INTEGRATED WATER RESOURCES MANAGEMENT AND THE HYDROSOCIAL BALANCE

Dr. Stephen MERRETT
water resources consultant,
43 Anson Road, London N7 0AR, UK email: steve@tufpark.demon.co.uk

1. Introduction

Integrated water resources management (IWRM) seeks to integrate in many different ways: the social sciences with the natural sciences, planning with implementation, and groundwater with surface water, to mention just three such ways. The first objective of this paper is briefly to introduce a planning method that I call *the hydrosocial balance* and to show how it integrates supply, losses and use *quantities*, as well as the present with the future. The paper then shows how the hydrosocial balance can be developed to integrate water *qualities* with water quantities. The paper's third and final objective is to apply this management tool to a case study from the island of Jersey in the English Channel. The understandable restrictions on the length of the papers presented in Madrid have necessitated me covering the theoretical approach, the tabulation of the situation in Jersey and my conclusions. Persons wishing to see the fully detailed discussion of the Jersey case-study should contact me.

2. A new implement for the IWRM toolbox

In this section are recapitulated the main features of a water resources management tool, the hydrosocial balance, that I have developed in the last five years, a tool that until now has been limited to the analysis only of quantities.

The hydrosocial balance is a quantitative water resources planning method applicable in principle to any space with a defined boundary. This might be a house on the coast of Andalucía, Wembley football stadium, the island of Gorgona, the catchment of the Yangtse, the State of California, or the continent of Africa. Such spaces are referred to here generically as 'regions'. The hydrosocial balance's principal distinctiveness from the 'water balance' familiar to hydrologists is that the former incorporates (almost without exception) only outstream, *hydrosocial* flows, and never the *hydrological* flows of precipitation, groundwater recharge, run-off and rivers. The water flows it places at the centre of analysis and measurement are those directly created by humankind; the idea of a hydrosocial balance is derived from my concept of the hydrosocial cycle (Merrett 1997: 6-7). A hydrosocial flow represents a human activity. So the hydrological balance, composed as it is of hydrosocial flows, is understood primarily through the social sciences. In contrast the hydrological balance represents natural flows and is understood primarily through the natural sciences

The generic form of the balance for a specified region is given in Table 1. A baseline balance is for a past time-period, such as the year 2001. A scenario balance is for a future time-period such as the year 2007. The shift in the quantity in millions of cubic metres (Mcm) of any one category of supply or use between the baseline year and the scenario year can be represented as an absolute change as in column 4 of Table 1 or as an annual rate of growth or decline as in column 5. Detailed discussion of the concept as well as baseline balances for the Thames catchment and the Palestinian West Bank are published elsewhere (Merrett 1997: 15-22, Merrett 1999: 268-274, Merrett 2002: 148-182).

The baseline balance provides a comprehensive, synoptic account of the scale and composition of the supply sources of water and their use in the region it covers. Where measurement is accurate and comprehensive, the total net supply is always equal to total use. Scenario balances provide options for the future, based on the forecast need for outstream water in different uses and the possible allocation conflicts that may be foreseen. Once again, total net supply must be planned to equal total use. The absolute difference of supply, and of use, between the base year and a specific scenario year, and the associated annual rate of change provide the basic input to the planning of infrastructural investment, capital financing and demand management.

3. The bridge

The previous section focused entirely on quantity. In this section the bridge is built that links quantity to quality. Table 1 for a given base year or scenario year has more than a dozen supply-side and demand-side flows. All these flows plus the post-use flows of waste water (including irrigation drainage) can be reclassified into the five groups set out in Table 2. Note that in a region where there is no treatment of the water supply or of waste water, we have only groups one, three and four: the supply flow, the use flow and the waste water flow.

For any of the flows of Table 2 its complex quality can be assessed provided that a water institution has the skilled professionals and the laboratories to carry out the necessary analysis. At the most general level a flow's quality can be measured by applying four criteria to samples taken from the flow:

1. The individual inorganics present in the samples (such as arsenic, mercury and zinc).

2. The individual organics present (such as atrazine, malathion and 2,4-D).

3. The microbiological content of the samples (in terms such as faecal coliforms, pathogenic staphylococci and salmonella).

