A Tool for the Analysis of Policy Options for Off-Allocation Water in the Namoi River Catchment

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Abstract: The Namoi river catchment in northern NSW is an important irrigation region. Water resources in this region are increasingly stressed. Both surface and groundwater supplies are overallocated in many areas of the catchment. Management options to reduce allocations in line with available supply and environmental requirements are expected to have long term social, economic and environmental implications. One water resource, off-allocation water, is currently unallocated. This means that no user is currently given a property right to this resource and it is available for reallocation to alternative users, including the environment. This paper looks at an integrated modelling tool which has been developed to assess long term outcomes of management options for off-allocation water. The framework of this tool has been developed to be general enough for reapplication to water allocation issues in other catchments. Some preliminary results from the model are presented and their implications for management in the catchment discussed.

Keywords: Integrated modelling; Water allocation; Decision support system

1. INTRODUCTION

The Namoi River Catchment, covers approximately 42,000 km^2 in northern NSW and is an important irrigation area. Groundwater and surface water supplies are overallocated in many areas. Management options for dealing with this overallocation are likely to have significant social, economic and environmental impacts.

Water management and use falls into three main areas in the catchment: unregulated and regulated system surface water, and groundwater. Groundwater allocations for extraction in many areas of the catchment currently exceed sustainable levels. Surface water resources in the Namoi catchment have been divided into two classes for the purposes of management: regulated and unregulated water. The unregulated system consists of those subcatchments of the Basin which are above the major dams [Keepit, Split Rock, and Chaffey dam]. The regulated system consists of the river below these storages, including the Peel river below Chaffey Dam. Off-allocation water is water that spills from the dams, or that flows into the regulated system from the unregulated system It is not currently allocated to any specific users by a licence or other type of property right. Currently, this off-allocation water may be extracted when it exceeds users' demands and identified environmental needs. These off-allocation extractions are not counted against the users' licensed allocations [see for example DLWC,1999]. Off-allocation water is usually made available during periods of high river flow (generally corresponding to the winter months in the Namoi catchment). Producers then store the water for the irrigation season in turkeys nest dams. Under current management, off-allocation may account for approximately one-third of surface water extracted in the catchment, with this proportion varying greatly between years with differences in climate [Donaldson Planning and Management Services, 1996]. In the past no property right has been given over this off-allocation water, with access being at the discretion of the NSW Department of Land and Water Conservation. The lack of such defined property rights or licences to this resource has resulted in off-allocation water being viewed as part of a solution to water allocation problems in the catchment.

This paper briefly outlines an integrated hydro-economic model which has been developed to investigate the following management question:

What are the trade-offs involved with different policies for off-allocation water in the Namoi catchment given:

- *overallocation of groundwater and the phase in of groundwater allocation reductions expected over a 5-10 year period in most groundwater zones in the catchment [NGERP,1999];*
- *expected activation of sleeper licences and further development of irrigation in the unregulated system, where the irrigation*

industry has historically been less developed than in the lower catchment;

- *the dependence of traditional users of off-allocation water on this resource; and*
- *environmental flow requirements; the interim rules for off-allocation in the catchment includes a 50:50 sharing rule of off-allocation water with the environment.*

Six scenarios capturing these management options are outlined and preliminary results from application of the model are given.

2. MODEL FRAMEWORK

The management question outlined above has two key characteristics. It concerns spatial trade-offs between users in the catchment. It is also intrinsically intertemporal due to the high levels of capital infrastucture which are needed to take advantage of different types of water, the uncertainty of supply of off-allocation water due to climatic influences and because of the phase in over a 5 to 10 year period of groundwater allocation reductions.

Given the nature of the management question being asked and the type of trade-offs being considered it was decided that a regional scale economic model was most appropriate for considering this off-allocation management issue. The intertemporal nature of the management issue suggested a "long run" model structure in which structural adjustment (investment in capital) was able to be taken into account. It was decided that in order to capture both the spatial and temporal nature of the off-allocation management issue, a regional scale model, linking regional scale dynamic programming models, simulating annual decisions over a twenty year period, and daily streamflow models should be developed.

