The use of modelling and reuse techniques in the development of water management systems in basins with limited water resources

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Abstract Drawing on experiences in New South Wales from 1950 to 1980 in modeling and re-use techniques in the development of desalination technology and its application in fresh water production for potable use, the paper describes how Australia realized its responsibilities in developing participative and sustainable approaches to land use and water resources management. An analysis of the lessons from the operation of the Bayswater zero-discharge power station significantly contributed to the debate on sustainable approaches, highlighting that no management policy of a water basin can be implemented without a model based on reliable data from all sectors (including the environment), and no management model can be implemented without the participation of all stakeholders. These ideals were reflected in the conception and establishment of the Murray-Darling Basin Commission. The Commission succeeded in bringing together all major stakeholders in this huge basin, though it took more than 15 years to do so. While widely recognized as one of the most advanced and successful experiences in integrated management of a drainage basin, it has still not achieved the reversal of many unsustainable agricultural practices, giving a clear indication of the difficulties and time required for producing sustainable solutions.
Keywords IWRM; sustainability; zero-discharge

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Introduction

I am aware that my paper will present some of the original sins of the narrow views of the Engineer looking back to the specific problems he has helped to address, often without being aware of the bigger picture, probably a mortal sin for the Executive Secretary of the Global Water Partnership (GWP), a network of the believers and practitioners of integrated water resources management (IWRM).

There is a reason for this. Professor Malin Falkenmark kindly invited me to present a paper at this Symposium, centered on Drainage Basin Security, during a meeting of the Technical Advisory Committee (TEC) of the GWP at the beginning of this year. Immediately after that we started discussing the paper she was preparing for the TEC called, “Water Management and Ecosystems: Living with Change”.

In the preamble, where Professor Falkenmark states that “Water resources have to be used to increase economic welfare but without compromising the sustainability of vital ecosystems,” she says:

> “Since the 1970s attention has been focused on the effects of water resources development on the environment and methods have been developed for environmental impact assessment (EIA) of water projects. Much less effort has been directed to assessing environmental impacts of water resources management strategies.”

That brought me back to reflect on my personal experience of the 1970s and 1980s and to the early attempts to manage and protect the Hunter Valley basin in New South Wales (NSW), Australia, through the development of a so-called zero-discharge water supply and management scheme for a coal-fired power station, and how it related to this statement. The track of my thoughts, while Professor Falkenmark and my GWP colleagues were discussing her paper, is in practice the subject of my paper. I hope you find this reflection on a specific struggle in addressing environmental issues, mainly from a one-sided technological perspective and trying to broaden the horizon, useful and relevant to the issues of the Symposium.

Experiences of water management in Australia's power industry

When I arrived to work in Australia in 1981, I had been involved for a number of years as a process engineer in desalination projects. This had been the period of development and consolidation of the desalination technology and the realization of the first significant desalination facilities, mainly for production of fresh water for potable use and mainly located in the Middle East.

Not that this is a modern technology. I have a drawing dating back to Ancient Greece of Greeks on a boat evaporating water to make drinking water (for twenty years I believed this image to be authentic, but it is not), an image of a desalination process dating from the time before the discovery of America, and another on the first applications on board a ship. But wider application of the technology only commenced after the Second World War, during the 1950s.

It was in fact at this stage that desalination techniques also started being used more and more in water reuse applications. In fact, normally in a sequence of users, water quality becomes lower and with a higher content of solids. Reuse or recycling is often only possible by removing some of the dissolved solids, thus applying a process of desalination.

I arrived in Sydney, in New South Wales, which had a development boom in the late 1970s, which unfortunately was soon to be followed by a serious and long lasting recession. Australia had been caught by the necessity to build additional power stations as quickly as possible so as not to hinder economic development.

In Australia, like in the US and South Africa, there is abundance of good quality steaming coal. In NSW coal-fired stations had been built mainly on the coast where seawater could be used as cooling water. These circumstances had been recognized as favorable from the water conservation point of view. On the other hand it also had become apparent that having to transport coal from the mines 200 km inland was environmentally unsound. Also, it was recognized that it would have been cheaper to produce electricity at the mines and transport electricity to the large centers on the coast like Sydney and Newcastle.

