UNESCO/IHA GREENHOUSE GAS (GHG) RESEARCH PROJECT

WORKSHOP FRAMEWORK AND SUMMARY OF DISCUSSION: MAIN CONCLUSIONS AND RECOMMENDATIONS

FROM MEASUREMENT TO MODELLING: INTERFACES BETWEEN THE FIELD DATA AND THE PREDICTIVE MODELLING TOOLS
03 - 04 AUGUST 2010 – OAK RIDGE - USA
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WORKSHOP FRAMEWORK AND SUMMARY OF DISCUSSION:
MAIN CONCLUSIONS AND RECOMMENDATIONS

Document track:
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WORKSHOP FRAMEWORK

List of Participants

The Workshop on the “Interfaces between the field data and the predictive modelling tools” was convened in Oak Ridge, USA, hosted by Oak Ridge National Laboratory (ORNL), with support from the U.S. Department of Energy (DOE) and the Electric Power Research Institute (EPRI), in collaboration with the UNESCO/IHA Greenhouse Gas (GHG) Research Project, as part of the Science, Technology, and Policy Summit on Carbon Cycling in Water Storage Reservoirs Workshop, on 02 – 04 August 2010.

The following professionals were present at the Meeting:

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Country</th>
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<tbody>
<tr>
<td>Andersen, Mark</td>
<td>California Department of Water Resources</td>
<td>USA</td>
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<tr>
<td>Arnold, Jeffrey</td>
<td>US Army Corps of Engineers - Institute for Water Resources</td>
<td>USA</td>
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<td>Bastien, Julie</td>
<td>Environnement Illimite</td>
<td>Canada</td>
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<td>Baummer, John</td>
<td>FERC</td>
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<td>Bevelhimer, Mark</td>
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<td>Canales Fuenzalida, Bernardo</td>
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<td>Chanudet, Vincent</td>
<td>EDF-CIH</td>
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<td>Choon, Tan Kee</td>
<td>Sarawak Energy Berhad</td>
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<td>Clow, David</td>
<td>U.S. Geological Survey</td>
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<td>Contreras Leiva, Manuel</td>
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<td>Damazio, Jorge</td>
<td>CEPEL - Centro de Pesquisas de Energia Eletrica</td>
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<td>Dixon, Doug</td>
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<td>Doria, Miguel*</td>
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<td>Florville Alejandro, Tomas</td>
<td>UNIVERSIDAD DE ANTIOQUIA</td>
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<td>Fortner, Allison</td>
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<td>Goldenfum, Joel**</td>
<td>International Hydropower Association</td>
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<td>Hancyk, Jeremy</td>
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<td>Nielsen, Niels</td>
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<td>Phillips, Jana</td>
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<td>Pinguelli Rosa, Luiz*</td>
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<td>Reddy, Rama Chandra</td>
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<td>Sale, Mike</td>
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<td>Santos, Marco Aurélio</td>
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<td>Smith, Brennan</td>
<td>Oak Ridge Laboratory</td>
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*Also members of the Governance Committee  
** Management Team
Background to UNESCO/IHA Project

Two scientific workshops on the Greenhouse Gas Status (GHG) of Freshwater Reservoirs were hosted by UNESCO, in Paris in 2006, and in Iguassu in 2007, as part of UNESCO IHP-VI (2002-2007) and continued under IHP-VII (2008-2013). One of the conclusions from the 2006 workshop was to focus on more research and better understanding of processes and key parameters leading to the emission of methane from tropical reservoirs. The 2007 workshop recommended that an analytical process should be developed to determine whether GHG emissions from future reservoir sites are likely to be a significant issue – to support this process, that a Measurement Specification Guidance should be developed, to be applied to a set of representative reservoir schemes in order to collect data for the development of predictive modelling tools and mitigation guidance for vulnerable sites.

