Supplementary Submission No 13c

INQUIRY INTO WATER AUGMENTATION

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Dr Peter Main

31/1/17

The Hon Michael Brown MLC
Parliament House
6 Macquarie St
Sydney NSW 2000
Chairman of the NSW Legislative Committee on Augmentation of Water Supply for Rural and Regional NSW.

Dear Sir
Acompanying is a copy of analysis of MAR water changes, written for to the Peel Valley and Cockburn water users, and Tamworth Regional Coucil. This applies ideas previously outlined at a preliminary design level for farmers, irrigation suppliers, water supply operators and council.

Some of your committee's other contributors may have similar problems. I thus submit a copy as a supplementary submission part 4 to my prior 3 part submission.

Sincerely

Dr Peter Main .

Tamworth's clever Water.

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Dr Peter R Main [2], Canberra 30/1/2017 rev 1.9b

SUMMARY

Tamworth NSW is famous for its Country and Western Festival, but in the summer and drought, it has unresolved water problems. New science and technologies of *aquifer recharge* offer an unrecognised opportunity to transform the region, especially in drought.

In normal seasons a prosperous area, Tamworth and its region in drought has significant *water conflicts*. Traditional agricultural activity includes large scale use of water for lucerne and other crops. Some adaptation has occurred towards mixed high and low water security, fixed crop,and higher return per unit of water, that would insulate the region's economy from increased drought. There is minimal open water for local recreational activities, and minimal choices for a balanced dynamic river flow control regimes in all conditions. About 50% of water from Chaffey dam, the city's major water source, is lost during flow down the Peel River.

Managed Aquifer Recharge (MAR), a technology to enhance water storage underground (often called "W*ater Banking*"), can significantly change the region's water opportunities. A new form of passive river *Natural Aquifer Recharge (NAR)*, that adapts lessons learnt from Menindee Lakes, the Burdekin River and the Coorong, is explored herein. This system can be adapted to neutralize the river-delivery losses, improve aquifer levels before a drought, and provide more flexibility to handle drought. This analysis explores four versions of pilot trial design of "*Shepherd Aquifers*", to provide flexible controlled flow regimes able to solve known man-made mistakes with rivers. It enables the flexibility we need within stream flow and drought water stores. European settlement in Australia is characterised by past adaptation of waterways producing short term benefit at long term expense of multiple other systems. At some critical switching points, we need to fix past mistakes and move on, and Australians are now trying to fix the problems. We still make mistakes, and when that happens we need to admit these openly.

We can ignore past mistakes, devalue or suppress the source of new mistakes, and not act on opportunities from new science. A *clever nation* would listen carefully to what *neutral science* discovers, not use *junk science* to support pre-conceived ideas strongly held by the partly informed[3]. Trials of new methods in partnership between private enterprise, and community councils, can be a minimal-cost working basis to test new methods, regardless of distant government decisions.

Tamworth could adopt the use of *clever water, or* <u>water that repairs not harms</u>. It already has elements of such water use with its recommissioned drought-reserve *"drift wells"*. A well informed community adoption of new water technologies is possible. Such change would enhance the local economy and insulate it from a future drier climate. Environmental and community amenity would improve with this prosperity. Four models of small pilot river-based projects, linked with enhanced town water supplies, are described as a potential basis for change.

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1 This document may be used freely in part or whole with attribution to the writer
2 The writer, now a Canberra GP, grew up near Tamworth and visits relatives in the district regularly.
3 *Junk science* can be defined as selectively funded parts of science to support prior belief, thus distorting reality.

A Tamworth Regional Council water numbers perspective.

To preserve an efficient pulse delivery via the Peel River in drought times,we need the a volume of water to return from aquifers to the river, to balance losses. This should negate the need for a new pipeline from Chaffey dam, and double the effective delivered water stored in Chaffey. It would ensure *storage aquifers* are full, in preparation for the next drought. Use of high security aquifer water should then depend on the *level of water in the aquifer*, not a remote calculation of reserves. [4]

For this exercise we will assume the following:

- Tamworth uses around 10GigaLitres per annum, 60% from Chaffey, 40% from Dungowan.
- the *drift well reserve water* source is not needed (more about that later).
- 50% of the river flow is lost to aquifer (*"losing stream"*) and evapo-*transpiration*
- for this exercise evapo-transpiration is set at nil (unrealistic but more about that later)
- we can achieve about 60Litres per second from a production bore adjacent to the river bank (it is in high yielding *alluvial riverine aquifer*)
- we have 3 phase power within 1 pole span from the *Shepherd aquifer bore* site [5]
- that we have a small number of cooperative farmers willing to contribute, and share the benefits of a *drought-proofed aquifer*
- we continue to deliver water down the Peel via a *pulse-flow regime* equivalent to 1 day in 10 water release (10% duty cycle to pump back into the river)
- The *shepherd bore water quality* has been tested as ok to return to the river
- The *Tamworth Aquifer Recharge Control Centre* (TARCC) is a remote data reporting and coordination system with some controls under council's town water supply operators.
- Synchronisation of bore water return, with pulse river flows, can occur by a fixed timer regime at the dam and pumps, and flow delay data from TARCC derived in actual operation.

We need to pump about 6/2 or 3GL pa back into the river to balance the pulse river flows. Per annum, the 3GL translates to 1 day in 10, or 36 days, or around 3/36, or 1/12 GL per day or 85megaLitres/day. Per *bore/recharge system* we can expect 60*3,600 litres/hour and 60*3,600*24 litres per day. Roughly 6*10*36*100*6*4 or about 5megaLitres/day *per shepherd bore system*. We would need 85/5 or about 17 systems to fully counterbalance the river losses.

