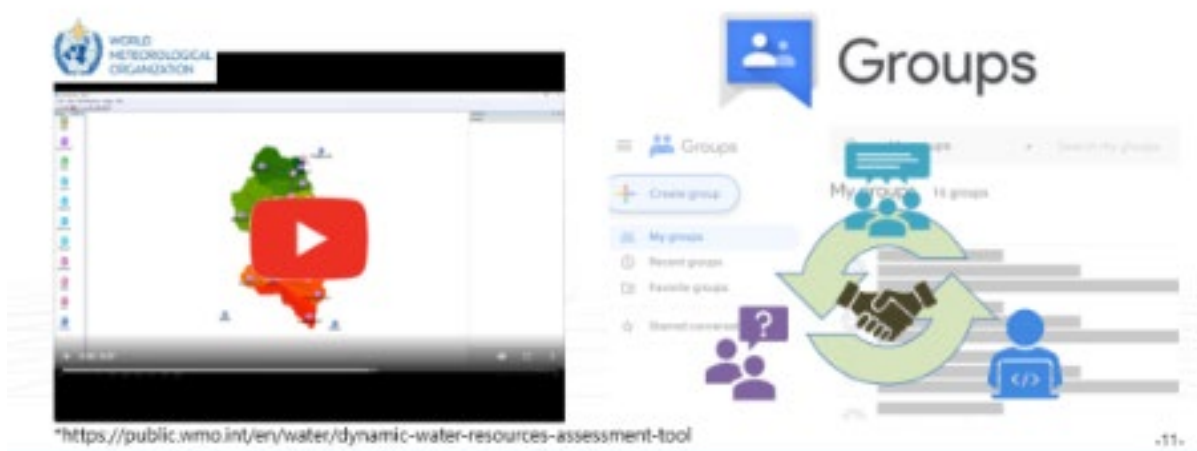
5. Introduction of DWAT v2.0

5.1 Dr. Hyeonjun Kim, the developer of DWAT, said that he is currently developing v2.0 by improving DWAT v1.3 and introduced the new version.

5.2 He said QGIS, an open source GIS, is linked with the preprocessing, which was previously conducted using GIS data, to facilitate the preprocessing in DWAT v2.0. He also noted that the tables and charts are being improved to present various results of the model, and the parameter input box is being upgraded by improving GUI to make the model more intuitive and accessible.

5.3 He said that DWAT v2.0 will be released in April next year (2023) and platforms such as YouTube and Google Groups will be used to provide video clips and facilitate communication and discussions between users and developers.

<Plan for user-to-user discussion and communication with developers>

5.4 He also said that DWAT will be applied to streamflow forecasting in 834 standard basins across Korea through the national research and development project. In addition, he mentioned that streamflow forecasting will be enabled by using ensemble rainfall forecast based on ensemble module.

5.5 Dr. Marcelo (Argentina) requested that input files from the previous versions of DWAT be used for newer versions and suggested that it would be helpful to have a feature that visually notifies the completion of the simulations through a message box. Dr. Hyeonjun Kim replied that he would reflect these opinions in the model.

6. Overview of workshop and discussions for plans

6.1 This section provides general overview of what was presented and discussed in the 4th international DWAT workshop.

6.2 Firstly, a summary of improvements of DWAT v2.0 was made. As introduced by Dr. Hyeonjun Kim, the improvements include QGIS for preprocessing, application of Chart-FX for post-processing, and GUI improvements. In addition, manuals and tutorial videos will be posted on WMO website and YouTube.

6.3 Regarding the use of community websites for user-to-user discussion and communication with developers, Dr. Hwirin Kim suggested using WMO's Community of Practice-area (COP, www.floodmanagement.info/e2e-ews–ff-community-of-practice -area/).

6.4 The plan for DWAT implementation will be applied to pilot basins in Central Asia by February 2023, and in Cambodia and Laos from 2023 to 2024. It was also mentioned that DWAT workshop might be held in RA III region.

6.5 Plans for the 5th international DWAT workshop

6.6 The main points discussed in the workshop are summarized as follows:

- Inclusion of options that provide visual definition on warm-up, calibration, and validation periods

- Consideration of automatic import of previous files upon relaunch of DWAT

- Consideration of integration with OSTRICH system (related to automatic calibration)

- Modification to enable selection of objective function according to the purpose of DWAT use

- Pop-up message to notify the completion of simulations

- Review on NSE efficiency criteria is required (requested by Dr. Marcelo)

- Calibration at exit node

- Cross-comparison with other water resources assessment tools

- Share reports of comparison between DWAT and SWAT

- Assessment of climate and seasonal forecasts available in Korea

- At the DWAT workshop in Central Asia,

  * DWAT automation and connection of the input flow of Hydromet information (real-time observation data and NWP)

  * Link DWAT with MCH to streamline the use of DWAT for operational hydrological services for consumers.

  * Link DWAT with existing web systems in the region. (Hydromet's monitor of UzHydromet, etc.)

- Addition of the developed materials (short-form manual and complete user manual), reports and case study presentations to the WMO DWAT website

- DWAT is mentioned in RA III HydroSOS implementation workshop

6.7 Candidates for the locations of the 5th international DWAT workshop include Bangkok, Thailand, considering the convenience of inviting participants, and Central or Western America, considering the ongoing DWAT-related projects. This needs further discussion.

6.8 Dr. Hyeonjun Kim said that online meetings and tutorials will be provided to reinforce training before the 5th international DWAT workshop. He also mentioned that special sessions on DWAT will be held at international conferences such as AOGS and EGU to promote the results of overseas applications in 2024. Dr. Hwirin Kim suggested integration of the 6th DWAT workshop with such international conferences.