The amount of water lost via evaporation for cooling in a large coal-fired power station is colossal: the order of magnitude, obviously depending on size and load, is still about 1 m^3/sec. Obviously the quantity of salts left behind is also significant, many tens of tons of dry salt per day, even up to 100 tons per day.

You may notice how thermally efficient the desalination plants of the Middle East are, as in their so-called double purpose plants (i.e. production of power and fresh water); it is this lost vapor that, once condensed, constitutes the fresh water produced. It is a shame that economics and flexibility of operations have not allowed the development of a less wasteful technology in terms of fresh water loss.

So, Wallerawang Power Station, about 100 km to the west of Sydney, had been built, and then in the early 1970s one at Liddel, in the heart of the Hunter Valley which was fast developing as one of the prime wine producing regions in Australia.

I think there was not much consideration about availability of water resources when Liddel was built (I tried to obtain the Environmental Impact Study (EIS) for Liddel and two other stations I will mention later, as so I could refer to them, but was unfortunately unable to do so). A lake, Lake Liddel, was formed in which water from the Hunter River was stored. To protect the quality of the Hunter River the lake also received the station blowdown. Not surprisingly the salinity of Lake Liddel started increasing at an alarming rate.

When construction of an even larger power station next to Liddel was decided in the late 1970s, Australia had already woken up to the critical state of its fragile environment. The salinity of the Murray River had already shown its ugly face and the first bolts of the Murray-Darling Commission were being tightened. The population at large had embraced the environmental cause and huge campaigns were undertaken, not always well informed or directed, but certainly in the very positive overall direction of establishing an environmentally responsible nation.

It was clear that the new station, Bayswater, 4 × 660 MW, would only be acceptable under strict environmental safeguards. New efficient fabric filters for flue gases were designed and so on, but the most critical issue was water. The Hunter Valley was rapidly developing its tourism, hand-in-hand with the wine industry. It became apparent that an approach *à la* Liddel would not be sustainable and in any case, that the Hunter River would not be able to supply enough water under all conditions of load and forecasts of recurring drought periods. To make things worse, a prolonged period of drought never experienced before, showed that conditions even worse than those presently considered in the EIS could occur, so that the EIS had to be revised. This unreliability of statistical data is unfortunately becoming a reality in our times of climate change.

Zero-discharge concept

A bold decision was then taken: the station could only be developed by applying a new concept, made possible by the application of seawater and brackish water desalination techniques in the field of water reuse. This is the zero-discharge concept. In Bahrain, in the world conference on desalination of 1981, for the first time there was a lot of talk about a large plant not intended for production of fresh water for potable use, that is, Bayswater.

In principle this is simple, but by definition not sustainable. This concept had been already applied once in the USA (San Juan Power Station) and was being considered in South Africa.

In Bayswater the ambition was even larger: to design a water management scheme also capable of improving Lake Liddel at the same time and to provide a mix of technologies which could minimize the blow-down, which meant being able to fully recycle under the worst conditions of water quality and load possible, maybe not even foreseen as the recent drought had shown.

The simplified scheme of Bayswater shows that it was originally thought that a line to carry the slurry of concentrated salts to the sea would be built. But to absolutely minimize the use of water (and for economic and public relations reasons) it was decided to use it for wetting the ash, which was being stored in a lined disposal pit practically on site.

The interesting thing is that the scheme was trying to capture all the possible operating conditions without affecting the environment or having to reduce the load, but was designed for only a handful of operating conditions. The scheme was conceptually given all the options to cover certain conditions, but not the tools to know its real limits of operation or how to optimize its running as one integrated system.

It was only after the plant was already operational that a full simulation model was developed and the real operational limits and conditions could be explored. It was only then that the plant operators had the driving tool for programming and running the plant in the most efficient and conservative way.

Needless to say, a simulation model like this was rather complex with a huge number of equations to be solved on an iterative basis. In these cases there is often a problem of numerical convergence of such a process to the required meaningful solution. Luckily enough, with water systems we have a well known fluid that is often satisfactorily described in terms of mass balance. So, provided techniques which simulate the system numerically are used as a sequence of nodes corresponding to the physical elements of the Process Flow Diagram, i.e., when the direct relationship between the physical scheme and the numbers representing it is not lost, the model normally behaves well and converges to a meaningful solution – as when a plant would be started and would be able to converge to its steady state. This is not always the case when the unit operations and substances of the typical chemical engineering processes are concerned.

