Workshop on
Development of Water Resources Assessment Methodologies and Establishment of an Information System for Water Resources Assessment in WMO RA-II

FINAL REPORT

Background

During the session of the WMO Regional Association II (RA-II), Working Group Hydrology (WGH) from 23 – 26 November 2010, the members of the Working Group recommended that Water Resources Assessment should be a priority working field in the period 2012-2016. In particular, the WGH proposed the table documented below:

Theme/Area of activities	**Strengthening the capability of Members to assess their water resources: Water Resources Assessment, its Variability and Use (Surface Water including reservoirs and Groundwater)**
Expected Outputs	• Develop and promote new approaches for WRA • Provide guidance materials for WRA and its variability
Expected Results	• Capacity building provided in WRA • Develop continuous monitoring tool for WRA
Specific Activities	• Link variability to climate predictions • Case studies • TBD

Introduction

The assessment of water resources is becoming increasingly important in the context of rapidly changing conditions related to human-induced changes including population, standards of living, industrialization, agriculture, land use changes and water use demand and patterns. Adding to this complexity is the experience of a changing climate resulting in generally higher variability of available freshwater resources.
Participants recognized that optimized water management as a result of improved monitoring of water resources availability and water demand structures and patterns is a key determinant for the sustainable socio-economic development of countries and entire regions with shared water resources.

On the offer of the Korea Ministry of Land, Transport and Maritime Affairs (MLTM), the workshop was held in the premises of the Han River Flood Control Office in Seoul from 10 to 12 October 2012. The programme of the workshop is attached as annex 1 to this report. Participants were members of the WMO Regional Association II (RA-II) Working Group Hydrology, experts of the WMO Commission for Hydrology (CHy) and experts from the Han River Flood Control Office that is also in charge of Water Resources Assessment in the Republic of Korea. The list of participants is attached as annex 2 to this report.

WMO and the Han River Flood Control Office jointly organized the workshop with the following expected results:

- Proposal for the development and testing of new methods for dynamic water resources assessment;
- Proposal for the establishment of RA-II wide Water Resources Assessment Information System;
- Proposal for the establishment of an expert team on water resources assessment in RA-II and in close liaison with CHy;
- Overview and feedback on current practices in WRA and feed-back to the CHy Draft Manual on Water Resources Assessment;
- Seek to obtain RA-II and CHy support in carrying out WRA activities as proposed by the RA-II WGH and based on the recommendations of the workshop;
- Provide for an appropriate outlook towards capacity building in WRA for RA II.

Results of the Workshop

This workshop was seen by participants as a first step in a series of activities that need to be undertaken to improve water resources assessments in terms of objectives, methodologies and tools needed to conduct these assessments. Therefore, aside from some concrete proposed actions, the workshop results highlight main pathways to be followed in reaching the objective of improved water resources assessments under rapidly changing conditions including climate change and socio-economic situations.

Participants agreed that background materials for the workshop including presentations made during the workshop as well as the workshop results would be made available on a dedicated web-page that could be hosted by WMO and/or mirrored on a web-server hosted by the Han River Flood Control Office. Specific workshop results are documented below.

General observations, conclusions and recommendations:
Towards a new Approach to Water Resources Assessment

Based on the presentations by country representatives and CHy experts, participants reviewed current practices in Water Resources Assessment (WRA) and identified the following common problems that need to be addressed with a view to improving WRA practices:

Participants welcomed the latest WMO Technical Report "Technical Material for Water Resources Assessment" that provides a useful insight in WRA practices and requirements. Participants observed the need to also collect and document good practices in WRA practices and approaches. This includes different methodologies used by various agencies in different countries to obtain a comprehensive overview of the current state of practices in WRA under different environmental and socio-economic conditions.

What is also needed is guidance on the step-wise development of WRA plans and activities and the development of new, innovative assessment methodologies that allow a dynamic assessment of components of the water balance to determine available water resources. This aims in particular to moving away from stationary assessment practices to dynamic, situation-oriented practices which provide a predictive capability.

