Building Capacity in Water Quality Modelling in South Africa

Report on a U. S. - South Africa Binational Commission training visit by staff of Ninham Shand, Department of Water Affairs & Forestry and Umgeni Water to the United States of America, September 2001

UMGENI WATER - AMANZI

INSTITUTE FOR WATER QUALITY STUDIES
DEPARTMENT OF WATER AFFAIRS AND FORESTRY

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Authors:	M J Silberbauer, J N Rossouw, W Kamish, K Chetty, S Hadebe and D Wildemans
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Mike Silberbauer, Kama Chetty, Wageed Kamish, Sli Hadebe & Nico Rossouw in Portland, OR

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Introduction

Statement of appreciation

On the second day of the course, the 11th of September, a horrific attack took place on the World Trade Center in New York and the Pentagon in Washington, DC. More than 5000 people died. As guests of the American government and people at the time, we came to appreciate the sense of grief and anguish in the days that followed the attack. We appreciate the willingness and dedication of the course presenters, Tom Cole and Scott Wells, their support staff and government officials who continued, as far as possible, with the scheduled programme, under the immensely stressful conditions prevailing after 11 September. Their efforts meant that we achieved almost all our goals for the training visit.

Background

In South Africa, integrated water resources management is an important aspect of the 1998 National Water Act. Successful implementation of the Act is dependent on having the right tools available to support water resources decision-making and competent people to apply these tools. South Africa, like other semi-arid countries, has large numbers of reservoirs to assure water supply for agricultural, industrial and domestic use. In many reservoirs, water quality has deteriorated as a result of increasing salinity, nutrient enrichment and bacteriological pollution upstream. Reservoir water quality models provide water resource managers with cost effective tools to understand the behaviour of reservoirs, anticipate water quality problems and to evaluate the effect of alternative management actions for time scales and on spatial scales that are not feasible for field studies.

For the past twenty years, reservoir water quality modelling in South Africa has tracked developments in the United States, usually lagging behind by several years. The CE-QUAL-W2 model is one model that has a good track record and has been applied successfully on reservoirs in South Africa, for example on the Buffalo River, Olifants River, Inanda Dam, Vaal Barrage and Witbank Dam. In recent years, though, South Africa has lost key reservoir modellers to Australia and Canada.

The purpose of this visit was to obtain training in the CE-QUAL-W2 model and to visit people in the USA who had used the model. The opportunity was also to be used to meet with agencies with

general experience in monitoring water resources, and to study the US National Hydrography Dataset (this stores data about every river reach in the USA and provides essential basic information for many models). Funding was secured from the U. S. - South Africa Binational Commission for four people to attend the CE-QUAL-W2 course, and from the South African Department of Water Affairs for one additional person to attend the course, and one to take part in the post-course visits.

(More details available on the Ninham Shand web site: http://www.web.shands.co.za/Hydro/BNCVisit/Private/Main.htm)

Explanation of funding sources

Although the bulk of the funding for this visit came from the U. S. - South Africa Binational Commission, the South African Department of Water Affairs paid for two of the delegates. The following diagram unravels the funding sources (Dark shading = U. S. - South Africa Binational Commission, light shading = Department of Water Affairs [DWAF]):

Delegate	Affiliation	Week 1 (CE-QUAL-W2 model)	Week 2 (US Water Institutions)	Week 3 (National Hydrography Dataset)
Nico Rossouw	Ninham Shand			
Wageed Kamish	Ninham Shand			
Slindokuhle Hadebe	Umgeni Water			
Michael Silberbauer	DWAF			
Kama Chetty	DWAF			
Danieël Wildemans	DWAF			

Portland: CE-QUAL-W2

Purpose of visit

Version 3.1 of the CE-QUAL-W2 dynamic reservoir model, incorporating many enhancements, is maintained and distributed by Portland State University in Oregon. The South African delegates attended the university training course from 10-14 September 2001 in order to learn how to run and interpret the model.