4. Other indicator measures (such as biochemical oxygen demand, total suspended solids and pH).

However, if we consider the hundreds of individual characteristics that can be generated by these four criteria, it would require a prodigious hydrochemical infrastructure to process comprehensively even a single sample from a single flow. So measurement always must be targeted, principally by considering the 'fit for purpose' needs of the analysis. That is to say, one reviews what the water flow under assessment is to be used for or to which location it is to be discharged. So, at the most elementary level, if we require that the water we are sampling has to meet drinking water standards as it will be pumped to domestic premises, then the water quality assessment is quite different from water that we plan to discharge to coastal waters.

In summary, the bridge crossing from the quantities of the hydrosocial balance to their qualities is built in the following manner. One recognizes *first* that the quantities of the hydrosocial balance fall into the flow types of Table 2; *second* that each flow's quality can be assessed in terms of the four criteria listed above; and *third* that the specification of the assessment should be based both on the resources available to carry it out and the fit-for-purpose requirements of the hydrosocial balance flows themselves.

This suggests a new term is required. Where we have a cross-tabulation for a specific hydrosocial flow with rows that refer to that flow's qualitative characteristics and with columns setting out the number of samples made and the measured concentration per litre or measured value of each characteristic, I shall call this *a quality matrix.*

Up to this point the text is at a high order of generality. The following sections 4-7 of the full paper (see section 1) record an attempt to apply theory to the island of Jersey as my fieldwork 'region'. Beginning with the geographical and hydrological background, the paper moves on to cover the supply-side of the hydrosocial balance, then the use of water in Jersey, and finally the complex issues of quality. The case study benefits from hydrogeological publications of great quality as well as a series of interviews with key personnel (see section nine).

4. Conclusions

With respect to the outstream flows of any defined region, whether or not it is a catchment, this paper has a central thesis. *Integrated water resource management is the planned transformation over time in the flow quantities of the region's hydrosocial balance alongside the purposive change of the quality matrix of each policy-priority flow.* My agenda here is to persuade IWRM institutions to take up this approach to the management of outstream flows. What remains to be done is to draw some lessons from the Jersey case study that will benefit planners who in the future follow this methodological path.

The hydrosocial balance. Jersey is a 'region' in the language of this paper, a space with a defined boundary. The fact that it is composed of many small catchments creates no problem. The year selected as the baseline is the most recent for which data is available. The scenario year does not appear in this case study because, at present, the island's water resource planners do not use this method and so there is no scenario year. My general view is that the scenario year should not be so close to the baseline year that it gives too little time for plan implementation nor so distant that the projection becomes an implausibility in the misty distance. A 5-7 year plan period is about right. The *hydrological* assumptions for the scenario year should reflect the region's long-term average. Since these assumptions are likely to be different from the actual conditions in the baseline year, the changes between say 2001 and 2007 (Column 4 of Table 1) will, in part, reflect the difference.

The row structure of the hydrosocial balance is always the same: the categories of supply composing total gross supply, the three entries for losses and storage change, and the categories of use. The column structure of base year, scenario year, absolute difference and rate of change are also a standard feature.

With respect to supply the Jersey data of Table 3 is structured principally by the actors responsible. This has advantages in policy formulation. The main difficulty is the unavailability of 2001 data on groundwater abstraction by private persons and surface water abstraction by farmers. This leads to a policy recommendation: that the island's authorities should begin to estimate these data on a regular basis, either by sample metering or by an interview-based survey. Constructing the hydrosocial balance for a region always leads to proposals for additional data collection. The same argument holds true for rainwater harvesting and for reuse, sources often neglected that may deserve policy initiatives. If these categories are not entered into the hydrosocial balance because the values are not known, they become invisibilized for the planner.