In a further step, allowing for the establishment of national water budgets, actual or proxy-data needs to be accessed to determine different categories of water uses and quantify these uses.

Where actual data is not available, participants identified the need for the development of robust indicators and assessment techniques to describe and assess water uses and use patterns in a format that allows the application of demand management practices and setting priorities in water resources assessment and development practices.

In discussing this aspect further, participants called for the establishment of a knowledge-management platform specifically dedicated to access WRA practices and the development and exchange of new tools and methodologies.

In this respect, participants called for an enhanced regional and international cooperation to ensure the sharing of knowledge and information. As a first step, this can be achieved through working mechanisms already established in the framework of regional

cooperation in WMO RA-II, cooperation with other regions including RA-V and in seeking closer collaboration with WMO's Technical Commission for Hydrology (CHy).
Other than climate change as a major driver on the supply side of water, man-made changes need to be better understood and quantified, including – among others - : demographic changes and changes in standards of living that imply a higher demand for freshwater, urbanization and changes in land use patterns and practices, industrialization, agriculture as well as husbandry practices and aquacultures and overall changes in water degradation and pollution. Changed environmental perceptions and the drive towards healthier environments need to be also included.

In this respect participants recognized that changes in the availability of water resources are an import indicator for sustainable development; in other words: Availability of, and optimized management of, water resources play a decisive role in the development potential of nations.

Recognizing the interactions between different elements of the hydrological cycle, participants observed a general lack of recognition of the importance of surface water – groundwater interactions that are seen as increasingly critical for sustainable development and utilization of water resources including in a changing climate.

During the discussion, numerous examples were cited that highlighted the importance of transboundary water resources assessments and water resources management. In this respect participants called for the full implementation of WMO Resolution 25 (Cg- XIII), calling for the exchange of hydrological data and information.

The workshop noted the paradigm that "we cannot manage what we do not know". The greatest obstacle for improved WRA and the subsequent development of national and transboundary water budgets is the lack of sufficient and quality-controlled data and information, accessible in a timely fashion to decision-makers and water managers. In this respect, participants called for the rigorous application of standardized data quality control procedures and data management practices that ensure the inter-operability of different observing and data management systems including their telecommunication and transmission protocols. Participants were aware that these issues are tackled through several initiatives including the WMO integrated global observing system (WIGOS) and the WMO Information System (WIS).

Outcome-oriented optimization of observing systems require substantial investments in the (re)-establishment of hydrometerological and groundwater monitoring networks, enlargement of networks, linkage of observation networks maintained by different agencies in an integrative manner and standardized quality management procedures such as those promoted through the WMO Quality Management Framework.

Participants noted that water resources assessment practices are inherently diagnostic tools and that it is desirable to add predictive capabilities to these tools. Participants were of the opinion that this could be achieved through the development and application of appropriate scenario-techniques that also would allow testing sensitivity and resilience of

water resources systems under various forcing conditions. Other options with a high added value would be the coupling of dynamic water resources assessments based on continuous monitoring with (seasonal) climate predictions.

Participants highlighted that the successful implementation of improved water resources assessments will require substantial efforts and investments in capacity-building programs and activities that also require international and transboundary cooperation. Participants noted the interest of Korea to support this concept.

In addition to improved water resources assessments, participants recognized the importance of the connection between water supply and the use of energy and recommended that this issue requires further research and investigation on national and regional levels. Participants proposed that the water resources assessment system includes the water and energy nexus and requested that this issue be further discussed both at regional level in RA-II and in view of the 2015 World Water Forum.