We could also return water to the river from the farmer's *storage aquifer*, since we have some pipeline capacity from the shepherd to the storage, and running it in reverse is possible. Assuming the pipeline is sufficient to double the return to the river, we now need around 17/2, or 9 installations to fully neutralize river losses. This does not allow for continuous pumping at a lower level from the Shepherd aquifer to the storage/local irrigation systems. Overcapacity in the system needs to be avoided, and thus each site will require *analysis to optimise pipeline size, pumping design, and discharge volumes*.

The simplest system is no pipeline return from the *storage aquifer* to river, an *adjustable flow pump* at the *shepherd aquifer*, and low pressure short drainage back into the river (with simple headworks for erosion control). About 4-10 systems would allow concept testing in practice, with a detectable change in pulse flow efficiency at Tamworth (20-50megalitres/day or about ½ that eventually needed).

As a fallback, the bores will be usable by the farmer if the system fails to deliver real net benefit. Replication of the shepherd bore units up and down the river could then follow. The cost of the pilot projects would depend on how the farmer or council constructs the system. [6]

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4 This assumes the MDBA can be legally forced to obey its founding charter and implement new science.

5 The *Shepherd aquifer bore* is the source adjacent to the river (functionally equivalent to Tamworth's *drift wells*)

6 Wide cost variance between private and government projects occurs, (some overengineering, some featherbedding).

Farmer perspective and numbers

Continuing the above assumptions, for the simplest system, with no return to the river from the *storage aquifer*, the farmer has access to the following:

- A drought-proofed *storage aquife*r able to source *high-security water*
- Pumping costs of around 1.5* normal from a conventional production bore (assuming the council pays for ½ the *shepherd bore* pumping costs)
- A new 60L/sec capable *low-pressure injection bore* (shallow, unconfined aquifer in riverine alluvium) near to a functioning production bore (no power is required unless conversion of a current production bore to dual purpose is attempted)
- no water treatment is required provided the water tests between the two aquifers are compatible;
- A short pipeline able to deliver an optimised flow from shepherd aquifer to storage aquifer
- special pumping permission to pump out additional water up to the cumulative volume stored in the storage aquifer (but limited by aquifer levels monitored by a monitoring bore)
- water licence costs reduced during drought (to be negotiated)
- a healthy river.
- Real time access to water system data for the overall aquifer recharge system
- Manual override for flood warning protocol.

The peak operation of 5megaLItres per day assumes there will be some operation time where the water is directed to the storage aquifer, not the river. The volume of water stored in the storage aquifer over time, will be part of calculation and aquifer measurement by TARCC and WaterNSW.

Proof of concept from operation in the real world would result in an opportunity to change irrigation land use according to overall system costs and water price. If water recharge pits are chosen to be constructed instead of a low pressure injection bore, these will need maintenance.
(They may be cheaper than a pipeline and bore in some landscapes particularly where shallow gravel beds exist)

In some locations, there may be a few neighbours willing to cooperate, and a single bore may create a locally managed drought reserve aquifer. Local pipeline distribution may be very cheap as current irrigation pipelines along fences already may exist, and distribution to both sides of a boundary may be possible. Cost and water sharing between neighbours, for the high security drought-proofed aquifer would thus be enabled, with over-arching governance by council, using level-based data from TARCC operations.

A series of local water cooperatives with high security water networks that differ a bit would thus arise. These would extend out from the river, the possible landuse change enabled by better drought water supplies.

A perspective from WaterNSW and others.

State and Federal water governing bodies would need to accept a requirement for *experimental drought water governance* in the Tamworth district, that enables a full practical pilot test of new water storage and distribution methods. Regular feedback, and access to real world data, would ensure new applied science is rapidly acquired from an implementation process.

An annual *Aquifer Recharge Conference* at Tamworth, with reports by TARCC, TRC, farmer participants, fishers, river ecologists, bore drillers, irrigation suppliers, and hydrogeologists would be a good outcome. Open report and debate of problems, successes and disputes would be a sound basis for overall community education about Managed Aquifer Recharge.

Four Models of choices for participants in an NAR system on the Peel follow.