2.1. Regional Economic Models

Irrigators have different access to surface and groundwater sources throughout the catchment, with different types of licences and different levels of security of access. This means that the question of where to provide access to off-allocation water involves a trade-off between upstream and downstream users, and is intrinsically spatial in nature. Thus to address this issue a framework that accounts for the important spatial variability of this management problem is required. For the consideration of this off-allocation problem, this has meant that the catchment has been mapped into a number of relatively homogenous regions. The term 'relatively homogenous' is with respect to important economic and social scales for water allocation in the catchment. In the case of off-allocation access, this means that regions are chosen to be relatively homogenous in terms of groundwater policy, surface water policy and production type. The development of these regional boundaries has involved an iterative process with stakeholder input into each stage of model framework development. Details of stakeholder participation in the issue framing and model development stages of this project are given in Letcher et al. [2000]. A first disaggregation into regions was developed by overlaying groundwater zones and subcatchment areas, and was further refined on the basis of advice on regional production differences provided by various stakeholders. The final regions developed in this framework are shown in Figure 1. A summary of the major features of these regions is given in Table 1. A set of alternative cropping activities has been developed for each region. These activities have been developed to be representative of those likely to be undertaken in each region on potentially irrigable land.

Table 1. Main Regional Features.

Region	Description	Stream Gauge[#]	LU*
A	Above Keepit	419022	1
B	Peel River	419006	1
D	Mooki River catchment to Caroona	419034	2
E	Western side of Mooki River catchment from Caroona to Breeza	419027	2
F	Eastern side of Mooki catchment from Caroona to Breeza	419027	2
G	Mooki River from Breeza to Gunnedah	419084	2
H	Namoi from Carroll Gap to Gunnedah	419001	2
I	Cox's Creek above Mullaley	419052	2
J	Cox's Creek Mullaley to Boggabri	419032	2
K	Namoi River from Gunnedah to Boggabri	419012	3
L	Namoi River from Boggabri to Narrabri	419002	3
M	Maules Creek	419051	3
N	Namoi River from Narrabri to Mollee	419039	3
O	Namoi River from Mollee to Walgett	419026	3
P	Pian Creek	419049	3
Q	Barradine Creek	419072	3

[#] DLWC Pinneena data base gauge numbers

* See the following page

*Land Use Options:

Option 1 (Regions A and B)
1. Irrigated Lucerne
2. Dryland Wheat

Option 2 (Regions D,E,F,G,H,I,J)
1. Irrigated wheat/ cotton rotation
2. Dryland wheat/ sorghum rotation
3. Dryland wheat/cotton rotation

Option 3 (Regions K to Q)
1. Irrigated cotton/ wheat rotation
2. Irrigated continuous cotton
3. Irrigated cotton/ faba bean rotation
4. Dryland cotton/ wheat rotation
5. Dryland sorghum/ wheat rotation

As can be seen in Table 1, each region also corresponds to a hydrological node (regions E and F share a hydrological node, other regions have a unique node). This structure forms the basis of the links between hydrological and economic components of the model.

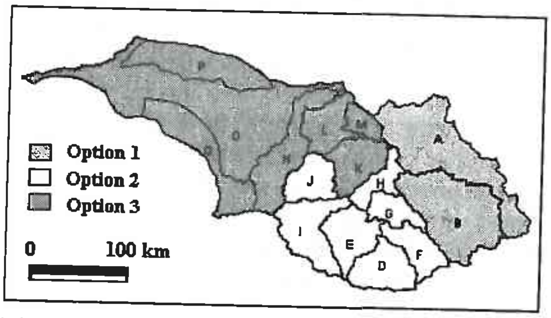

Figure 1. Land use options for Namoi Regions.