Achievements

The course provided a comprehensive description of the theory and mathematics behind the CE-QUAL-W2 model, and a series of hands-on workshops where users could perform model runs using various settings for controlling variables. The group gained valuable experience in how to set up the control files and how to differentiate between "finger trouble" and real bugs in the software. The grounding of the entire US airline fleet meant that many of the planned seminars by various users from around the USA had to be cancelled. Jack Harrison drove through the night from Idaho to discuss applications on the Brownlee Reservoir and Lower Snake River. Stewart Rounds from the Portland USGS office stepped in to fill one of the gaps, with a presentation on the Tualatin River. Gabriela Friedl, a Swiss limnologist on the course, discussed the use of the model on the lower Danube.

Rob Annear discusses details of CE-QUAL-W2 with K. Chetty and S. Hadebe

Visits to agencies

Washington D.C. (M. Silberbauer, K. Chetty, D. Wildemans)

EPA

D. Wildemans and K. Chetty at the White House

On the 17 September K. Chetty and D. Wildemans met with Paul Cocca of the BASINS development team at the offices of the U.S. Environmental Protection Agency (EPA) in Washington (Because of the cancellation of flights to Washington's National Airport, M. Silberbauer was not able to attend this meeting). Paul Cocca gave us a quick fly-through the application and operation of BASINS, paying particular attention to its application in policing Total Maximum Daily Loads (TMDLs). The enhancements in the BASINS software over the past few months had left K. Chetty with many questions for Paul who was more than eager to point him in the right direction.

After the question and answer session with Paul Cocca, it was time to meet with David Wells, also a Hydrologist of the BASINS development team but whose key focus areas are the SWAT and QUAL-2E models. This session proved to be very informative as we became exposed to many of the Soil and Water Assessment Tool's (SWAT) capabilities, which we previously could not explore due to the unavailability of ESRI's Spatial Analyst software at the IWQS. Both Paul and David emphasised the application of BASINS and its related suite of models for evaluating best management practice options. Our discussions also highlighted the need in South Africa, as elsewhere, for adequate and good quality monitoring networks and data as many of the management tools place a high demand on data like solar radiation, time series of water quality and meteorological data. Due to the limited time at the EPA not all our requirements for advice could be satisfied so Paul and David offered their future support via E-mail. David also made the offer to obtain Spatial Analyst at a very reduced cost for the Department from the developers.

[2001-09-18 and 2001-09-21 were open days.]

USGS (I)

Lory Solley (USGS), D. Wildemans, K. Chetty

Lory Solley of the USGS prepared a comprehensive series of meetings with USGS staff on 2001-09-19 and 20, at their offices in Reston, Virginia. On the first day, Jim Peters of the Director's Office welcomed us with an overview of the USGS and its programmes. Ken Lanfear and Lorna Schmidt gave some illuminating insights into the presentation of data and information on the Internet, especially in the areas of planning, accessibility and data consistency. David Stewart introduced the DBView application, an Arc/Info GRID-based utility for data extraction and catchment model input. Finally, Keven Roth explained the National Hydrography Dataset and gave some hints on management (D. Wildemans arranged to have further discussions with her the following week).

On the second day at the USGS, Kernell Ries gave a formal presentation on a regression equation front-end for the state of Massachusetts, which will soon be available nation-wide. Richard Alexander

and his colleagues, Mike Erardi and Dick Smith, demonstrated the SPARROW model, which helps to determine the origin and final destination of contaminants in water (this was our first look at SPARROW, and it looked like a very useful system). Glenn Patterson highlighted the advantages and pitfalls of real-time water quality monitoring: while the ability to monitor events as they happen is useful in critical catchments, some probes do not calibrate well, and the capital and running cost of a really good remote system approach those of a conventional laboratory. The last talk was by Walton Low, who explained how all the information collected by USGS programmes (for certain regions) is synthesised into national assessment reports on a ten-year cycle.