1. MODEL 1: Complete NAR Shepherd Aquifer upstream to Tamworth.

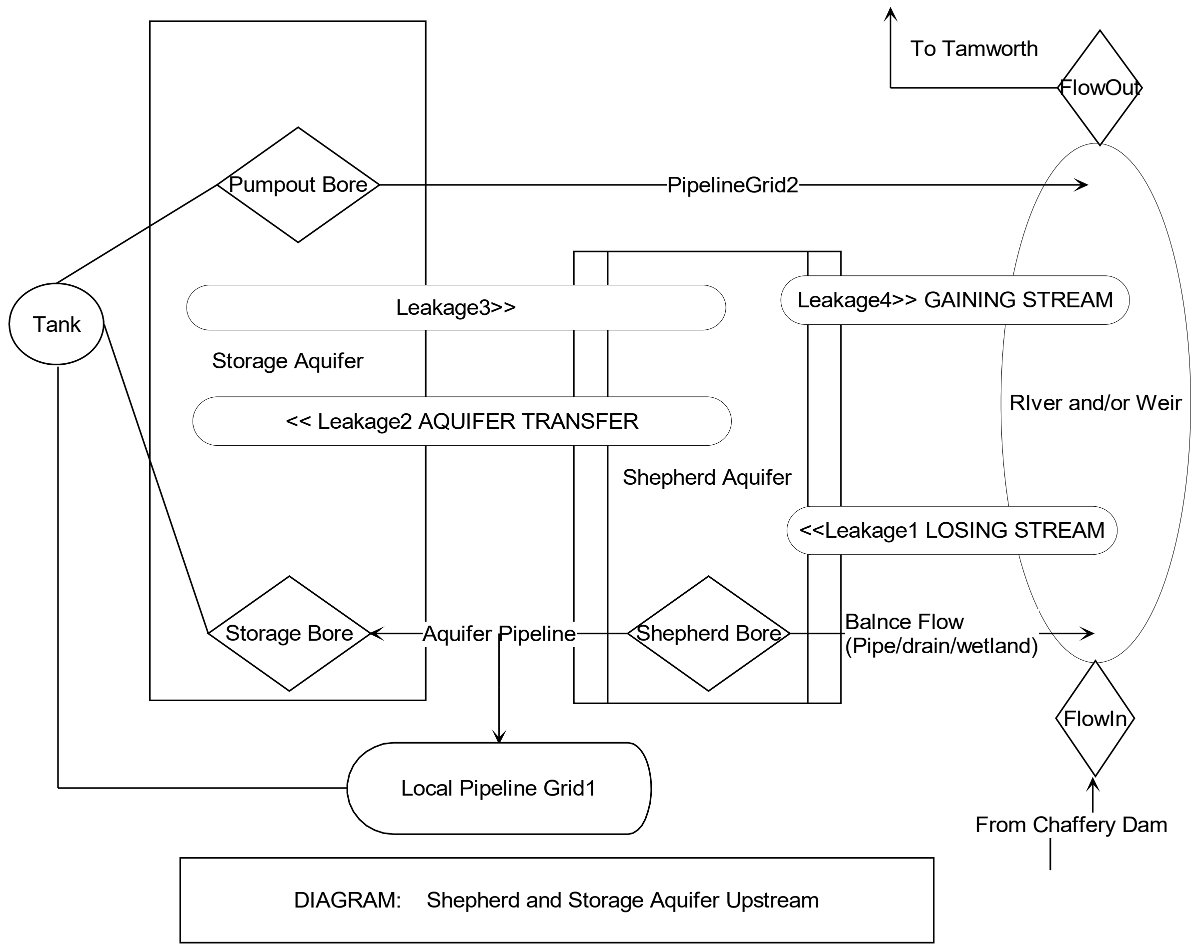

Fig 1. Operation of a complete shepherd aquifer system NAR upriver to city.

Notes:

Some parts of the above are optional : i) local pipeline grid1 ; ii) Storage Bore (if limited hydraulic connectivity between aquifers exists, and an *absorption bed* is chosen). Leakage 1 to 4 determines the design requirements of bores and pipelines. Participation of local farms and communities determines local pipeline grid, and extent of *storage bores*.

Discussion

Dependant on participation of locals connected to a small shepherd-aquifer pipeline grid, one or more of both a shepherd aquifer adjacent to the river, and nearby storage aquifer is needed. The Storage aquifer may be part of the same aquifer as the Shepherd aquifer, with delayed transfer or limited hydraulic connectivity to each other. The Shepherd aquifer is assumed to have high hydraulic connectivity to the river, with rapid volume exchange.

In operation there need to be significant benefits for local grid participants as follows :

- Drought preparation providing a full storage aquifer as part of routine drought planning
- Flood planning for free off-river storage to be transferred back to the river for water credits
- Reticulated local pipeline would enable participation of members without a bore, but temporary storage capacity (dam or offstream weir)
- Modified water costs during routine seasons to make it attractive to participate.

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2. MODEL 2: A city storage *shepherd aquifer* via NAR downriver to city