Indeed, the Bayswater model was validated by showing its capability to converge and predict the actual operation of the water management scheme with acceptable accuracy under all the actual running conditions experienced, so that it could be used with confidence in extrapolating and simulating any possible conditions or emergency situations. This meant that a more meaningful discussion could be entertained with other authorities and entities dealing with water supplies for human consumption, tourism, agriculture (the wine industry in particular) and the industry of Newcastle including one of the largest Australian steel making complexes. The potential was there, including the use of the Bayswater scheme and the associated model as a management tool within the integrated management of the Hunter River basin.

Bayswater reviewed

So, was Bayswater a success? All considered it probably was, even if it never lived up to its potential. It certainly contributed significantly to the debate and the maturing of more sustainable approaches.

What is incontrovertible is that the NSW Electricity Commission, as it was called in those days, listened to the general public demand and invested significantly to apply the most advanced technology of the time in an effort to minimize the use of water and protect the environment. On the other hand, until I left Australia in 1995, the station management in reality perceived its prime responsibility still to be to produce power at the cheapest possible cost under all circumstances rather than, for instance, try to improve the quality of Lake Liddel as no mandatory environmental targets were enforced. This became even more evident in the 1990s when all power stations in NSW started to compete to be able to feed the state grid.

In particular, notwithstanding the original intention and the capability of Bayswater to operate as a zero-discharge scheme, it had been granted permission to discharge to the Hunter River up to the maximum salinity admissible in the river at any point in time on the basis of the capability of dilution of the river. With this, there was no real incentive to operate as a zero-discharge scheme and it was easier and cheaper for the management of the station to negotiate the maximum discharge into the Hunter River whenever there was just enough dilution capacity than to run the full scheme and to ensure zero discharge. I do not remember if there was a fee associated with this discharge into the river, but if there was it was obviously cheaper than running the fully recycling plant. Having said so, it is quite possible that this was also the most appropriate solution from the environmental point of view.

As I said, even with the ease of prediction given by the model, it was easy to detect when visiting Bayswater that there was no real planned operation to improve Lake Liddel and its quality kept deteriorating. In fact, the cost of operating and maintaining such a complex plant was such that very soon one of the treatment loops, the alkalinity reduction plant based on weak-cation ion exchange resin technology, was practically abandoned. There was the feeling that this occurred also because of the simple fact that a full simulating model had become only available when the scheme had been operating for some time and simpler practices had consolidated. The full commitment to match monitoring and forecast of water quality and prediction of load patterns in order to allow a real optimum running of the plant and improvement of Lake Liddel was never reached.

What became evident in the environmental debate was that for the protection of the whole drainage basin of the Hunter River, an integrated model based on reliable data on all actors, including the environment, was essential. Indeed, in general, no management policy of a specific drainage basin can be implemented without reliable statistical data and a model of the basin, including its major actors.

Bayswater was a first, and was considered the most complete and complex water scheme ever designed and built for a coal-fired power station worldwide, incorporating the latest technological advances in the desalination field like reverse osmosis (RO) and vapour compression (VP) units. Perhaps it was too complex. When a few years later a similar power station was to be built further south in the basin of the Fish River and the same concept of zero-discharge was applied, things went differently. As Bayswater had been built close to Liddel, this time the new power station, Mt Piper, was built close to Wallerawang. By the time Mt Piper had to be designed a detailed model derived from Bayswater was available. It was therefore, possible to simulate a full range of environmental and load conditions and choose the solution that appeared optimal from an economical, operational and environmental point of view.

As the salinity of water available in the Fish River basin was one quarter that of the Hunter River, this solution is based on just one step of treatment for reuse, a so-called brine concentrator, based on a vapor compression principle. It is just one of the three loops of Bayswater. Although an expensive machine to build and run, it is easier to run and maintain than a complex mix of technology to achieve the same task. Also, the Fish River had an average natural salinity lower than the Hunter River, which obviously created the conditions for a lower blow-down than in Bayswater, thus a lower volume of water to be treated for recycling. Indeed, as far as I know, Mt Piper has worked as a zero-discharge power station since commissioning about ten years ago. This, together with a subsequent power station in Western Australia (WA), Collie, is certainly an indirect benefit of the experience gained in Bayswater.