Through the UNESCO initiative, the issue of GHG emissions from reservoirs has been pursued with assistance from a group of scientists through a project proposal for a global assessment of GHG emissions from freshwater reservoirs. This work was followed up by a meeting in Paris in January 2008 to finalise a Scoping Paper, a Workshop on Measurement Guidance in London in November 2008, a Workshop on Site Selection and Database in São Paulo in May 2009, a Workshop on Field Measurements and Data Analysis in Montreal in September 2009, and the present Workshop on Interfaces between the field data and the predictive modelling tools.

The Project aims to improve understanding on the impact of reservoirs on natural GHG emissions, to obtain a better comprehension on the processes involved and to help overcome knowledge gaps. The overall objective of the Project is the evaluation of the carbon footprint (net GHG emissions), resulting from the construction of a freshwater reservoir within a river basin, as well as potential mitigation measures. The main strategies of the Project can be summarized as:

1. development of a measurement guidance;
2. site election, field measurements and measurement coordination;
3. development and validation of one or more empirical modelling tools;
4. development and calibration of one or more process-based modelling tools;
5. guidance and assessment tools for mitigation of GHG emissions for vulnerable sites.

The first two years of the Project culminated with the publication of the *GHG Measurement Guidelines for Freshwater Reservoirs*, a pioneering document, describing standardised procedures for field measurements and the calculation methods to estimate the impact of the creation of a reservoir over the GHG emissions.

Workshop structure

The event was hosted by ORNL, with support DOE and EPRI, as part of the Science, Technology, and Policy Summit on Carbon Cycling in Water Storage Reservoirs Workshop.

During the first day (02/August/2010), the activities comprised welcome and introductions, presentations and discussions on the water management context for reservoir GHG assessment in the U.S.

The second day (03/August/2010) included a general overview of the GHG Research Project, presentations on Field Measurement, Database and Modelling Issues and general discussions on the presentations.

The third day (04/August/2010) was dedicated to group discussions on specific subjects, and Conclusions.

Each one of the delegates received a copy of the *GHG Measurement Guidelines for Freshwater Reservoirs*.

The detailed meeting Agenda is presented in Annex 1.
SUMMARY OF DISCUSSION:
MAIN CONCLUSIONS AND
RECOMMENDATIONS

1. Introduction

The UNESCO/IHA GHG Research Project reached an important milestone, with the publication of the *GHG Measurement Guidelines for Freshwater Reservoirs* (the *Guidelines*), describing standardised procedures for field measurements and estimation of the impact of the creation of a reservoir on the GHG emissions. These Guidelines collate the key products developed under a consensus-based scientific approach, as result of an intensive international collaborative initiative, and set the basis for the next stages of the research, with the application of the agreed protocols in the field.

The *Guidelines* is to be used to plan and conduct measurement campaigns to estimate net GHG emissions from freshwater reservoirs before and after their construction, aiming to ensure objective assessments and to ease comparison, transferability and the global use of data (subject to rules of access). It aims to promote scientifically sound evaluation of the GHG exchange due to the construction of a freshwater reservoir. The *Guidelines* is to be applicable world-wide, for all types of climate and different reservoir conditions, and for reservoirs of all types and purposes.

The *Guidelines* is not intended as a general method for routine assessment and monitoring in existing and future reservoirs. Rather, it is meant to establish a standard methodology to ease comparison and transferability of detailed field data collected from reservoirs and watersheds through comprehensive research studies, to better understand the all of the underlying processes and their relative significance.

The next steps of the Project are:

- application of the *Guidelines* to a set of representative reservoirs, to build a reliable, standardised results database;
- development of predictive modelling tools to assess the GHG status of unmonitored reservoirs and potential new reservoir sites.

The present workshop aimed to provide guidance to these next steps, discussing the interfaces between the field data and the predictive modelling tools. The discussions started with the field measurements, moved into database and provided information to identify key parameters to be used to feed predictive models.

The next sections present the main conclusions and recommendations from the workshop:

- Database;
- Representativeness of Reservoirs;
- Predictive Models
- Quality Assurance, Quality Control and Capacity Building Needs
2. Database

The main discussed aspects included format and structure of the database, data to be included, rules and level of access, confidentiality, intellectual property and other related issues.