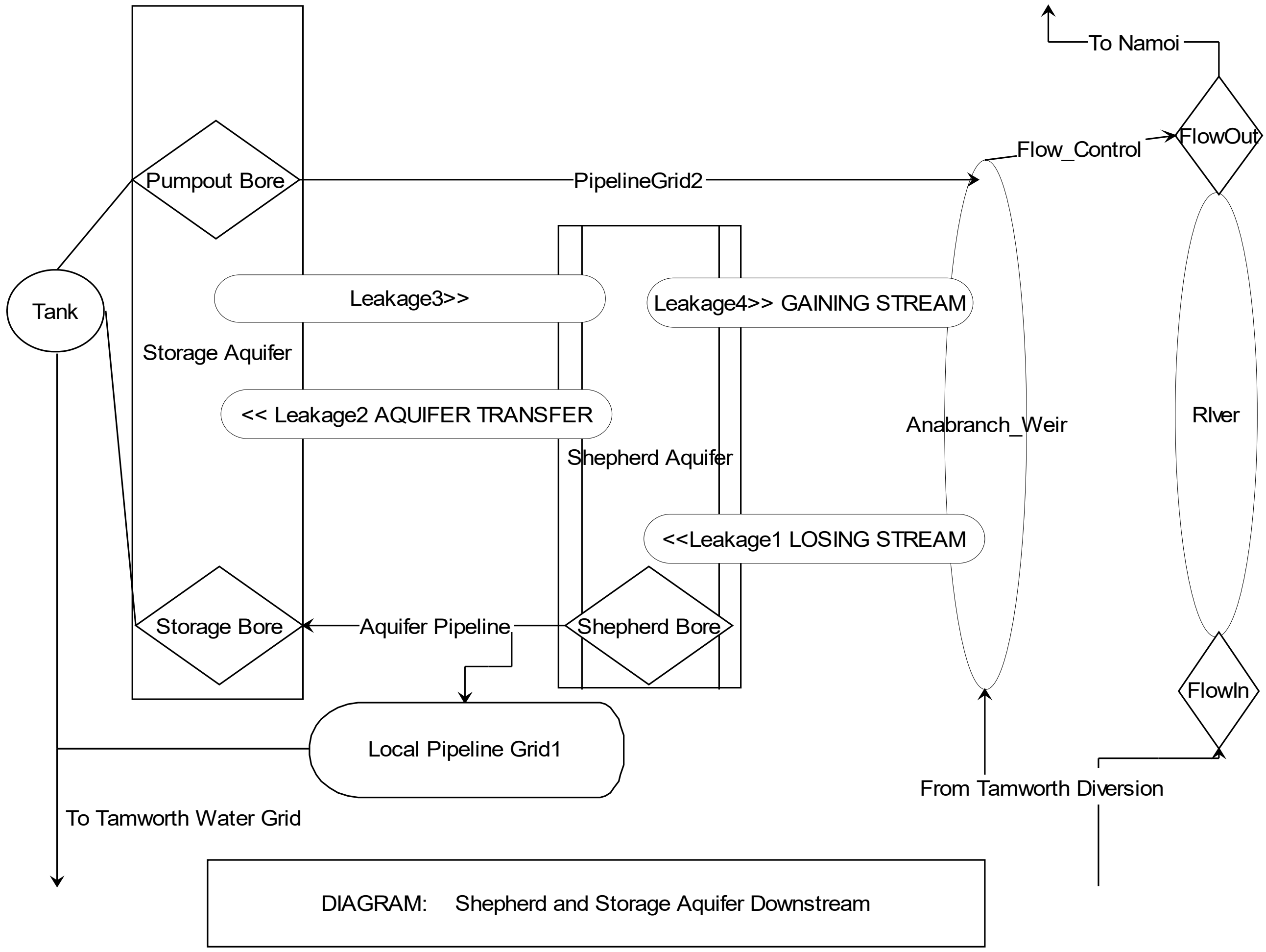

Fig 2. Operation of a city storage shepherd aquifer via NAR downriver to city.

Discussion:

There is about 6km of Anabranch NW of the city that may be a logical site for a pilot NAR development. The size of the potential aquifer storages are unknown, however a grid-connected rural water pipeline that provides reasonably secured priced water without the hassles of bores and licenses would be a good starting point. As per Model 1, there need to be benefits for both rural pipeline grid participants, and the city. Again, one or more of both a shepherd aquifer adjacent to the river, and nearby storage aquifer are needed. The Shepherd aquifer is assumed to have high hydraulic connectivity to the river, with rapid volume exchange.Weir flow control both inlet and outlet may be required, for multipurpose control

Benefits:

In operation there need to be significant benefits for the city and participants as follows :

- Drought preparation providing a full storage aquifer for city and pipeline participants, enhanced water security and drought planning
- Low cost potential for extension of routine and drought supplies
- Flood planning as per upstream aquifers
- Transfer of water from Chaffey to storage Aquifer for local city supply without using river
- An additional extension of water supply flexibility and local volume should occur, dependant on practical effects of mixing sources.

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3. MODEL 3: Minimal cost, simplified NAR using current Town Water infrastructure