The table below summarizes the issues mentioned related to Water Resources Assessments:

Some common issues/problems/needs related to Water Resources Assessments (WRA)

Data

- Need guidance and standards for how much and which data are required
- Need a data collection system
- Need uniform data-quality management system
- Need consistency in data collection
- Data need to be shared among countries
- Withdrawals and other aspects of water use need to be quantified
- Need better groundwater data
- Need to assess uncertainty of data (and models)

Budget

- WRA needs to be inexpensive and simple to implement

Other considerations

- Effects of non-stationarity and periodicity on WRA
- Role of groundwater/surface-water interactions
- Regional impacts are important
- Is water a private resource or a public commodity
    - Water that is a private commodity may be very difficult to assess
- Change scenarios
    - Climate
    - Land use
    - Prediction or sensitivity analysis
    - Evaluate sensitivity of water resources to changes in climate and land use using historical information

Cooperation and standardization

- Need more cooperation among Asian countries

- For hazards (floods and droughts) assessments
- For early warning systems
- Operational exchange
- Trans-boundary cooperation
- Data need to be shared among countries, particularly when one country is "upstream" of another country

- Consistent indicators
  - Uniformity
  - Core requirements
  - Interoperability of systems
- Estimation of water-budget components is more challenging than assessment of hazards (floods and droughts)

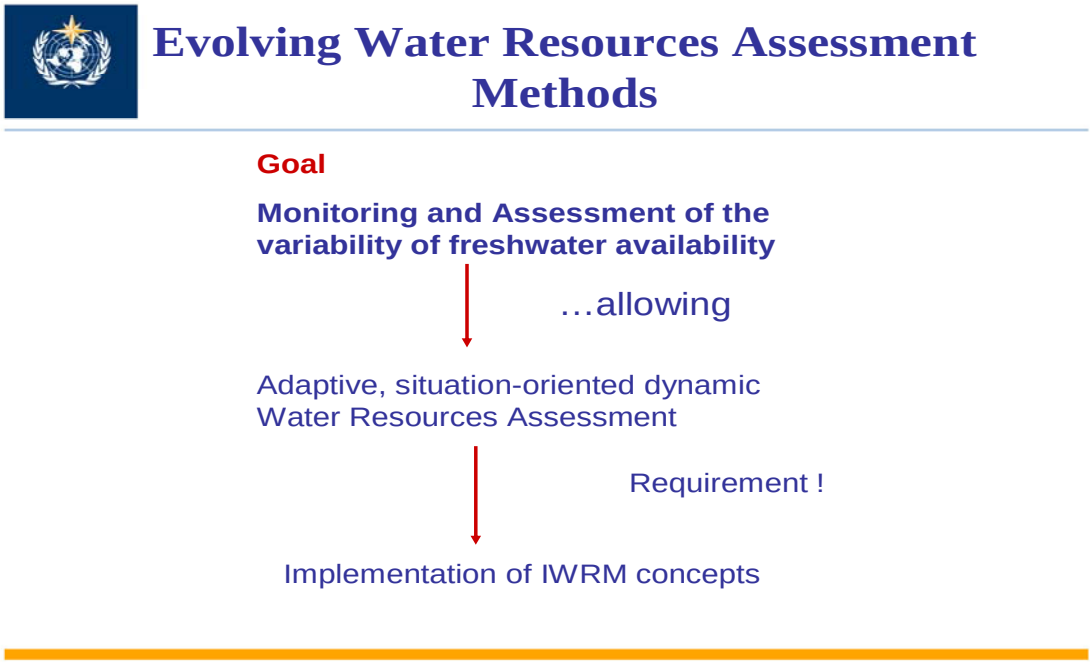
Compatible IT infrastructure among countries

Specific feed-back to the CHy Draft Materials on Water Resources Assessment

Participants welcomed the Draft Technical Report on "Technical Materials for Water Resources Assessment" becoming available soon in its final version. Participants expressed their intent to send specific observations on the report by email to the organizers of the workshop before the end of October 2012.

Innovations and Improvements in Water Resources Assessments

The figure below provides an oversight of the goal of evolving methods for improved integrated water resources assessments in the framework of Integrated Water Resources Management (IWRM).



Participants discussed in detail historic approaches and possible new approaches to WRA. Noting that historic approaches were mainly using “Snap-shot” type Assessments, based on water balance models using long time-series of average values, deficits in historic approaches were identified as having insufficient capability to respond to short-time variations of the water balance and no, or limited, predictive capability.