Turning to exports, losses and storage change, the Jersey story appears simple. There are no exports. Storage change is negligible (see section five). Loss estimation and reduction is a priority for the main supplier, the JNWWC. But no loss estimate exists for private abstraction. I used the water utility's 6% datum in this case.

With respect to use I discovered that the data is available separately for the two dominant sources of supply, i.e. the JNWWC and private actors. From both an analytic and a policy point of view this has its advantages. Unfortunately the classification of types of use differs between the sources, creating an adding-up problem. The researcher's choice of supply and use categories should always reflect the particularities of the region in which the work takes place as well as its planning focus. I was surprised to discover that 'private services' has the second largest recorded use after 'households'. This is explained by the vital role of tourism and financial services in the island as well as by the fact that (outside the polytunnel and glasshouse sector) irrigation is supplementary to the island's (877 mm average) rainfall. The main weakness of the use data is that for private actors it is based on a sample last made in 1989-91. The lack of registration, licensing and metering of private groundwater abstraction in Jersey deserves to be reviewed by the States' government. In fact the Water Resources (Jersey) Law to control abstraction and impoundment will be presented to the States in 2003.

The final comment on Table 3 is that an error term of 0.1 Mcm was added to total use to give equality with the total net supply figure of 10.2 Mcm. We know that, properly defined and accurately and comprehensively measured, total net supply is mathematically identical to total use. However, in practice any real life calculation will always contain a disparity. Unfortunately, with respect to Table 3 we cannot conclude that the error is only of the order of 1% (0.1/10.2). This is because the table is sure to contain self-cancelling errors.

Quality matrices

The principal methodological objective of this paper is to integrate quality with quantity, that is, to bring together quality matrices with the hydrosocial balance. In deploying matrices in the field the biggest challenge is to specify which of the potentially innumerable flows should be measured, given the high overhead and prime costs of quality assessment. I suggest that the key guidelines to such a choice are:

- The importance of any specific flow's quality in understanding how other downstream flows are polluted.

- The impact of any specific flow's quality on the environmental health of the region's population.

- The significance of a specific flow's quality on the natural environment.

Using Tables 2 and 3 I selected just five flows for discussion in the Jersey case. The first is irrigation returns with its recognized wide externalities. Here it is immediately clear that the hydrosocial flow has to be combined with farmland drainage sourced by rainfall; the two are not separable. Much is available on the sources of contamination of farm drainage and the relative importance of such contamination island-wide. But there appears to be no up-to-date quality matrix for this specific flow. Jersey's planners may wish to take action here, particularly in the light of the EU's nitrate-sensitive areas.

The second selected flow is groundwater abstraction by households for their domestic needs, because they are unconnected to the JNWWC's water supply network. These families are exposed to the aquifer in its polluted condition. This flow is monitored twice per year for its quality.

The third flow is households' discharge of their own waste water via septic tanks and soakaways and concerns households unconnected to the PSD's sewerage network. They may thereby pollute groundwater, for example with ammonia and faecal coli.

The fourth and fifth flows are the JNWWC's water supply and the PSD's discharge of waste water and stormwater to the Channel. These are the dominant hydrosocial flows of the island and are discussed at greater length in this paper. In both cases the quality matrices are detailed and informative. The main policy issues here are the nitrate content of the water utility's output and the move towards more stringent maximum admissible concentrations for the sewage treatment works at Bellozanne.

With these comments on constructing in practice the hydrosocial balance and the quality matrices of some of its flows, this paper is now complete. I hope that the research may be of practical use to the people and institutions of Jersey as well as suggesting to my professional colleagues throughout the world new ways of integrating water resource management.