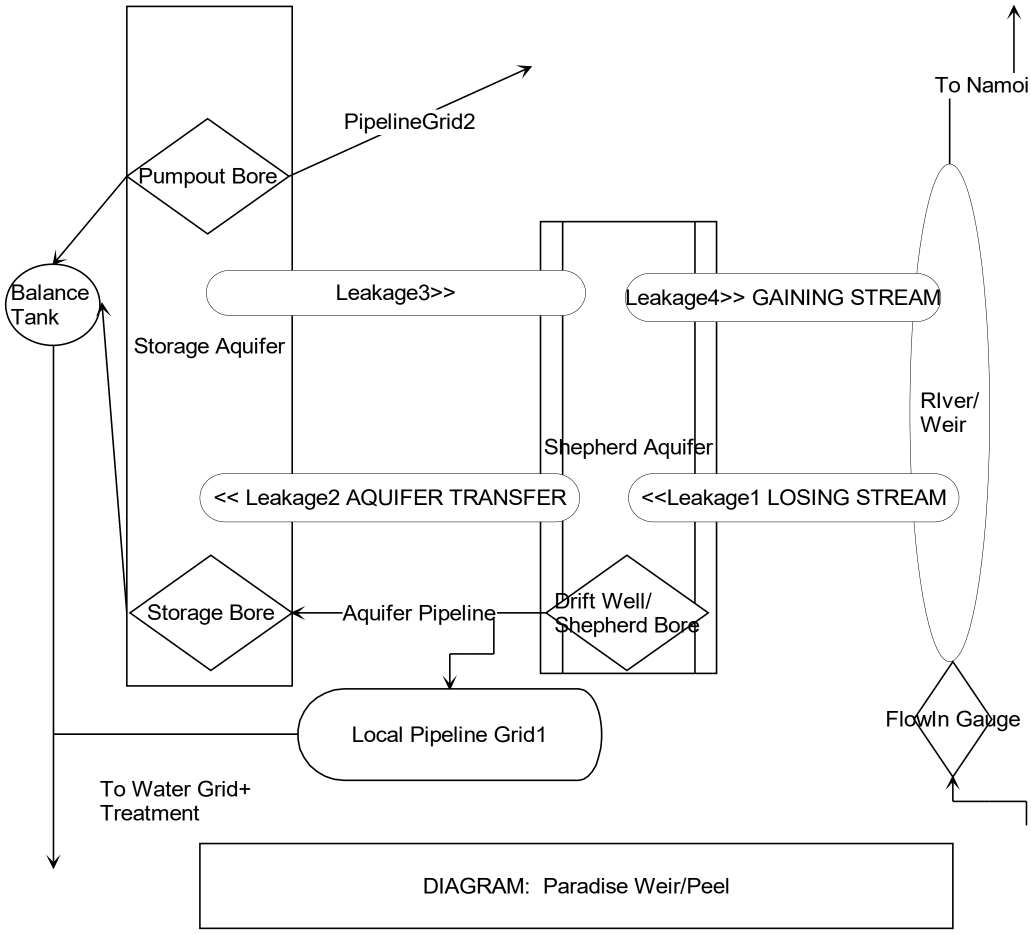

Fig 3. Minimal cost pilot test simplified NAR using current infrastructure.

Notes:

This version requires minimum investment by private or public initiator.

Model 3 involves :

- the use of current drift-wells, or a mix of these plus new shepherd aquifer bores
- the use of an aquifer pipeline or junction to the current transfer pipeline to the Water Treatment works.
- 1 or more *storage and production bores* at the storage aquifer (or dual use bores).
- A secondary pipeline grid for agricultural water distribution(which is dependant on customers and may be split into different segments)
- Use of current drift wells appears to match Shepherd bore requirements.
- Model 3 requires Tamworth Regional Council governance and cooperation.

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4. MODEL 4: Minimal cost, upriver NAR using current production bore.

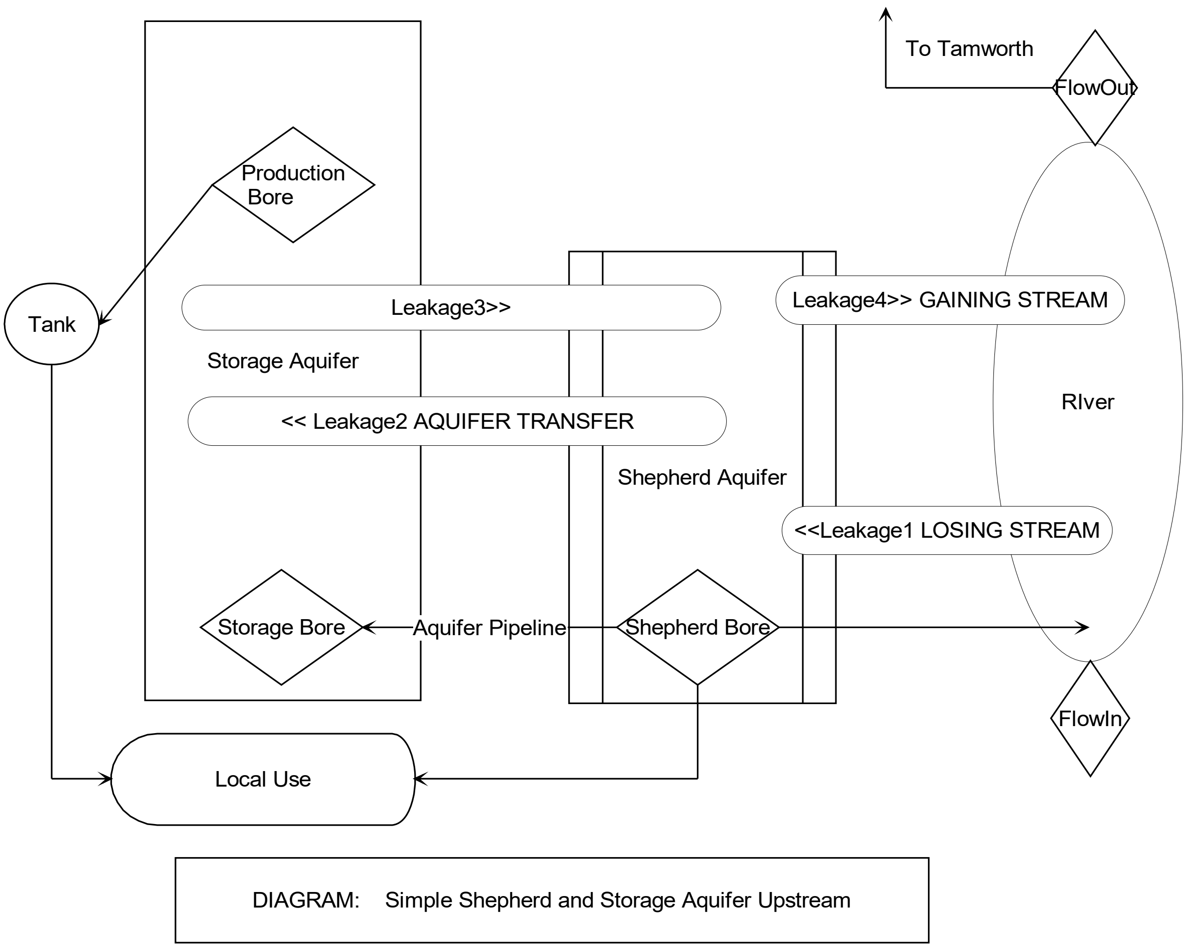

Fig 4. Minimal cost pilot test upriver NAR using current production bore.