In contrast, future approaches would be based on the dynamic monitoring of the water balance, based on near real-time information (meaning at least on a monthly base, initially). Advantages of future approaches are, among others, the ability to assess the short-term variability and trends of components of the water balance, and adding predictive capability through coupling water balance models to (seasonal) climate outlooks.

Participants agreed to the necessity to compile state-of-the-art overviews and case-studies on the use of new methods for dynamic water resources assessments with a view to identify current approaches as well as gaps that that need to be addressed in close cooperation between science and field applications. Likewise, good practices should be documented for different countries and, where available, in transboundary basins.

The goal would then be to develop innovative WRA methods, tools and applications, testing them on a pilot scale under various climatic and socio-economic conditions in different countries and basins to demonstrate the proof of concept of these new methodologies.

Development and Use of Models

The meeting went into great detail to outline needs and requirements for the development and use of models in WRA and concluded on the following issues:

Dynamic models being observations-based (data based) or stochastic-based models should use variability and trends, and using continuous model runs (using data in monthly time steps refining time steps further as may be appropriate).
Participants also commented on the paradigm that "stationarity is dead" due to climate change and rapidly changing socio-economic developments and saw this also as a field that requires more scientific insights as how this paradigm would impact WRA models and their outputs.

Participants commented that the use of dynamic computational models, need to be linked with socio-economic development models, and also should include predictive components based on models coupled to climate predictions.

As water resources engineers continue to be more familiar with regression models, it was felt that efforts should be made to adapt and further develop (regression) statistic-based models suitable under non-stationary conditions. Participants noted that this approach requires further research including review of available literature and testing of robust methodologies.

Participants recommended that models should be used to provide scenario-based supply and demand estimates, assessing the variability of water resources availability that is the key to optimized water management practices. Such scenario-based models could be generated using ensemble prediction approaches with the prediction of water demand and water supply on time steps ranging from seasonal to inter-annual or decades. Commenting on prediction uncertainties, participants further recommended communicating model uncertainties to increase the credibility of model results for decision-makers. One way to address uncertainties would be to provide weather forecasts, particularly precipitation information and (seasonal) climate outlooks in the form of ensembles or NWP products, where these are available.

Basic Requirements for Data and Information

Participants recognized that further detailed discussions were necessary to compile a comprehensive list of data and information requirements that are needed to undertake model-based WRA and referred in this aspect to the draft WMO Technical Report on "Technical Material for Water Resources Assessment". As an overview, participants listed the following data requirements on the water supply side (water resources) and the user-side (water demand):

“Supply Side”

- Network optimization in regard to hydrological stations, including water quality variables (including nutrients, oxygen, temperature …), stations in estuaries and deltas, at the mouth of rivers, stations required to monitor cross-border flows (states, countries, transboundary rivers);
- Precipitation information (terrestrial stations as well as radar- and, satellite-based estimates..), stations including those in high mountain areas and snow and glacier regions, need for snow and glacier coverage and melt information, ice conditions in rivers;
- Satellite information specifically related to snow water equivalent, snow cover extent, soil moisture, evapotranspiration and temperature, water storage in reservoirs and lakes (using altimetry information), mapping of open water surfaces areas (lakes, reservoirs, flooded areas;
- Groundwater information was seen as especially critical, specifically: recharge of aquifers, water tables, pressure head and groundwater quality.

“Demand Side”

Some high priority requirements for data and information were identified including the necessity to obtain information on water abstractions, (groundwater) pumping, diversions, distinction between consumptive and non-consumptive use of water (types of use, priorities of water use), water use patterns (changes as a result of user patterns and including differentiation along weeks, seasons..), water quality requirements considering different types of water as to their suitability to use; water use estimates (such as crop water requirements).

Participants recognized the importance of socio-economic data as an important driver of demand-side requirements and changes. Amongst these, participants listed the following information requirements:

Demographic development and status, standards of living, communities attitude to water use, changing use patterns, development of industry and agriculture, land use changes, cost of water (debate: water as public good or private good), noting the importance of derived information, proxy information in cases where there are no hard data, need for indices and indicators and identification of water saving measures.