On Saturday 2001-09-22, D. Wildemans and M. Silberbauer rented a car with the optimistic aim of seeing the whole of Chesapeake Bay. This estuarine system features in many international reports and papers, and they hoped to be able to draw comparisons with South African systems. After half a day on highway 50, they had progressed less than quarter-way around the Bay and had to turn back. The Blackwater National Wildlife Refuge was the main stop. This park comprises mainly swamp forest and looks very different from most of South Africa's wetlands. They had an unexpected meeting with a local reptile, believed to be a Northern Black Racer (*Coluber constrictor constrictor*). Apparently this is not a venomous species, but one cannot be too careful... its recently-shed skin was two metres long. Snakes apart, the message picked up on this excursion was that one must be extremely careful when comparing African and American aquatic ecosystems.

USGS (II)

D. Wildemans stayed on in Washington for a further week: the original plan was that she should spend the whole week at the USGS to work on the National Hydrography Dataset and project and river reaches with Keven Roth (USGS Geomatics). The disruption to everyone's schedules caused by September 11 meant that she had to be content with a shorter but highly intensive tutorial session with Keven Roth on 2001-09-27.

Keven Roth demonstrated the User Interface operation for the National Hydrography Dataset and it was clear that their hard work of the past 10 years has paid off. They are a group of enthusiastic people and are passionate about what they have achieved. The National Hydrography Dataset has a very comprehensive website that provide information about surface water features such as lakes, ponds, streams, rivers, springs and wells. Within the National Hydrography Dataset, surface water features are combined to form “reaches” which provide the framework for linking water-related data to the National Hydrography Dataset surface water drainage network. These linkages enable the analysis and display of these water -related data in upstream and downstream order.

The importance of a National Hydrography Dataset:

a) Provides a single system for everyone to use and this allows for interagency compatibility between GIS projects.

b) The maintenance of a national coverage allows all users to benefit from the enhancements made by others.

c) A national coverage provides stability and ensures “Institutional Memory” for work performance using the national standard.

d) Using the national standard ensures a readably accessible replacement for coverages that are inadvertently damaged during processing.

D. Wildemans got the reassurance from Keven Roth that the effort by the GIS team at the Institute for Water Quality Studies to spatially correct South Africa’s 1:500 000 rivers coverage is a good starting point to get a River Reach-project running, and to establish a dataset similar to the US National Hydrography Dataset.

USBR, USGS, TVA (N. Rossouw, W. Kamish, S. Hadebe)

Nico Rossouw of Ninham Shand has kindly provided this record of the visits undertaken by himself, Wageed Kamish and Sli Hadebe. Please contact him directly (nrossouw@shands.co.za) for information about this leg of the USA visit.

Salt Lake City, UT: US Bureau of Reclamation: Water Quality Group, Technical Services & Dams division

Date:	17 September 2001	
Hosts:	Jerry Miller	Water Quality Hydrologist
	Amy Cutler	Civil & Environmental Engineer
	David Trumann	
	Robert Radtke	

The discussions with Jerry Miller and Amy Cutler focused on the application of the CE-QUAL-W2 model to reservoirs.

Discussions with Jerry Miller focused on the importance of understanding the physical and chemical processes that govern water quality in a specific reservoir because it helps a modeller make intelligent decisions about which parameters to adjust during the model calibration process. He also suggested that doing a sensitivity analysis on the model would help identify those processes that should receive more attention. He felt strongly that modelling should guide field data collection because it can identify which processes are important in a specific reservoir. We also discussed internal sources of nutrients and it appears that bacterial decomposition can often be a source that is overlooked. He also led a discussion on selective withdrawal structures and how modelling can help in the design of these structures by predicting the in-lake and downstream impacts. He illustrated this with examples from the Jourdanelle reservoir, a reservoir that supplies drinking water to Salt Lake City.