Notes:

A current irrigator with or without assistance could add the components needed to provide flow buffering along the river via an NAR system

Features of such a project are:

- The storage bore may be a modified current production bore
- Funding requirements are minimal with short term planned for some components (5 years)
- Aquifer Pipeline may be low pressure dependant on distance between the two aquifers;
- Decision as to siting determined by known hydrology from past bore drilling logs and currently known hydrogeology;
- 1 to 5 participants- may be fully private
- Minimal requirement are irrigation licence, and water testing to prove fitness to return to river.
- Enables add-on high water security, water based enterprise (fishery, reed beds, typha,)
- Opportunity for salt and nutrient removal as a spin off from on-farm aquifer management, and possible separate income streams in some contexts.[7]

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7 Farmers now pay for water use, but future, well-informed governments are likely to also pay for salt and nutrient removal, drought water returns, and flood water removal, to and from streams.

Participating farmer and organisational process around flow splitting.

Some basic numbers *per unit of NAR* are set out below using common field figures for high yielding riverine alluvial aquifers and modern bore construction. Standard grid powered submerged pump operation on either a timer or remote control is assumed.

Table 1: spreadsheet output to test some basic flow splitting, and target flows.

I unit = shepherd bore +shepherdPotentiometer+ discharge pipe + balanceValve+ storage pipe+ bore +monitorBore

	Litres/sec		**megLitre/Day**		**Glitre/Yr 100% dut**		**FlowBalancing (GL pa**		**maxFlow)**
NAR Units	**BoreFlowMin**	**BoreFlowMax**	**Min**	**Max**	**Min**	**Max**	**River**	**Town**	**Farm**
							0.3		0.11
							0.63	**0.27**	**0.11**
1	20	60	1.73	5.18	0.63	1.89	1.18	0.51	0.2
2	40	120	3.46	10.37	1.26	3.78	2.37	1.02	0.4
3	60	180	5.18	15.55	1.89	5.68	3.55	1.52	0.6
4	80	240	6.91	20.74	2.52	7.57	4.74	2.03	0.8
5	100	300	8.64	25.92	3.15	9.46	5.92	2.54	1
10	200	600	17.28	51.84	6.31	18.92	11.85	5.08	2
20	400	1200	34.56	103.68	12.61	37.84	23.69	10.15	4
50	1000	3000	86.4	259.2	31.54	94.61	59.23	25.38	10
100	2000	6000	172.8	518.4	63.07	189.22	118.45	50.76	20
PulseFLowDutyCycle PERUNIT									
10%	2	6	0.17	0.52	0.06	0.19	0.12	0.05	0.02
20%	4	12	0.35	1.04	0.13	0.38	0.24	0.1	0.04
50%	10	30	0.86	2.59	0.32	0.95	0.59	0.25	0.1

How the story might unfold.

A diversity of responses occur to the NAR proposal. Tamworth Regional Council does see some possible merit and funds a small feasibility study. The process of planning an installation by negotiation might follow a provocative path such as below.

The Players:

The Federal Government is willing to spend a small amount of money towards converting the failed BHMAR exercise at Menindee, towards an affordable underground water mapping toolset applicable everywhere. It donates $20,000 to the project. The NSW Government has spent all its water money on the new pipeline to Broken Hill and so declines to contribute any funds.

The relevant NSW Ministers decide that underground water is no good because you can't fish, swim or ski in it, you can't open an aquifer like a dam, and there are no good pictures for media events. A Green activist does 17 recorded interviews on Youtube claiming that the endangered *Barking Frog* [8] will have its habitat destroyed. A journalist points out that the Barking Frog only resides in Tasmania. The ABC leaves the false headline on its website because it looks nice with its new experimental font, and a pretty frog picture. Our shaky project finally gets off the ground with a few meetings at a local Pub. The Peel Valley Water Users group and the Cockburn Valley Irrigator council chip in some money. A few independent, robust farmers volunteer as participants. They feel they've nothing to lose, since their traditional farm incomes are insecure without change.

8 Not really – I made this up: *Limnodynastes fletcheri* has a reasonable SE Australian mainland distribution, but these days we need a 2 second headline to match a 4 second media attention span.

This results in model 4 above being adopted, with 1 test installation in the Cockburn and 4 on the Peel River, and no bore or pumping changes at Tamworth. Tamworth Regional Council (TRC) does agree to install more stream flow monitors at Kootingal and the Peel, and a regular scheduled pulse flow regime from Chaffey for testing with and without NAR operation. TRC also agrees to a minimal development of *TARCC* [9] as a simulation software platform initially, able to handle a simple aquifer/river MAR network, in real time, with published website status.

Table 2. Using Table 1 above, and goal-seek, we derive different farmer/river flow ratios.