Institutions and Regulatory Frameworks

Participants realized that improved water management practices not only require improved WRA methodologies and tools, but need to be based on a well documented water policy of a country, basin or administrative region. An ideal start-up is a regulatory

framework for the implementation of Integrated Water Resources Management (IWRM) practices, embedded in a water law that is supported by regulatory frameworks, including by-laws, ordinances and the like that can be effectively used to enforce regulative frameworks. These regulative frameworks typically concern water use restrictions but can also be used to conserve water resources including the management of rivers, lakes, reservoirs and groundwater.

Requirements for and the Establishment of Water Resources Assessment Information Systems

In accordance to the intention of the workshop, the meeting discussed in detail the purpose and requirements for water resources assessment information systems and concluded on a number of recommendations that are documented below. At this point, such an information system would concentrate on requirements for national information systems that could be up-scaled for a regional information system tailored to the requirements of WMO RA-II (Asia).

Purpose of a Water Resources Assessment Information System

The primary purpose for a Water Resources Assessment Information System is to:

Ensure continuous monitoring and effective communication of changes of key variables of the water balance and water use/consumption patterns as a basis for decision-making in water resources management that is situation-oriented and adaptable to the variability and change of the climate system and determinant socio-economic factors, affecting water use and consumption.

Participants identified the following objective functions for an information system as envisaged:

- Serve as the basic monitoring system to generate information related to the variability of available water resources as well as water demand development and water use;

- Assist countries with tools and methodologies focussing on: methods of observations, data quality management, development and use of different models, review of data availability and quality;

- Establishment of metadata catalogues to obtain an overview of accessible data and information versus data and information requirements for WRAs.

Further concrete objective functions were identified, including information systems serving

- As a knowledge hub
- Disseminate information and
- Provide national and regional water resources overviews

A pre-requisite for any development step would be the following starting points:

- Identify user requirements (Know who your users are)
- Service-oriented development of information systems: Define desirable suite of products
- Address update and maintenance concepts and procedures

In terms of development steps of information systems, participants concluded that on a national level, an initial information system should provide the platform for national consultations and consensus finding in Water Resources Assessments. Recalling that water resources assessments are often undertaken by a multitude of (sector-oriented) stakeholders and organizations on national level, the establishment of a WRA Information System would require the identification of national focal organizations to be the mandated flag-bearer of such an information system. From the national scale, the development of a proto-type regional water resources information system could be undertaken.

On regional level, participants recommended to work in cooperation with existing regional establishments such as: RA-II Working Group Hydrology, ESCAP/WMO Typhoon Committee, UN-ESCAP, River Basin Organizations and other entities as appropriate. Participants reiterated the need to liaise these activities closely with the WMO Commission for Hydrology (CHy).

There was overall agreement that the implementation needs to be undertaken in a step-wise approach, adding as one important component the water and energy nexus that had been explicitly promoted by the representatives of Korea in the meeting.

The building of an information base founded on examples of existing water resources information systems or those under advanced stages of development were a pre-requisite. Experts present in the workshop volunteered to provide first information for Korea, China, US, Australia, Japan, Russia. These descriptions should include: concepts of information systems for WRA; description of what is there, what is missing and ongoing development plans as well as lessons learnt where available.

Basic Requirements for Capacity Building

Participants highlighted a number of components that need to be reflected in building a comprehensive “Requirements Document” for capacity building in water resources assessment.