2.1. Overview

The GHG Measurement Guidelines identifies the main elements to be included in the database, as presented in its Appendix 4.1 – Measurement Questionnaire (pages 125-130), including:

- the reservoir main characteristics (Geographic Data – Country, Climatic region, Province, State, Water basin, Land use in the contributing areas, Station name, etc.);
- the parameters measured (meteorological data, Hydrological data, Essential Water Quality Parameters, etc. – always adopting SI Units);
- GHG concentrations and fluxes and key parameters in the GHG Measurement Guidelines:
  - Include Key parameters, as described in the GHG Measurement Guidelines, Appendix 4.1 – Measurement Questionnaire (pages 125-130)
  - SI Units, moles recommended for consistency and clarity
  - Include tools to convert units
  - If grams used for concentrations or fluxes, it must be explicitly noted if the mass refer to the mass of the gas of interest (e.g., mg CH₄) or if it refers to the mass of carbon and nitrogen from the gas (mg C-CO₂ or C-CH₄ or N-N₂O)
  - Device Used with a detailed physical description
  - Sampling method description and details
  - Equations used including assumptions/constants applied
  - If mg/sq. meter/day used, gas must be explicitly defined

Regarding Data Governance, the workshop delegates agreed that it is necessary to define the Rules and Level of Access, including:

- Need to define the Field Data entry mode (e.g. single entity entry with password protection)
- Different tiers of access depending on individual level of participation
- Uniform software and file formats
- Differentiate between confidential, to be published, work in progress, and/or data collected for regulatory compliance

2.2. Outstanding issues

The following aspects of Data Governance and Confidentiality were identified as still having to be defined:

- Confidentiality Agreement
- Public Entity considerations
- Investor Owned Utility considerations
2.3. Next steps
As result of the discussions, the following activities were outlined as most pressing:

- Establish software and/or database uniformity
- Firm up access protocols
- Reinforce data collection uniformity
- Determine IHA/UNESCO resources to coordinate the next phase(s)

3. Representativeness of Reservoirs
The discussed aspects included main concepts and parameters to be considered for reservoir site selection (including physical, political, economical and practical criteria), and reservoir/sites currently available for monitoring.

3.1. Overview
Contacts and agreements have been (or are being) developed for application of the GHG Measurement Guidelines in reservoirs of hydropower dams in Brazil, Chile, Colombia, United States, China, Malaysia, Laos, Australia. Reservoirs identified as already applying the Guidelines (or ready to apply) are:

- Mekong River: 3 reservoirs – 1 new, 1 around 30 years old, 1 around 5 years old
- Malaysia: 3 reservoirs – 2 new, 1 around 30 years old
- China: to be defined
- Australia: studies developed by HydroTasmania, EI
- US: the U.S. National GHG Project, funded by DOE/EPRI, and coordinated by ORNL will investigate around 10 to 12 reservoirs – 25 to 60 years old
- Brazil: 3 new sites and 8 reservoirs up to 30 years old
- Chile: 5 new sites and 2 reservoirs around 20 – 30 years old
- Canada: studies performed by HydroQuebec
- SINTEF: Norway and other studies

Need for data was acknowledged for Africa, Europe, Asia and other South America countries (such as Venezuela, Colombia).