Goal Seek: Farmer wants 200MegL pa droughtproofed additional water (0.2GL)		River/town split	Town	Farm
Has 1km of river suited for up to 4 units		0.5		0.11
Has power to 2 sites without additional poles		0.45	0.45	0.11
His aquifer bores currently yield 60Litre/Sec from existing bores	**GigaLitres=**	**0.85**	**0.85**	**0.2**
He can measure aquifer level storage aquifer level inbore method and bore switched off				
He can negotiate cost-sharing for 1 system construction since he only needs the 200mL at this stage				
City requires maximum river buffering from Shepherd Aquifer and is willing to share this 50/50 with river		River/town split	Town	Farm
Duty cycle is planned at 10% during drought with 1 day in 10 release pulse or 2 in 20, or 3 per month		0.8		0.11
Environmental water holder object, and Tamworth negotiates up to 80% for the river, 20% for town		0.18	0.72	0.11
	GigaLitres=	**0.34**	**1.35**	**0.2**
NSW Office of Water intervenes declares this a drought water security system, 30% to river, 70% of balance to City				
MDBA agrees that this is a special experimental NAR system and the drought drawdown		River/town split	Town	Farm
Will be limited by measured level, and stored water as decided by NSW-OW		0.3		0.11
Flow records to be monitored by TARCC		0.63	0.27	0.11
	GigaLitres=	**1.18**	**0.51**	**0.2**
Commonwealth Environmental Water Holder pulls out when it is realised there are ongoing costs				
City and Farmer agree to donate 50% each extra running costs to Environment. Back to Status quo.				
City budgets for 5 units with 5 stakeholders as pilot test project				
5 sites are available with ready power, simple discharge, and storage aquifer bores around 400metres				
Commonwealth agrees to fund a re-analysis of BHMAR technology to derive a vastly cheapened form suited to general community use				
2 best models are derived, and run in compariosn on the aquifers covering the participant farmers.				
The water resource mapping shows only three of the 5 planned participants have storage potential suited to the requirement.				
Nearby farms have suitable aquifers, and a local pipeline grid connects the re-sited bores, with benefits/costs to be shared by neighbours.				

Reality Checks

A few players change their minds and do chip in to the project. Re-analysis by some decent mathematicians and real hydrologists, discover that my above figures are rubbery and need recasting. (it happens). The program looks like a fiasco in the making.

In the nick of time, the Federal Minister for Water has a change of mind, and obtains cabinet approval for a $2 million test of both adapting BHMAR technology, and a pilot MAR project along the Peel-Cockburn. Wanting to avoid allegations of political favoritism, the Federal cabinet insists that similar sums for Brewarrina, Bourke, Wilcannia, Menindee and Pooncarie are allocated, for similar test projects to improve water supplies, and test by installation the new BHMAR adapted methods.

The Murray Darling Basin Authority re-reads its founding charter, and discovers it <u>must</u> implement new science in its operations. (Such a change might, however take a long time.)

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9 TARCC = ***Tamworth Aquifer Recharge Control Centre*** : a laptop and 5 broadband wireless connected microcontrollers donated by a local bore-driller.

CONCLUSIONS:

Tamworth has all the pre-requisites for a highly secure water future. A permanent, balanced restoration of river ecology, new enterprises and improved economic use of water, and markedly increased community amenity, are all possible at the same time. Water that repairs old mistakes by humans I have referred to as *"clever water"*. Of course water has zero intelligence, but we people that use it can sometimes be wise, sometimes stupid, and sometimes clever, and sometimes slow learners.

In my initial analysis, I thought that weirs may be essential to a working NAR project along a river. Traditionally, weirs have been constructed along rivers to provide weir pools for human use. Add-on fishways have been designed around this problem, but can be expensive. Poorly maintained weirs are often leaky, and may become dangerous. Designing a small weir or billabong, around the fishway, is a different insight, now possible with new science. The numbers I found do not add up to a need for new weirs. Weirs are thus not essential to a test project of NAR at Tamworth, but I suspect a series of fish-pools that restore the Murray Cod fishery above Tamworth, would be a major key marker of success.

The Natural Aquifer Recharge models described above are new untested versions of Managed Aquifer Recharge that have proven success. New science from Menindee revealing the behaviour of related natural hydrogeology is important. In my view, using these behaviours in new combinations holds a key to fully resolvingTamworth's drought water conflicts, without new dams or major pipelines. All theory however needs scrutiny, and proof by installation and real world testing.

Attached are some brief notes on many related problems that appear to have good solutions using MAR/NAR thinking and installations. They are worthy of serious thought and consideration.

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Thanks:

This document is dedicated to all those scientists out there who have generated lots of good *neutral science*, that has been ignored, forgotten or suppressed, by others with little insight into the harm that can then result. Published research from CSIRO and Geoscience Australia scientists enabled my study of how Australia's waterways probably work.

Thanks are also given to Peter Andrews, whose original books alerted me to major knowledge gaps in the topic, relevant to my own study interest.

Thanks to The Canberra Times, for its timely story on the Turallo Creek saga, that publicised a major mistake being made by NSW authorities. That mistake in retrospect, emerged from misunderstanding of what Sequence Farming really is: a simplified, low cost version of Natural Aquifer Recharge.

Thanks also to Badger Bates of the Barkindji tribe, who eloquently described to the Parliamentary committee what to him are Rainbow Serpent Waters – or Nadji Waters – the same entwined aquifers and river of the Darling researched by Geoscience Australia.

Finally thanks to my family, who put up with a sometimes preoccupied grandpa, and his enthusiasms for interesting and strange ideas, that somehow have not made it from research to implementation.