Amy Cutler gave a presentation on her work on Lake Powell to evaluate the effect of a temperature-compensating device (TCD) on in-lake and downstream water temperatures. Lake Powell only has a bottom outlet which discharges cold water into the Colorado River downstream of the reservoir. The objective of installing a TCD is to selectively draw water from a shallower depth (warmer water) for discharge into the Colorado River, thereby creating a more favorable habitat for the return of native fish species in the Colorado River. She worked closely with Blair Hanna of the USGS in Fort Collins who developed optimization code for the CE-QUAL-W2 model.

David Trumann gave a presentation on the salinity management programme in the lower Colorado River. Water is used extensively for agricultural purposes in the lower Colorado River, leading to an increase in salinity to such an extent that dissolved salt concentrations of 1000-2000 mg/l are measured at the US-Mexico border (<450 mg/l is regarded as ideal for drinking water). About half of the additional salt comes from natural sources (evaporation) and about half from agricultural sources. Their programme is aimed at maintaining salt levels at less than about 880 mg/l at a specific point in the river. They have been able to quantify the damage that elevated salts cause to crops very well so that rehabilitation costs can be offset against salt damage costs. The program has been successful in reducing salt loads and reducing rehabilitation costs.

Denver, CO: US Bureau of Reclamation: Land Suitability and Water Quality section

Date:	18 September 2001	
Hosts:	Merlynn Bender	Environmental Engineer
	Robert George	Water Quality Engineer
	Alan Harrison	Environmental Engineer

The meeting was started with a presentation by Nico Rossouw on the water resources situation in South Africa and the need to model reservoir systems. The group then discussed a number of water quality modelling topics. These included discussions about different watershed modelling systems (WARMF, BASINS, AGNIPS and RIVERWARE) that are in use in the US and how these relate to reservoir modelling, pre- and post processors to the CE-QUAL-W2 model which included AGPM developed by Loginetics in Knoxville (Gary Hauser), W2 Studio that was developed by Edinger &

Associates and a system developed by Brigham Young (no name yet) which helps a user to quickly develop the bathymetric data for the CE-QUAL-W2 model. The Brigham Young system was also referred to in discussions with other groups and people felt that it was one of the more useful support tools that were developed recently for the CE-QUAL-W2 model.

The group also discussed river models (ADYN/ARQUAL and ARMIS), a model to simulate the effects of bottom growing periphyton (DSSAMPT) and a model to simulate stream temperatures (SNTEMP) that was developed and are being used by the USGS. A discussion followed about the use of steady state models rather than dynamic models. It was concluded that steady state models are fine for rough estimates of water quality changes but that they have limited application during the wet season when flow and quality changes rapidly. The meeting concluded with a discussion of a document that Merlynn Bender produced for the meeting on data collection and planning the modelling process. This provided some a number of good guidelines to the process of modelling a reservoir system.

Fort Collins, CO: US Geological Survey: Midcontinental Ecological Science Center

Date:	18 September 2001	
Hosts:	John Bartholow	Ecologist
	Blair Hanna	Engineer

The meeting at the Midcontinental Ecological Science Center was originally scheduled for Wednesday morning. However, the check-in time at Denver airport was increased to at least two hours due to increased security, which would have reduced our meeting in Fort Collins to about 1.5 hours. John Bartholow agreed to move the meeting forward to Tuesday afternoon even though one of his staff members who was due to meet us, could not be present. The group therefore met with John Bartholow and Blair Hanna who were very well prepared for our meeting.

We discussed the application of the CE-QUAL-W2 model to Shasta Lake in detail. Shasta Lake was a large hydropower project built and operated by the USBR in California. The USBR wanted to change the operation of the reservoir to accommodate the requirements of Chinook salmon downstream of the dam. They needed to evaluate the in-lake impacts of releasing colder water in summer and fall from low-level outlets and releasing warmer water in winter and spring from the high level outlets. A temperature control device was installed at the dam at a cost of $80 million. The CE-QUAL-W2 model was applied to assess the effect of changed operations on in-lake fisheries. We discussed this application in depth, especially the temperature calibrations and what type of data was required for the modelling.