The workshop delegates agreed that It will be important to identify the site characteristics and the reservoir characteristics, as defined in the UNESCO/IHA Measurement Questionnaire (GHG Measurement Guidelines, pg 125-130), including:

- Site characteristics:
  - Carbon (C) and nutrient load
  - Oxygen concentration
  - Water temperature
  - Wind speed and direction
  - Rainfall
  - Soil use and occupation
- Reservoir characteristics:
  - Design: Climatic characterisation; Max and Min Depth; Max and Min Flooded area; Altitude; Land use and cover in the contributing areas; Soil type; Qualitative estimation of C and Nutrient input (high, low); Trophic status (Qualitative); Anthropogenic activities
contributing to C load; Humic content (colour); Purposes of the reservoir; Residence time; Presence of low level outlets; Increased turbulence downstream of the dam associated with ancillary structures, e.g. spillways and weirs; Stratification of the reservoir body (likelihood); Reservoir shape (e.g. shoreline/surface ratio); Biomass of plants, algae, bacteria and animals in the reservoir and in drawdown zone; Reservoir age

- Operation: Drawdown zone exposure (changes in water depth)

### 3.2. Outstanding issues

The main elements to be developed were identified as:

- Right to use (and protection against misuse of data)
- Assessment of hydrologic and hydraulic characteristics of the basin management
- Need to establish correlation among parameters, including water quality (to reduce further efforts for future assessments)
- Reservoir typification:
  - Around 10 types (or less), according to reservoir characteristics
  - Set of empirical relations for each type
  - Mitigation measures
  - Operational alternatives
  - Design of new projects
- Possible use of data from previous studies
  - Need to verify compliance with Guidelines
- Temporal representativeness of data (need for Long term monitoring)
  - Identify years during which extreme events occurred
  - Climatic change
  - Climatic variability (such as El Niño/Southern Oscillation-ENSO)
- Available resources for monitoring campaigns
  - Manpower and qualification → Capacity building
  - Financial resources → equipment and measuring programme

### 3.3. Next steps

As result of the discussions, the following activities were outlined as the most urgent:

- Obtain reservoir characteristics
  - Reservoirs already in the Project
  - Global survey
    - All Reservoirs (in general)
    - Reservoirs with GHG already measured
- Define reservoir types and frequency
- Identify new potential sites according to the needs
  - Geographical distribution
  - Reservoir types
  - Site, design and operational characteristics
  - Basin management
  - Other criteria that may be identified
- Identify the need for financial and capacity building support
4. Predictive Models

The main discussed aspects included objectives, advantages and limitations of the different modelling approaches to be selected/developed/applied under the UNESCO/IHA GHG Research Project.

4.1. Overview

Different modelling approaches can be used for different objectives.

In the case of the UNESCO/IHA Greenhouse Gas (GHG) Research Project, empirical predictive models can be developed with the goal to assess the vulnerability to gross/net GHG emissions, and be used as screening tools to identify new sites or new reservoirs to be investigated. Process-based models can be very useful to understand GHG generating processes in system scale considering meteorology, hydrodynamics and trophic structure, mass balances, space and time dynamics, GHG production and watershed uses relationships, comparison of the impacts of different alternatives, and also to evaluate potential mitigation measures for vulnerable sites.

Several models are already being developed by different research teams, under different approaches:

- Mass balance, empirical or process based;
- General or site-specific;
- Distributed or concentrated;
- Other alternatives

It was recognised that it is important to correctly identify the needs of the Project, in order to select the most appropriate approaches for each different objective.

4.2. Outstanding issues

The need for guidance on objectives of different models approach was identified, in order to properly define what sort of models should be used. The following main groups of models were described:

Mass balance

Advantages: provides quantification of individual sources and sinks; indirect estimate for GHG emissions; more feasible for smaller reservoirs;

Disadvantage: huge amount of data; difficult to collect some of the needed data; does not include dynamics of the system; should not be considered as predictive modelling (it is not possible to extrapolate the results to other reservoirs);

Empirical

Advantage: can be applied to other reservoirs with minimum information; can be used as a screening tool (estimation/qualitative); Not time consuming;

Disadvantage: does not provide gain for understanding of processes; might not extrapolate beyond limits of the model calibration (input data);
Deterministic (process-based)

Advantage: test the understanding of processes; test of mitigation options, rates and mass space distributed, predictive, test of scenarios, including reservoir operation, watershed uses, mitigation processes in lake and watershed, and climate changes;

Disadvantage: site specific input data (calibration); time consuming and expensive;