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5. Persons interviewed

Rosemary Collier: States of Jersey Department of Agriculture and Fisheries
Nick Dotter: The Jersey New Waterworks Company
Jon Howard: The Jersey New Waterworks Company
Gerry Jackson: States of Jersey Public Services Department
Ralph Nicols: Groundwater Review Committee
Iain Norris: States of Jersey Department of Agriculture and Fisheries
Peter Redmond: The Jersey New Waterworks Company
John Rive: States of Jersey Environmental Services Department
Debbie Rowland: States of Jersey Public Services Department
Catherine Vint: Hamptonne Country Life Museum

TABLE 1: THE HYDROSOCIAL BALANCE FOR A SPECIFIED REGION IN A BASE YEAR AND A SCENARIO YEAR

IN MILLIONS OF CUBIC METRES

	BASE YEAR	SCENARIO YEAR	SCENARIO YEAR MINUS BASE YEAR (+ or -)	ANNUAL COMPOUND RATE OF GROWTH FROM THE BASE YEAR TO THE SCENARIO YEAR(%)(+ or -)
CATEGORIES OF SUPPLY				
Rainwater collection	**A1**	**A2**	**A2-A1**	**Ga**
Groundwater abstraction	**B1**	**B2**	**B2-B1**	**Gb**
Surface water abstraction	**C1**	**C2**	**C2-C1**	**Gc**
Desalination	**D1**	**D2**	**D2-D1**	**Gd**
Import of water from other regions	**E1**	**E2**	**E2-E1**	**Ge**
Internal reuse of wastewater	**F1**	**F2**	**F2-F1**	**Gf**
External reuse of wastewater	**G1**	**G2**	**G2-G1**	**Gg**
TOTAL GROSS SUPPLY	**H1**	**H2**	**H2-H1**	**Gh**
Supply leakage and evaporation	**-J1**	**-J2**	**(-J2)-(-J1)**	**Gj**
Export of water to other regions	**-K1**	**-K2**	**(-K2)-(-K1)**	**Gk**
Fall (+) or rise (-) in volume of water abstracted and stored	**+/-L1**	**+/-L2**	**(+/-L2)-(+/-L1)**	**-**
TOTAL NET SUPPLY	**M1**	**M2**	**M2-M1**	**Gm**
CATEGORIES OF USE				
Households	**S1**	**S2**	**S2-S1**	**Gs**
Agriculture	**T1**	**T2**	**T2-T1**	**Gt**
Mining	**U1**	**U2**	**U2-U1**	**Gu**
Manufacturing	**V1**	**V2**	**V2-V1**	**Gv**
Public services	**W1**	**W2**	**W2-W1**	**Gw**
Private services	**X1**	**X2**	**X2-X1**	**Gx**
Other uses	**Y1**	**Y2**	**Y2-Y1**	**Gy**
TOTAL USE	**Z1**	**Z2**	**Z2-Z1**	**Gz**

Note: Gj and Gk are calculated using absolute values of leakage and exports. Gl is not calculated because of the possible change of sign.

Source: Adapted from Merrett (2002) Tables 7.1 and 7.2.

TABLE 2: FLOW TYPES IN THE HYDROSOCIAL CYCLE

SUPPLY-SIDE FLOWS (a)		USE-FLOWS	WASTE WATER FLOWS (b)	
1	2	3	4	5
PRIOR TO TREATMENT	AFTER TREATMENT	AT THE POINT OF USE	PRIOR TO TREATMENT	AFTER TREATMENT

Notes. a. Includes supply leakage. b. Includes irrigation drainage.

TABLE 3: THE HYDROSOCIAL BALANCE OF THE STATES OF JERSEY IN 2001

CATEGORIES OF SUPPLY	Mcm
Surface water and groundwater abstraction by the JNWWC	6,2
Desalination by the JNWWC	1,1
Groundwater abstraction by farmers, households etc.	3,6
Surface water abstraction by farmers	not known
Rainwater collection net of evaporation	<0.1
Internal reuse	<0.1
External reuse	<0.1
Imports from other regions	0,0
TOTAL GROSS SUPPLY	10,9
Less: exports to other regions	0,0
Less: supply leakage and evaporation	-0,7
Change in volume of water abstracted and stored	<0.1
TOTAL NET SUPPLY	10,2
CATEGORIES OF USE	Mcm
Sourced by the JNWWC	
Households	4,5
Agriculture	<0.1
Manufacturing	<0.1