Blair Hanna then discussed the optimisation of dam operations to meet downstream temperature targets for Shasta Lake and for Glen Canyon Dam. The optimisation routines he developed were a unique application of the CE-QUAL-W2 that has not been attempted previously. It demonstrated how the model could be used to support operational decisions about reservoir releases while satisfying temperature and power generation objectives. This has potential for application in South African reservoirs where water is often user for multiple purposes (irrigation, domestic water supply, recreation etc.).

Knoxville, TN: Tennessee Valley Authority: Engineering Laboratory

Date:	20 September 2001	
Hosts:	Gary Hauser	Senior Technical Specialist
	Ming Shiao	Civil Engineer, Hydraulic Engineering

Gary Hauser and Ming Shiao have for many years been involved in two-dimensional water quality modelling of reservoirs which the TVA is responsible for. In the early years they used the BETTER model, a more simplified 2D reservoir water quality model developed at TVA. However, in recent years they have started to use CE-QUAL-W2 for all new model applications. The TVA uses 2D reservoir models to evaluate the in-lake and downstream impacts of different reservoir operating rules.

The group had a long discussion with Gary Hauser about the impact of reservoir operations on in-lake and downstream water quality. At TVA they have been investigating the water quality impacts of keeping reservoir levels higher into the winter months rather than drawing the levels down in early winter to create capacity for flood retention. The purpose of the higher reservoir levels was to satisfy the needs of recreational fishing and lakeside property owners. They were also working on improving water quality (temperature and dissolved oxygen) downstream of their hydropower dams to mitigate the tailwater effects on biota. Their work has focused on improving conditions downstream of dams but not optimising it. We discussed the process by which stakeholders were involved in the process of setting goals downstream of dams.

Discussions with Dr Ming Shiao focused on the application of the model to two reservoirs, J Strom Thurmand and Richard B Russel. The objective was to improve the dissolved oxygen in the middle layers of the reservoir (in the 18-24 °C zone) through changing the operation or release structures at the dam wall. The way in which this was accomplished in the modelling of the system was discussed.

Gary Hauser developed the AGPM (Animation and Graphics Portfolio Manager) software that is regarded as one of the best pre- and post processors that have been developed for CE-QUAL-W2. A version of AGPM has been developed for Version 3 but due to the recent changes in the input and output format of Version 3.1, the new version of AGPM has not been released yet. This software is being used at Ninham Shand and collaboration with Dr Hauser in this regard will continue.

Raleigh, NC: US Geological Survey

Date: 21 September 2001
Host: Jarred Bales

Due to disruptions in flight schedules, the early morning flight from Charlotte to Raleigh was cancelled. The team was then put onto a flight scheduled for later in the morning, which meant that we only arrived at the USGS at about lunchtime. Just after lunch, Nico Rossouw gave a presentation to staff of the Raleigh office on the water resources situation in South Africa. The presentation was well received.

After the presentation, discussions with Dr Jarred Bales focused on the application of the CE-QUAL-W2 model to Mountain Island Lake, a water supply reservoir close to Charlotte. The purpose of their project was to develop an understanding of water circulation and constituent transport in Mountain Island Lake in order to manage the reservoir more effectively and to predict water quality responses to changes in flow or constituent loads. We discussed how they went about setting up the model, how they calibrated the model and how different scenarios were evaluated and the results simulations presented.

A wide range of related topics were discussed which included estuary modelling (elevated nitrogen problems due to poor flushing of estuaries in North Carolina), the composition of modelling teams (minimum team is limnologist and water quality modeller), data collection techniques and calibration of field equipment, dissemination of modelling data and information, river water quality modelling and bacteriological water quality problems (finger printing pollution sources by means of DNA analysis).