6.9 Key points from the 3rd international DWAT workshop were discussed again. The first agenda was the addition of desalination and hydropower generation functions. Regarding desalination, it was concluded that it was necessary to discuss with Waleed and clarify what was needed. For hydropower generation, the components can be added to the current detention pond module. The second agenda was the development of DWAT in Linux version. The source code of DWAT will be disclosed later and the version can be converted if necessary. The third agenda was to provide fellowship program for students to apply DWAT. Graduate course of KICT was introduced. Dr. Hwirin Kim suggested that the students can have indirect experience of DWAT applications through the special sessions. She also requested that KICT consider taking charge of WMO's water resources assessment capacity development center.

7. Closing

7.1 The DWAT development team expressed gratitude for the efforts of regional experts. The team also greatly appreciated the feedback from regional experts and looked forward to continued cooperation to improve DWAT.

7.2 The Director General of Nakdong River Flood Control Office Hyo Seob Cho expressed gratitude for the efforts of WMO water resources committee, regional experts, and DWAT development team.

7.3 The 4th global DWAT workshop was closed at 16:00 on Friday, November 4, 2022.

[Appendix 1]

□ Attendees of DWAT symposium

No.	Organization	Name
1	World Meteorological Organization	Hwirin Kim
2	World Meteorological Organization	Roberto Silva
3	World Meteorological Organization	Nakul Prasad
4	Standing Committee on Hydrological Services (SC-HYD)	Marcelo Uriburu Quirno
5	Ministry of Environment	Hyoseob Jo
6	Ministry of Environment	Manshin Han
7	Ministry of Environment	Jungsool Park
8	Korea Institute of Civil engineering and building Technology (KICT)	Sung Kim
9	Korea Institute of Civil engineering and building Technology (KICT)	Hyeonjun Kim
10	Korea Institute of Civil engineering and building Technology (KICT)	Cheolhee Jang
11	Korea Institute of Civil engineering and building Technology (KICT)	Deokhwan Kim
12	Korea Institute of Civil engineering and building Technology (KICT)	Jeonghyeon Choi
13	Hydromet Center of Russia Russian Federal Service for Hydrometeorology and Environmental Monitoring (ROSHYDROMET)	Sergei Borsch

14	Hydromet Center of Russia Russian Federal Service for Hydrometeorology and Environmental Monitoring (ROSHYDROMET)	Valeria Koliy
15	Hydromet Division of India Meteorological Department New Delhi	Rahul Saxena
16	Kazhydromet, Kazakhstan	Serik Sairov
17	Ainur ABENOVA, Head of International cooperation and public service division, Administrative Department, NHMS of Kazakhstan	Ainur Abenova
18	Islamic Republic of Iran Meteorological Organization (IRIMO)	Yashar Falamarzi
19	Climate Research Division Office of Climate Research and Services India Meteorological Department	Pulack Guhathakurta
20	National University of Colombia	Erasmo Rodriguez
21	Water Assessment Division, DWR, MoNRE	Sysamouth Milattanapheng
22	Environment Remotesensing Institute	Hyoungsub Shin
23	Environment Remotesensing Institute	Seokho Song
24	Toconet	Youngryong Cha

[Appendix 2]

□ The 4ᵗʰ International DWAT Workshop Program

Thursday, November 3, 2022		
Time (ICT)	**Item**	**Facilitator**
13:30 – 14:00	Registration	All

Time	Item	Facilitator
14:00 – 14:10	Opening of the session and welcome Ministry of Environment, Republic of Korea, KICT and WMO	Dr Hyo Seob Cho, ME Dr Hwirin Kim, WMO
14:10 – 14:40	Introduction of DWAT Workshop	Dr Manshin Han
14:40 – 15:00	Introduction of Needs and Requirements for Water Resources Assessment	Dr Hwirin Kim, WMO
15:50 – 15:30	Presentation for the development of the Dynamic Water resources Assessment Tool	Dr Cheolhee Jang
15:30 – 15:45	Coffee/tea break	
15:45 – 16:15	Lessons from operational use of DWAT in the Republic of Korea	Dr Deokhwan Kim
16:15 – 16:45	New approach and strategy for water resources management in the Republic of Korea	Dr Jungsool Park
16:45 – 17:15	Discussion	All
17:15 – 17:30	Wrap up Day 1	Dr Hyeonjun Kim
18:00 – 20:00	Official Dinner Kindly hosted by Korea Institute of Civil Engineering and Building Technology (KICT)	

Friday, November 4, 2022		
Time (ICT)	**Item**	**Facilitator**
9:00 – 9:05	Short recap	Dr Hyeonjun Kim

		Dr Erasmo Rodriguez, Colombia
9:05 – 10:30	Testing and piloting of DWAT by experts across different RAs with a focus on how to apply the tool to Water Resources Assessments and Management	Mr Sysamouth, Lao PDR Dr Marcelo Uriburu, Argentina
10:30 – 10:45	Coffee/tea break	
10:45 – 11:45	Discussion on results of DWAT testing and piloting for enhancing Water Resources Assessments and Management	Dr Hyeonjun Kim
11:45 – 12:30	Discussion on future activities related to Dynamic Water Resources Assessment by RA II including linkages and guidance to activities of WMO	Dr Hyeonjun Kim
12:30 – 14:00	Lunch Break	
14:00 – 14:30	Outcomes of the Central Asia DWAT Workshop	Dr Yuri Simonov
14:30 – 15:30	Drafting Session of workshop report and recommendations	Dr Hyeonjun Kim & Dr Hwirin Kim, WMO
15:30 – 15:45	Closure of the Workshop Ministry of Environment, Republic of Korea and WMO	Dr Hyo Seob Cho, ME Dr Hwirin Kim, WMO