Glossary

alluvial	A geological deposit occurring through deposition by water
alluvial aquifer	An aquifer formed from alluvial strata
aquiclude :	Strata of rock or sediment completely impervious to water (eg. required at the floor of saltpan)
aquifer recharge	Refilling an aquifer with water
aquifer:	an underground strata of rock or sediment that holds and transmits water ;
aquitard :	an underground strata of rock or sediment that impedes water flow;
BHMAR	*Broken Hill Managed Aquifer Recharge:* a geophysical and water research project to map underground water at Menindee Lakes , NSW 2011-2013
desalination :	the removal of salt from water to produce fresh water supplies;
evaporation	Loss of liquid to a vapour – water loss to the atmosphere
evapotranspiration	Combined evaporation plus transpiration by plants
GigaLitres	1,000,000,000 litres or 1 billion litres, or 1,000 megaLitres. Or 1 million cubic metres;
hydraulic connectivity	How easily water can flow between water bodies
managed aquifer	An aquifer controlled by human engineering
managed aquifer recharge (MAR)	Recharge of an aquifer by engineering design
murray darling basin	The river catchment including all tributaries of the Murray and Darling Rivers
natural aquifer	An aquifer naturally occurring in place
natural aquifer recharge	Natural flows of water that recharge an aquifer (for example from a river or lake)
pilot trials :	a small scale test, or controlled experiment, of a new strategy wherein costs, benefits and unforeseen consequences can be tried with controlled risks
production bore	A bore used to pump water out of for production of a water supply
pulse flow regime	A method of water transfer by intermittent higher flow periods
SDL	Sustainable Diversion Limit – the estimated limit of water extraction per annum set by the MDBA for a water resource
shepherd aquifer	An aquifer adjacent to a water body used to ”shepherd” water elsewhere
shepherd bore	A bore drilled into a *shepherd aquifer*
storage aquifer	An aquifer used to store water – in this analysis to be filled via a shepherd aquifer
transpiration	Plant transfer of water from roots to atmosphere
water security :	the capacity of a system to deliver continuous, reliable supply

APPENDICES:

This is a brief list of salient past and current human water mistakes that may be solved with new solutions from MAR/NAR.

SNOWY HYDRO

The Snowy Hydro Scheme, an engineering success, was an ecological disaster for the Snowy River. It is fixable, but only with significant re-balancing of priorities. The sticking point is re-allocating about 25% of flow to the river in ecologically effective manner[10]. This conflicts with providing baseload power for Sydney and Melbourne peak power demands. A coordinated use of aquifer and stream bed flows, with pulse flow regimes, forms a likely solution for this.

THE COORONG

The Coorong is a disaster maintained by mixed motives. The Coorong's original causative problem remains the the creation of Adelaide's food-basket by draining the Limestone Coast. It is fixable. Curiously, its hydro-geology is a vast MAR project with nature-made sand-dams preventing rainfall drainage via major rivers, of the whole South East of South Australia. (there aren't any major rivers- the water always drained underground and Northwest via the Coorong). The MAR system provided by nature was too good, and so drainage by the early European Settlers made landforms suited to farming, but destroyed the natural water system. [11] A part-way restoration of some of the natural system, using new hydrology, remains a necessary fix for these long term problems.

SALT INTERCEPTION SCHEMES

The Murray Irrigation Area created a salt disaster that is well on the way to being fixed by Salt Interception Schemes, and over-arching flow controls with the Murray Darling Basin Authority. (MDBA). There is only one SIS on the Darling, and it is a qualified success. Its' problem is that it removes water volume from the Darling. Loss of water volume is the key failure of our management of the Darling to date. Both must be fixed together..

STRANDED DESALINATION ASSETS

Perth, Adelaide, Melbourne and Sydney have major sea-water desalination systems. Only Perth has a likely reasonable utilisation prospect for these assets. The others represent major *stranded assets* invested for water security. New desalination plants have become modular, and converting some capacity to containerised units, for shipping and use anywhere in Australia may be economically viable. These could then be leased on such terms, that return to the city of source would occur during drought, for use at their original intended site and purpose.

BHMAR

The Darling River and Menindee Lakes represent a new disaster in the making, created by unbalanced decisions emerging from sacrificing Broken Hill and the local community to the needs of other political powers. Misunderstanding of the implications of MAR has led to community suspicion of borefields and aquifer recharge. The Darling and Menindee represent drought refuges of unprecedented importance to inland NSW. The Darling does not overlie the Great Artesian Basin, as does much of its upriver catchment. Communities with secured water from the GAB need to imagine how they would cope if their drought water resource was destroyed. The MDBA has made decisions ignorant of the drought reserve water functions of Menindee, and how they could be maintained with some small investments, and minor changes to flow regimes and drought reserves.

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10 Theresa Rose : 2016 personal communication

11 See : *Woakwine Cutting* by Murray McCourt 1985 & reprint 1987

CHAIN OF PONDS and NICHE CONSTRUCTION by organisms
Peter Andrews' [12] sequence farming has long been controversial, and rejected by many hydrologists. It is past time it was brought into mainstream science, recognising his ideas for what they are: *"niche construction"* by Australian flora and fauna that once used to maintain a string of waterholes in drought. This process also maintained residual secured habitat for fish and their food-chain, waterbirds, and fire-tender flora. The integrated flow regime enabled continuous low-flow underground that has yet unknown effects on benthic ecologies. Destroying these has been simple- allow hard hooved grazing at the downstream weir-bank to drain the pools, and obtain short term grazing (at a cost of loss of long term drought reserve water). Restoring them can be simple too: see *Turallo Creek.* [13]

FRACKING
"Fracking: for short term sales of natural gas to Asian markets, without regard to irreversible aquifer damage, and the permanent economic base that represents, is simply not understood. Assertions that any damage can be repaired are completely at odds with failure to be able to create artificial *aquitards*, and *aquicludes* reliably, that rectify failures. (See Miami USA, Fraser island QLD, and *aquiclude failure* in solar ponds).

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12 Back from The Brink : Peter Andrews concepts of sequence farming.
13 See Local Aquifer Trusts: the writer's 1st part submission to the NSW Parliamentary Water Augmentation inquiry