Appendices

Documents

(Only selected US documents that may be of interest to others are listed here.)

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Cole, Thomas M. & Scott A. Wells (2001) Water Quality and Hydrodynamic Modelling Using CE-QUAL-W2 Version 3.1. Workshop Program. Portland State University, Environmental and Water Resources Engineering.

Cole, Thomas M. & Scott A. Wells (2001) A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.1. User Manual. U.S. Army Corps of Engineers Instruction Report EL-00-1.

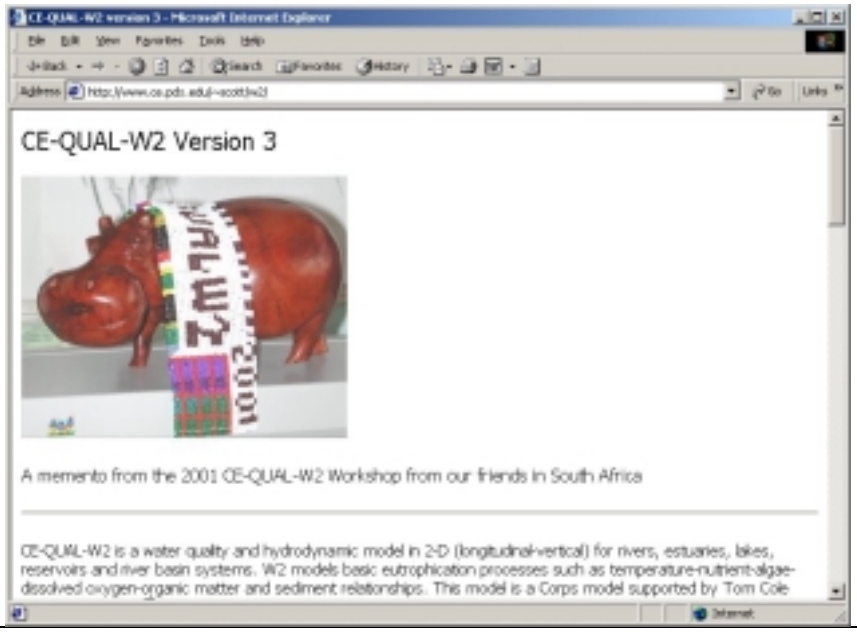
Multimedia

USGS and EPA (2000) National Hydrography Dataset Applications Symposium. University of Texas, Austin. Two CD-ROMs.

Stewart Rounds (2001) Using CE-QUAL-W2 and Animated Visualization to Better Understand Water Quality in the Tualatin River, Oregon. U.S. Geological Survey, Portland, Oregon, Seminar for the CE-QUAL-W2 workshop, September 14, 2001.

Contacts (visited by DWAF staff)

Name	Affiliation	Address	Phone, Fax	E-mail
CE-QUAL-W2 (http://www.ce.pdx.edu/~scott/w2/)				
Scott Wells	Portland State University	Department of Civil Engineering P O Box 751 PORTLAND, OR 97207 USA	+1 (503) 725-4276 +1 (503) 725-5950	scott@eas.pdx.edu
Tom Cole	US Army Corps of Engineers	Waterways Experiment Station 3909 Halls Ferry Road Vicksburg MS 39180-6199 USA	+1 (601) 634-3283	colet@wes.army.mil
EPA (http://www.epa.gov/)				
	Paul Cocca	Office of Science and Technology U.S. EPA 401 M Street, SW Washington, DC 20460 United States of America	+1 202-260-8614	cocca.paul@epa.gov
USGS (http://www.usgs.gov/)				
	Lory Solley	U.S. Geological Survey International Water Resources Branch 420 National Center Reston, Virginia 20192 USA	+1 (703) 648-6686	lseverin@usgs.gov



Beadwork by Johanna Sibanyoni