4.3. Next steps

As a result of the discussions, the following activities were outlined as the most urgent:

- Establishment of an expert panel from different fields to evaluate the models and simulations;
- Evaluation of the use of published developed models (available free of charge);
- Development of a comparison exercise, including different available models:
  - Participatory exercises can be performed at project base, involving people from the very beginning;
  - There is a need for basic knowledge on modelling in the group to perform the exercise, implying the necessity to provide training courses;
  - Development of guidelines for the comparison exercise, including data base structure and type of information.
- Availability of a common data set to test models, including watershed and reservoir data.

5. Quality Assurance, Quality Control and Capacity Building Needs

The main discussed aspects included Quality Assurance, Quality Control (for measurements and estimations of GHG emissions/carbon balance) and Capacity Building Needs.

5.1. Overview

The Guidelines set out broad principles for Quality Assurance/Quality Control (QA/QC). In short, a QC/QA programme contributes to improve transparency, consistency, comparability, completeness, and confidence in any study programme, taking into consideration that:

- Quality Control (QC) is a system of routine technical activities to measure and control the quality of the inventory as it is being developed. QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardised procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting.

- Quality Assurance (QA) activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews verify that data quality objectives were met; ensure that the inventory represents the best possible estimates of emissions and sinks given the current state of scientific knowledge and data available; and support the effectiveness of the QC programme.
QA and QC should operate on feedback loops, where QC mechanisms should reflect desired outcomes of project, while QA evaluates final product quality against the desired outcomes. Any systematic deviations of final product from its desired outcomes should lead to QC systematic changes.

5.2. Outstanding issues

It was agreed that the QA/QC programme must be designed to ensure that the application of the procedures does not deviate from existing standard methodologies.

It is important to clearly evaluate each project’s characteristics and peculiarities to properly apply the available methodologies to specific projects. The main aspects to be considered are:

- Avoiding Needless complexity;
- Need to account for national implementation, while applying universal principles;
- Need to establish basic QC procedures around core measurements, for all GHG species under evaluation: CO₂, CH₄, N₂O;
- Need to establish minimum required measurements and standards, with ‘options’ for further measurements;
- Need to develop control mechanisms for validation of measurements.

5.3. Next steps

The most pressing activities for QA/QC were identified as:

- Development of detailed Standard Operating Procedures (SOP) for core measurements, to be provided as a separate annex, to complement the GHG Measurement Guidelines and to guide the use of this document (in a second edition it can be integrated in the guidelines);
- The SOP to be broken down into different elements for each gas (CO₂, CH₄ and N₂O) and source (diffusion; bubbling; degassing etc.) such as: monitoring schedule; measurement procedure; equipment and calibration; Field data collection and checks; Database; Data storage and retrieval; Calculations.
- Feedback loops for Guidelines and emerging alternative methods
- to establish sub-group(s) on QA/QC and calibration / controls specific to core measurements: SOP’s need to be developed and circulated for peer review

There is also the need to develop Capacity Building tools, under the following course of action:

- UNESCO / IHA to prepare training course on guidelines;
- Course will ‘train trainers’;
- Target: international or regional training depending on demand;
- Teaching opportunities (expressions of interest from project members);
- Identify Funding opportunities;
- Define need and rules for Certification;
- Define need and rules for training for consultant companies.
6. Deliverables

The products of this workshop are:

- Workshop documentation (Proceedings, Summary of the discussions);
- Input to develop the format and structure of the Database;
- Input to define the criteria for selecting representative reservoirs to be included in this research;
- Input to establish the modelling approaches to be selected/developed/applied under the UNESCO/IHA GHG Research Project;
- Main criteria for Quality Assurance, Quality Control and Capacity Building Needs.
ANNEX 1 – Meeting Agenda
Science, Technology, and Policy Summit on Carbon Cycling in Water Storage Reservoirs Workshop
Hosted by Oak Ridge National Laboratory in collaboration with the UNESCO / IHA GHG Project
August 2 - 4, 2010