Public services		**0,6**
Private services		**1,3**
Other uses		**<0.1**
SUB-TOTAL	**6,5**	
Sourced by groundwater pumped by farmers, households etc.		
Households		**0,9**
Agriculture		**1,4**
Industry		**0,1**
Hotels and hospitals		**0,1**
Leisure		**0,8**
Other		**0,3**
SUB-TOTAL	**3,6**	
Irrigation water use sourced by farmers' surface water abstraction		**not known**
Irrigation water use sourced by rainwater collection		**<0.1**
Error term		**+0.1**
TOTAL USE	**#¡VALOR!**	

TABLE 4: A QUALITY MATRIX FOR THE JNWWC'S TREATED WATER SUPPLY IN JERSEY IN 2001

		Concentration				
	Maximum Admissible Concentration or Value (MAC)(2)	**Minimum**	**Mean**	**Maximum**	**Number of samples taken**	**% of samples > MAC**
INDIVIDUAL INORGANICS						
Nitrate	**50 milligrams NO3/litre**	**28,5**	**46,7**	**69,0**	**157**	**31**
Nitrite	**0.1 milligrams NO2/litre**	**0,001**	**0,037**	**0,219**	**155**	**12**
Chloride	**400 milligrams Cl/litre**	**54**	**73**	**90**	**155**	**0**
Manganese	**50 micrograms Mn/litre**	**<20**	**<20**	**65**	**157**	**<1**
Lead	**50 micrograms Pb/litre**	**<1**	**5**	**53**	**74**	**1**
INDIVIDUAL ORGANICS						
Atrazine	**0.1 micrograms/litre**	**<0.01**	**<0.01**	**0,013**	**10**	**0**
Simazine	**0.1 micrograms/litre**	**<0.01**	**<0.01**	**0,012**	**10**	**0**
Cyanazine	**0.1 micrograms/litre**	**<0.01**	**<0.02**	**0,12**	**52**	**1**
Mecoprop	**0.1 micrograms/litre**	**<0.01**	**<0.01**	**0,02**	**50**	**0**
Dalapon	**0.1 micrograms/litre**	**<0.01**	**<0.01**	**0,02**	**9**	**0**
MICROBIOLOGICAL STANDARDS						
Total coliforms (1)					**523**	**<1**
Faecal coliforms (1)					**523**	**0**
OTHER MEASURES						
pH	**6.5-9.5**	**7,2**	**7,4**	**8,3**	**229**	**0**

Turbidity (suspended solids)	**4 N.T.U.**	**0,08**	**0,27**	**1,5**	**154**	**0**
Colour	**20 Hazen units**	**<0.5**	**4,3**	**5,0**	**155**	**0**
Dissolved solids	**1500 milligrams/litre**	**230**	**389**	**485**	**153**	**0**

Notes: 1. Zone 1 - East. Random consumer taps and fixed points. 2. These all appear to be EU values but the source does not make this clear.
Source: JNWWC (2002): 28-30.

TABLE 5: A QUALITY MATRIX FOR THE PSD's WASTE WATER DISCHARGES TO JERSEY'S COASTAL WATERS IN 2002

		Concentration					
	Measure	**MAC in 2002**	**MAC in 2003**	**MAC in 2004**	**Actual 2002 Minimum**	**Actual 2002 Mean**	**Actual 2002 Maximum**
Biological oxygen demand	**milligrams per litre**	**50**	**25**	**25**	**6,3**	**8,2**	**13,4**
Chemical oxygen demand	**milligrams per litre**	**250**	**125**	**125**	**21,0**	**46,0**	**64,0**
Suspended solids	**milligrams per litre**	**150**	**45**	**35**	**11,5**	**18,5**	**29,8**
Total nitrogen	**milligrams per litre**	**none**	**20**	**10 or 15**	**not measured**	**not measured**	**not measured**

Note: Actual 2002 data are based on monthly averages for January-October

Source: PSD pers.comm.