2.2 Economic Model Equations

Each of these regions is modelled as though controlled by a single profit maximising farmer. Farmers may choose in the long run to change their area laid out to irrigation, on-farm storage capacity and/or irrigation efficiency. This choice is modelled using a dynamic programming approach. Short run production decisions in each year are then modelled using a set of nested linear programming models, according to constraints on the amount of water and land available. The model considers only potentially irrigable land, and considers dryland cropping as the only alternative to irrigated cropping (ie. grazing is not considered by the model). The economic model in each region can be written as:

Maximise

$$f_{t+1}(k,d,\Omega) = \frac{1}{(1+r)^{t+1}}\left(\pi_{\alpha,t}(k,d,\Omega) - C_{\alpha,t}(k,d,\Omega)\right) + f_t(k,d,\Omega)$$

$$f_0(k,\ d,\ \Omega) \equiv 0$$

where:

r is the interest rate (discount factor), k is the level of irrigation efficiency, d is the level of on-farm storage capacity, Ω is the level of area laid out to irrigation, $\Pi_{\alpha,t}(k,d,\Omega)$ is the short run profit for the production decision in a region (α) in a year (t) given a policy scenario (p) and state space option (k,d,Ω), and $C_{\alpha,t}(k,d,\Omega)$ is the capital cost of moving from (k_0,d_0,Ω_0) in time t to (k_1,d_1,Ω_1) in time t+1.

The short run production profit, $\Pi_{\alpha,t}$, in a given region, α, for a given year, t, and for a specified level of capital investment is calculated as the solution to a linear programming problem, which differs by region. Variable definitions and dependencies are:

G = groundwater limit = G(d,t)
R = regulated surface water limit = R(d,t)
U = unregulated water extraction limit = U(d,t)
O = off-allocation water extraction limit = O(d,t)
u = efficiency of unregulated water use = u(k,t)
r = efficiency of regulated water use = r(k,t)
g = efficiency of groundwater use = g(k,t)
A = area of land limit = $A(\Omega,t)$
a_i = area of land devoted to crop activity i = $a_i(t)$
P_i = price of activity i
c_i = cost of activity i
y_i = yield of activity i
w_i = water use per ha of activity i

Regions A and B
Objective Function

$$\text{Max } \Pi_{\alpha,t} = \sum_{i=1}^{2}(P_i y_i - c_i)a_i$$

Constraints

$$\sum_{i=1}^{2} a_i \le A$$

$$\sum_{i=1}^{2} w_i a_i \le uU$$

Regions D, G, H, I, J
Objective Function

$$\text{Max } \Pi_{\alpha,t} = \sum_{i=1}^{3}(P_i y_i - c_i)a_i$$

Constraints

$$\sum_{i=1}^{3} a_i \le A$$

$$\sum_{i=1}^{3} w_i a_i \le uU + rR + gG + uO$$

where R=0 and O=0 if the region corresponds to an unregulated river section.

Regions E and F
Regions E and F are modelled with a single LP because they share a streamflow node (and

therefore a surface water limit). It is assumed that surface water is transferable between these two regions but groundwater is not.

Objective Function

$$\text{Max } \Pi_{E+F} = \sum_{\alpha\in\{E,F\}} \sum_{i=1}^{3} (P_i y_i - c_i) a_{i,\alpha}$$

Constraints

$$\sum_{i=1}^{3} a_{i,E} \le A_E$$

$$\sum_{i=1}^{3} a_{i,F} \le A_F$$

$$\sum_{i=1}^{3} a_{i,E} w_i + \sum_{j=1}^{3} a_{j,F} w_j \le uU + g(G_E + G_F)$$

$$\sum_{i=1}^{3} a_{i,E} w_i \le uU + gG_E$$

$$\sum_{i=1}^{3} a_{i,F} w_i \le uU + gG_F$$

Regions K to Q

Objective Function

$$\text{Max } \Pi_{\alpha,t} = \sum_{i=1}^{5} (P_i y_i - c_i) a_i$$

Constraints

$$\sum_{i=1}^{5} a_i \le A$$

$$\sum_{i=1}^{5} a_i w_i \le uU + rR + gG + uO$$

where R=0 and O=0 if the region corresponds to an unregulated river section.

2.3 Hydrologic Network

Each of the regions shown in Figure 1 is linked to a flow node. The hydrological network used in the model is shown in Figure 2. The integrated model uses the IHACRES model [Jakeman *et al.*, 1990; Evans and Jakeman, 1998] to represent rainfall-runoff generation. Flow routing between nodes is done using a variable parameter Muskingham-Cunge routine [adapted from Ponce and Yevjevich, 1978].