- Hydrological sciences:
- Basic hydrology, instruments and methods of observation, data management, product development, guidance on how to do water quality assessments as part of overall water resources assessments;
- Knowledge in assessing and using global water resources assessment information including in the context of climate variability and change
- Use of water balance models and methods to establish water budgets
- Geospatial analysis capacity, compile and manipulate geospatial data, adaptation of software and IT-trainings (hardware, software)
- Knowledge in CC downscaling techniques, training in basin scale water balance modelling,
- Need expertise in decision support systems (development and use, configuration of DSS), estimation of water use and demand, assessment of status of water resources,
- Improve on observations (surface water, lakes reservoirs, groundwater…) reservoir operation, inclusion of surface water - ground water interactions, Water quality assessments, use of WRA models and predictions, including water balance models under different situations and scenarios, provide decision support to government agencies; documentation of regularly updated water budgets (Water resources availability and water use); Decision-making involves management decisions, facts-based and multi- criteria, including socio-economic acceptance levels.
- Decision-making:
- Thinking in terms of different science-supported options for WR management;
- Scenario development and analysis including technical and socio-economic as well as and climate and environmental views.

Summary

Participants felt that what is needed are:

- Improved methodologies and tools (models) for Water Resources Assessment

… linked to

- Improved methodologies and tools for dynamic adaptation of water management (supply and demand management) as well as

- Scenarios and predictions

… linked to

- Action Plans for Adaptive Water Management under climate variability and change, as well as
- Human factors influencing local and regional water balance (population increase, standards of living, industrialization, agriculture, land- use changes)

A Water Resources Assessment Information System will provide the information base to generate information needed for decision –making.

Future Activities in WRA in WMO RA-II

Participants recommended to

- ❖ Develop further cooperation mechanisms with CHy and other Regional Associations
- ❖ Develop further cooperation with regional programmes and entities such as: International River Basin Organizations, Typhoon Committee, UN-ESACAP, other UN organizations including organizations represented in UN-Water…
- ❖ Development and implementation of a regional prototype water resources assessment information system including a water and energy component
- ❖ Develop an operations plan to assist countries in the region in national WRA

Next Steps and Time-Lines

Participants agreed that

1. The upcoming session of RA-II will be informed of the results of the workshop (December 2012);
2. Proposal for the establishment of an expert team on water resources assessment in RA-II as part of the RA-II Working Group Hydrology will be developed on the basis of this report (November 2012) and will be promoted during the upcoming RA-II session in December in Qatar (December 2012);
3. Support from RA-II and CHy will be sought to carry out WRA activities as proposed by the RA-II WGH and based on the recommendations of the workshop (November and December 2012);
4. Provide for an appropriate outlook towards capacity building in WRA for RA II (Spring 2013);
5. Document status of water resources assessment practices and access to information in countries (Summer 2013),
6. Document current WRA practices in countries (Summer 2013)
7. Organize follow-up workshop in fall 2013.

Closure of the Workshop

The experts reviewed and agreed to the findings and recommendations of the workshop. The participants expressed their highest appreciation and thanks to the Korea Ministry of Land, Transport and Maritime Affairs (MLTM) and the Han River Flood Control Office, and WMO for providing financial and technical support for the workshop. Participants also thanked the hosts for their extraordinary hospitality extended during the workshop including the highly instructive technical excursion.
The workshop closed after the field excursion on Friday 12th October at 15:00.

Annex 1

PROGRAMME

Workshop on
Development of Water Resources Assessment Methodologies and Establishment of an Information System for Water Resources Assessment in WMO RA-II

Han River Flood Control Office
Ministry of Land, Transport and Maritime Affairs
Seoul, Republic of Korea
10 to 12 October 2012

10 October 2012
Day 1 Morning: Introduction and Overview of Water Resources Assessment Methods (WRA) and Requirements (10:00-11:50)

- Opening session and introduction to the workshop (10:00-12:00)
  - Session Chairman: Dr. Sung Kim
  - Opening address (10:00-10:05)
    - Dr. Byeong-Kuk Jeon (Director General of Han River Flood Control Office, MLTM)
  - Introduction to the workshop (10:05-10:20)
    - Dr. Wolfgang Grabs (Chief, Water Resources Division, Hydrology and Water Resources Department, WMO)
    - Dr. Sung Kim (Chair, WMO-RAII WGH/Senior Research Fellow, KICT)