August 2, 2010, Day 1

8:00 Depart from Doubletree Hotel arrive Building 5200

8:15 Registration and Information Distribution 2nd floor Lobby
Becky Rumbaugh, Facilitator
Lindsey Amason, Administrative Assistant

Breakfast 2nd floor Lobby

9:30 Welcome and Introductions Room 202c
ORNL Welcome and Carbon Cycle Research Overview – Gary Jacobs, Director, Environmental Sciences Division
ORNL Support of DOE Water Power Program - Brennan Smith
EPRI Water Power Program Overview – Doug Dixon
National Hydropower Association – Jeff Leahey
Participant Introductions

11:00 Hydropower and Water Quality Assessment in the U.S.
Regional Summaries of Hydropower Characteristics – Boualem Hadjerioua, ORNL
Water Quality Assessment in the U.S – David Clow, USGS.
Questions and Answers

12:00 Lunch 2nd floor lobby

13:00 Environmental Regulation and Management of U.S. Reservoirs Room 202c
Licensing and Regulation of Non-Federal Hydropower, John Baummer, FERC
Reservoir Management by Non-Federal U.S. Hydropower Asset Owners (East) – George Martin, Georgia Power
Questions and Answers

14:00 Water Quality in Federal Hydropower Operations
Questions and Answers

14:30 Afternoon Break & Discussions 2nd floor lobby

15:00 Water Quality Tools and Technology Room 202c
Reservoir Water Quality Investigations and Mitigation Technology – Boualem Hadjerioua, ORNL
Questions and Answers

15:30 ORNL Reservoir GHG Investigations
Greenhouse Gas Emissions from a Temperate U.S. Hydropower Reservoir - Jennifer Mosher, ORNL

16:00 Summary and Wrap-Up
Summary of Issues Discussed – Brennan Smith, ORNL

16:30 Adjourn
FOM MEASUREMENT TO MODELLING: INTERFACES BETWEEN THE FIELD DATA AND THE PREDICTIVE MODELLING TOOLS

August 3, 2010, Day 2
8:00 Depart from Doubletree Hotel arrive Building 5200
8:15 Breakfast 2nd floor lobby
9:00 Opening Room 202c
ORNL Support of DOE Water Power Program - Brennan Smith
UNESCO/IHP – Miguel Doria, UNESCO/IHP
9:10 Schedule and Objectives of the Workshop
Update on the UNESCO/IHA GHG Research Project
The GHG Measurement Guidelines for Freshwater Reservoirs - Joel Goldenfum, IHA
9:45 Field Measurement and Database Issues
Julie Bastien, Environnement Illimité – Canada
Marco Aurélio dos Santos, COPPE-UFRJ – Brazil
Fréderic Guérin, LMTG – France
10:45 Modeling Issues
Elizabeth Sikar, Construmaq São Carlos – Brazil
Vincent Chanudet, EdF – France
David Motta-Marques, IPH/UFRGS – Brazil
11:45 Lunch 2nd floor lobby
12:45 General Discussion of Presentations
13:15 Group Discussions rooms 202c (42 seats), 202b (50), 214 (19), 212 (7)
15:00 Afternoon Break & Discussions 2nd floor lobby
15:30 Group Discussion Presentations rooms 202c
16:30 Adjourn

August 4, 2010, Day 3
8:00 Depart from Doubletree Hotel (arrive Building 8600)
8:15 Breakfast room C150
9:15 Opening and Group Discussion Designations room C156
9:30 Group Discussions: rooms C150, C152, C156
Database Structure
Representativeness of Reservoirs
Predictive Models
Quality Assurance/Quality Control and Capacity Building Needs
11:00 Group Discussion Presentations room C156
12:00 Lunch & Discussions room C150
13:00 Concluding Discussions room C156
14:30 Afternoon Break & Discussions room C150
15:00 Closure room C156
16:00 Adjourn room C156