This flow network provides the limits of surface water extraction and allocation in each of the regions detailed in Figure 1 and Table 1, and can be considered to provide some of the constraints in the regional economic model. Additionally any extraction decision made in each region can be fed through the hydrological network in order to determine the impacts of different allocation decisions on catchment discharge.

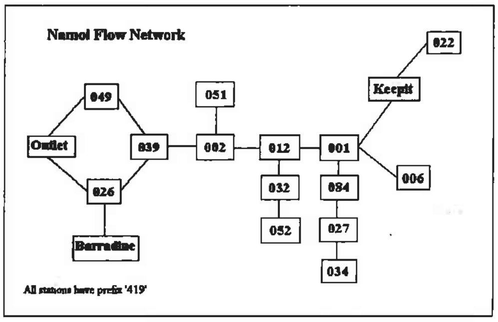

Figure 2. Hydrological Network.

2.4 Links to the Hydrology

The economic and hydrological models, as described above, are linked by two models as shown in Figure 3. The first of these models, the policy model, mimics daily extraction rules which have been suggested in NSW. These extraction rules are based on a series of flow classes, with maximum extraction rules in each class for each subcatchment. This model takes daily modelled streamflow and calculates from this an annual extraction limit. The second link is through the daily extraction model. This model takes the annual extraction decision from the economic model and uses it to determine daily flows left after extraction. These extracted flows are then routed downstream. In this way, production decisions at upstream nodes impact on resource availability at downstream nodes.

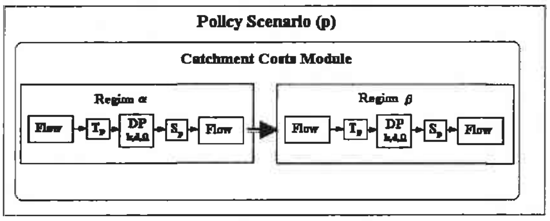

Figure 3. Conceptual framework for model.

3. SCENARIOS

There are six main policy scenarios considered by the model. The way in which these are enacted in each region depends on the groundwater situation in each region, as well as whether the region is in a regulated or unregulated subcatchment. These scenarios are represented in Table 2.

These scenarios impact differently on the different types of licensed allocation for each region. All regions experience a change in their "unregulated" licence when sleeper licence activation is considered. This means that all regions have changed "unregulated" licence volumes in the model for scenarios 2,3,5 and 6. No scenario impacts on the "regulated" extraction limit in a region. However the transfer of off-allocation water to regions experiencing cuts in groundwater allocation changes the "off-allocation limit" in regions H, K, L, N, O and P. In many cases this transfer of off-allocation access reduces the total off-allocation water able to be extracted in the region.

Table 2. Scenario options.

	Active s/w* users only	Half s/w sleepers activate	All s/w sleepers activate
No transfer of off-allocation water to g/w# users	1 (Base Case)	2	3
Transfer off-allocation water to g/w users	4	5	6

* s/w - surface water, # g/w - groundwater

4. PRELIMINARY RESULTS

The model was run for the six scenarios outlined above to produce preliminary results. The impact of changing scenario from the base case (scenario 1) on both economic and environmental indicators was analysed. The total farm profit and percentage change from the base case (scenario 1) over the entire 20 year simulation period for the whole catchment is given in Table 3.

This preliminary model run shows that it is more profitable for the catchment as a whole if no water is transferred to current off-allocation water users (i.e. scenarios 4 to 6). The highest total catchment profit is achieved when all sleeper licences are activated (scenario 3).

Table 3. Total farm profit by scenario.

Scenario	Profit	Change from Base Case
1	$1,682,184,900	
2	$1,696,878,419	0.87%
3	$1,700,199,214	1.07%
4	$1,569,060,257	-6.72%
5	$1,573,599,110	-6.46%
6	$1,575,720,884	-6.33%

The economic impact by region of the various scenarios (as a percentage change from the base case) is given in Table 4. This shows that the decrease in profit under scenarios 4 to 6 is not uniform across the catchment. However no region is better off under scenarios 4 to 6 than they would have been under the equivalent level of sleeper activation (scenarios 1 to 3), without changed access to off-allocation water. Substantial reductions in profit are also faced in several regions in the lower catchment under scenarios 4 to 6. When economic impact is considered by region, scenario 3 is still clearly optimal.