- WRA Lectures by WMO experts
  - Session Chairman: Dr. Wolfgang Grabs
  - Themes
    - Introduction of needs and requirements for WRA
    - Review of guidance materials for WRA
    - Approaches and methodologies for dynamic WRA
  - Schedule:
    - Dr. David Wolock, USA (10:20-10:50)
    - Dr. Grace Mitchell, Australia (10:50-11:20)
    - Dr. Junichi Yoshitani, Japan (11:20-11:50)

Lunch break (12:00-13:00)

Day 1 Afternoon: Current status and issues in WRA in RAII (Country Reports) (13:00-18:00)

- **Chairman: Dr. Junichi Yoshitani**

  - China: Prof. WANG Guangsheng (Deputy Division Director, Water Resources Monitoring and Assessment Division, Bureau of Hydrology, Ministry of Water Resources) (13:00-13:30)
  - Russia: Dr. Mikhail Georgievskiy (Researcher, State Hydrological Institute) (13:30-14:00)
  - Thailand: Ms. Patchara Petvirojchai (Senior Meteorgologist, Hydrometeorological Academic Group, Meteorological Development Bureau, Thai Meteorological Department) (14:00-14:30)

  - Break (14:30-14:50)

- **Chairman: Dr. David Wolock**

  - Uzbekistan: Dr. Sergey Myagkov (Deputy Director of NIGMI, Uzhydromet) (14:50-15:20)
  - Vietnam : Dr. Dang Ngoc Tinh (Chief, Hydrological Forecasting Division, North National Centre, Hydro-Meteorological Forecasting Hydro-Meteorological Service of Vietnam) (15:20-15:50)
  - Republic of Korea: Dr. Sang Heon Lee (Director, River Information Center, Han River Flood Control Office, MLTM) (15:50-16:20)

- Break (16:20-16:40)

- Group discussion (16:40-18:00)
  - Themes
    - Feed-back to current WRA practices and available guidance materials, including the CHy draft Manual on WRA
    - Data and information requirements for WRA

  - Moderator: Dr. Grace Mitchell
  - Panels: all participants

Reception hosted by Ministry of Land, Transport and Maritime Affairs (18:30-20:00)

- Venue: Seoul Palace Hotel

13 October 2012

Day 2 Morning: Innovations in Water Resources Assessment and related Information Systems

- Group Discussion: Development and testing of innovative methods for dynamic Water Resources Assessment

    - Theme 1: Global/Regional Information System for WRA (09:30-10:30)
        - Moderator: Ms. Patchara Petvirojchai
        - Panels: all participants

    - Theme 2: Purpose outputs and requirements for WRA Information systems (10:40-12:00)

        - Moderator: Dr. Mihail Georgievskiy
        - Panels: all participants

Lunch break (12:00-13:00)

Day 2 Afternoon: Proposals for the development of new methodologies and tools and the establishment of WRA Information Systems (13:00-17:30)

- Proposal for establishing an information system for WRA in RAII by KICT Research Team (presentation), followed by group discussion (13:00-14:00)
    - Presentation: Dr. Sung Kim (Senior Research Fellow, KICT) (13:00-13:30)
    - Group discussion: all participants (13:30-14:00)

- General discussion on future activities related to Water Resources Assessment by the RA II WGH, including the possible establishment of an expert group on WRA and linkages and guidance to activities of the WMO Commission for Hydrology (CHy) (14:00-15:40)
    - Moderator: Dr. Sung Kim & Dr. Wolfgang Grabs
    - Panels: all participants

- Break (15:40-16:00)

- Drafting Session of workshop report and recommendations (16:00-16:30)
- Adoption of the workshop report with its recommendations (16:30-17:00)
- Closure of the technical part of the workshop (17:00-17:30)
    - Dr. Sung Kim and Dr. Mr. Wolfgang Grabs
    - All participants

Dinner and cultural show hosted by Korea Institute of Construction Technology (18:30-22:00)

Day 3: Technical excursion

- Visit the Gangcheon Weir in the Han river basin (09:00-15:00)

Annex 2

List of Participants

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