The need for integration

But the greatest limitation of Bayswater is that in the end it was managed and operated in isolation. In fact, in my opinion, the major challenge of IWRM, also shown by these early attempts at environment protection, is exactly the fact that it can only be realized through a partnership, a multi-stakeholder approach. Integration takes time and patience, is a non-exact science, is never concluded or fixed; in fact it is a process. So, even within the GWP we must be aware not only of the tendency of engineers to operate within a limited technological scenario, but also of the fact that there is always urgency out there – whether for economic development, for the protection of the environment, or ensuring that everybody, especially the poor, have access to water. And, unfortunately, it is difficult for “hurry” and “urgency” to go well together with “participation” and “sustainability.”

But there is no other way. This means the global community, not only the water one, needs to redouble its efforts in striving towards integrated and sustainable solutions, to have the intelligence and patience to try to build consensus of all actors at all times, even at times of growing pressure. Integrated water resources management is not a process which has a start or an end, or one where all actors can happily converge to a compromise solution, but it must be our reference goal and we must follow its continuous adjustment to make sure we create solutions which are more sustainable in a context of increasing pressure on water resources. This is certainly the most glaring missing link in what I have been describing.

In the case of Australia where its relatively scarce aboriginal population had managed to find a delicate equilibrium in a very fragile and water-starved environment, the continent suffered severely from unrealistic and foreign development expectations and criteria.

The painful waking up to a model based on unsustainable fundaments came quickly to the foreground of a community deeply proud of its uniqueness and environment, so that the assumption of responsibilities and social mobilization was as rapid as anywhere else in the world, and its politicians and technicians followed suit.

As a consequence, I am sure that few would dispute the pre-eminence of Australia in understanding the relationship between land use and water, or that the Australians, as I said, were among the first ones to embrace a vision of an environmentally sustainable world. The formative years were those of Bayswater, when the Murray-Darling Commission was also being conceived.

This remarkable effort towards integrated basin management has succeeded in bringing together all major stakeholders in this huge basin, but it took more than 15 years to do, and while widely recognized as one of the most advanced and successful experiences in integrated management of a drainage basin, it has still not achieved the reversal of many unsustainable agricultural practices for instance, and probably it could not do so in such a short time. This gives a clear indication of the difficulties of producing sustainable solutions through cultural change and mediation of different interests beyond the good will of single actors.

The result for Bayswater was an advanced technical solution that largely fell back into a sectoral operation because an integrated approach was not taken. In fact, the NSW Electricity Commission still did not have a structured link with other players like the Water Board or the agricultural, mining or industrial associations, universities and representatives of civil society.

Also, when I think of the zero-discharge concept which NSW was at the forefront in adopting, I wonder if it was adopted so quickly and with apparent ease because it also had a striking resemblance and relation with what John Williams – responsible for land and water at the CSIRO (Commonwealth Scientific and Industrial Research Organization) – calls one of the great myths haunting the Australian thinking (but not only the Australian thinking), "That water allowed to run to the sea is wasted". I believe there is a perfect resemblance of this conceptual node representing a zero-discharge solution, with its implicitly unsustainable accumulation of salts, with that of a river turned back inland for complete utilization of the water, thus losing, among other things, its natural function of flushing salts to the sea.

Concepts like minimum flows and, more recently, environmental flows and the environment are seen as just some of the multiple actors and users of a basin and are becoming more and more part of our immediate professional consciousness. For myself and many other people in NSW, the management of water resources in the basins where the coal-fired power stations were being built was our elementary school in the arduous path to understanding and pursuing integrated water resources management.

Conclusions

1. No management policy of a water basin can be implemented without a model based on reliable data from all sectors (including the environment).
2. No management model can be implemented without the participation of all stakeholders.
3. It takes a considerable amount of time to produce sustainable solutions through cultural change and mediation of different interests beyond the good will of single actors.