Table 4. Change in Farm Profit From Base Case by Region.

Region(s)	*Sc. 2*	*Sc. 3*	*Sc. 4*	*Sc. 5*	*Sc. 6*
A	0%	0%	0%	0%	0%
B	8%	13%	0%	8%	13%
D	1%	1%	0%	1%	1%
E and F	0%	0%	0%	0%	0%
G	2%	2%	0%	2%	2%
H	-4%	0%	0%	0%	0%
I	0%	0%	0%	0%	0%
J	0%	0%	0%	0%	0%
K	17%	17%	11%	11%	11%
L	0%	0%	-4%	-4%	-4%
M	0%	0%	0%	0%	0%
N	0%	0%	-16%	-16%	-16%
O	0%	0%	-11%	-11%	-11%
P	0%	0%	-8%	-8%	-8%
Q	0%	0%	0%	0%	0%

Table 5 shows the impact of various scenarios on the flow magnitude (as measured by the median flow).

Table 5. Impact of Scenario on Flow Magnitude (as percentage change from base case).

Region(s)	*Sc. 2*	*Sc. 3*	*Sc. 4*	*Sc. 5*	*Sc. 6*
A	-1%	-1%	0%	-1%	-1%
B	-1%	-2%	0%	-1%	-2%
D	0.0%	-12.5%	0%	0.0%	-13%
E and F	-13%	-25%	0%	-13%	-25%
G	-14%	-29%	0%	-14%	-29%
H	0%	0%	0%	0%	0%
I	0%	0%	0%	0%	0%
J	0%	0%	0%	0%	0%
K	0%	0%	0%	0%	0%
L	0%	0%	0%	0%	0%
M	0%	0%	0%	0%	0%
N	0%	0%	0%	0%	0%
O	0%	0%	2%	2%	2%
P	0%	0%	0%	0%	0%
Q	0%	0%	0%	0%	0%

Flow magnitude is substantially reduced in many areas when sleeper licence activation occurs. In particular, sleeper licence activation on the Mooki river (D, E, F and G) has relatively large impacts on the size of median flows (up to a 28% decrease in median flow). Changes to the access of off-allocation water lead to a slight increase or no change in median flows. The only "regulated" region (ie. H,K,L,N,O,P) which experienced a decrease in median flows was Region K. This decrease appears to be in response to sleeper licence activation rather than changes in off-allocation access.

These preliminary results show that there is a substantial trade-off between economic and environmental performance where sleeper licence activation is expected to occur. Future economic development which involves the expansion of irrigation areas, especially in the unregulated system, can be expected to have significant impacts on flow magnitudes. The model shows that policies which provide access to off-allocation water as compensation for reduced groundwater allocation are likely to reduce the amount of off-allocation water extracted in the catchment. This would have positive environmental impacts (slight), but would reduce the total farm profit in the catchment. Importantly this policy would not be expected to improve economic outcomes on average in affected regions of the catchment.

5. CONCLUSIONS AND FUTURE WORK

This paper presented an integrated hydro-economic model for considering water allocation issues in the Namoi River catchment. Whilst this model has been developed for a specific water allocation issue (changed access to off-allocation water), it has clear potential for investigating the economic and environmental trade-offs of a range of water allocation issues in the catchment. The scope of the off-allocation issue used to focus the model is broad enough that the model can consider many aspects of the three water systems (unregulated, regulated and groundwater) present in the Namoi system. This means that the model should be able to be applied to issues such as changes to daily flow allocation rules, analysing the impact of changes in the phase-in of groundwater allocation reductions, as well as the introduction of water markets in the catchment.

The results which have presented from the model in this paper are preliminary. Further work must be done on testing and improving the model and finalising parameter values before these results can be considered conclusive. Nevertheless the model is already able to demonstrate the significant economic and environmental trade-offs involved in activation of sleeper licences in the catchment, as well as the impact on economic performance of the catchment as a whole if access to off-allocation water is provided to offset the impacts of reductions in groundwater allocation in the catchment.

It is intended that the sensitivity of the model to key assumptions such as the cost of investing in capital or the daily flow extraction rules will be tested. A number of climate scenarios will also be used to test the sensitivity of the model results to a range of climate sequences.

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