AQUATIC ECOSYSTEM PRODUCTIVITY RELIES ON WATER MANAGERS AND SUSTAINABLE CITIES.

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ABSTRACT
A major proportion of the 22,000 square kilometers of Hawkesbury-Nepean Catchment is the source of the Greater Sydney and Metropolitan Water Supply. Numerous studies, reports and a statement of joint intent have recognised that the Hawkesbury–Nepean River system was and is stressed.

Sydney Water manages Sydney's water supply and sewerage disposal to river and ocean outfalls. Local Government water utilities such as Gosford and Wyong Councils manage water supplies for the city of Gosford and Wyong that influence tributary flows to the lower catchment.

School prawns, squid, crabs and fish are harvested from the Hawkesbury-Nepean River for human consumption and bait. The Hawkesbury prawn trawl fishery utilises less than 4% of the river and estuarine system 5 days a week (except public holidays) to harvest the school prawn (*Metapenaeus macleayi*) and Eastern king prawn (*Penaeus plebejus*), Greasy back prawns (*Metapenaeus Bennettae*) Broad squid *(Photololigo etheridgei*) and Bottle squid *(Loliolus notiluca).* The Hawkesbury prawn trawl fishery is the second largest estuarine prawn trawl fishery and the only estuarine squid trawl fishery in NSW. Both products command top prices for their quality and texture at market outlets as a food and as bait for recreational fishing.

Fishers are increasingly concerned for the survival of this significant and quality product. The increases in effluent disposal, water demand, and environmental flow changes may well see the end to this historic fishery if care and recognition is not identified. The Department of Primary Industries has commenced reviewing this fishery and four other fisheries in the State, to determine the need for further reductions in endorsements, effort and possible buyouts.
I argue that the Government and water managers are failing to recognise the critical impacts on the productivity of fish species within their management of water and wastewater systems, guidelines and future planning objectives.

INTRODUCTION j

The Hawkesbury Nepean River is a drowned river valley that narrows after the flood plain, its total river area to the junction of the Grose River is approximately 172 square kilometres. Its hydrological processes are influenced by urban development, 21 drinking water supply dams and in excess of 180 megalitres of tertiary treated effluent disposal daily.

Growth
Regional Strategies implemented by the NSW Government for the City of Sydney and greater metropolitan local government areas plan to absorb an expected population increase of 1.1 million people within the next 23 years. (*Sydney Metropolitan Strategy 2006)*

Most of these proposals will rely on the Hawkesbury Nepean Catchment and its ability to absorb impacts from infrustructure required to deliver water supplies, dispose of effluent, absorb brine, biosolids and chemical/pharmaceutical increases and accommodate recreational demand, new housing, as well as industrial and commercial developments.

Climate
La Nina and El Nino and climate change are the current symbols for talking weather patterns and climatic conditions, these changes and the management of our lands and water resources collectively influence the productivity of aquatic ecosystems. Low rainfall over the last decade has meant that water restrictions have been in place for four years in Sydney. Environmental flows ceased from Warragamba Dam and water temperatures in the Hawkesbury Nepean River rose by 2 degrees*.(Derek Channon report 2007).*

Water Quality Guidelines
There is a plethora of guidelines regulations and standards to meet human and environmental requirements as well as river health strategies but these continue to fail to keep pace with climatic changes, population growth and subsequent timely protection for all aquatic ecosystems.

Guidelines for the health of humans have been developed over decades in particular the Australian Drinking water guidelines are to Australian and NewZealand Environmental Conservation Council guidelines (ANZECC) and World Health Organisation (WHO) standards. New National Guidelines for water recycling are now finalised. They are designed to allow human use and contact with recycled water for non potable uses such as irrigation and industrial purposes. Building guidelines incorporate a Building Sustainability Index (BASIX) program of energy savings *(Sydney Metropolitan Strategy 2006)* and water friendly appliances. Primarily these guidelines are designed for saving water and energy, to comply with regulated reduction targets and the planned growth of Sydney.

There are marine and freshwater aquatic ecosystem objectives and effluent disposal and industrial waste guidelines designed to ensure disposals meet minimum standards and are now administered by the Department of Environment, Climate Change and Water.

National and State Environmental Strategies
The National Water Initiative, new Standards and Targets and Government approved water quality and river flow objectives 2000, were set to influence improvements to the health of oceans, rivers and estuaries, yet the condition of the Hawkesbury – Nepean river system has continued to deteriorate. A water committee, expert panel and the Hawkesbury Nepean River Management Forum (FORUM) deliberated for four years (2000-2004) to evaluate and determine a strategy for environmental flows for the Hawkesbury-Nepean River. Many of the FORUM recommendations have now been completed, ie adjustment to transfers from the Shoalhaven River, environmental flows from the Avon and Nepean Dams, pumping from Warragamba and Avon Dams at lower water levels, delivering significant changes to the availability of water for Sydney, freeing up

access to a reported 30 billion litres. These changes were recommended by the FORUM to deliver environmental flows to the Hawkesbury-Nepean River while maintaining Sydneys' water supply.

In 2006/07, following further State Government deliberations for the water needs of Sydney, the Metropolitan Water Plan revealed a plan for a Desalination Plant in Sydney and Recycle Scheme for Western Sydney. These developments are approved under the critical infrustructure Act. They will provide an alternative solution to water for Sydney, environmental flows for the Hawkesbury-Nepean River and reduced nutrient loads, by lowering sewage disposal volumes down South Creek. An estimated 18 Billion litres a year proposed for environmental flows from Warragamba Dam, now to be retained for potable water and 50 ML/day environmental flow to be released below Penrith Weir. (18,250ML per year) Variable flows to be reconsidered 2009 and 2015.

The Metropolitan Water Plan and Water Sharing plan propose security for existing water entitlements and was expected to determine water allocations for the Hawkesbury Nepean River System, this plan is still under development with numerous 'assumed volume' water entitlements to be determined while changes to guidelines and allocations are progressing.

The productivity of migratory species such as school prawns, crabs and fish under present river conditions will continue to be under significant pressure if the Metropolitan Strategy, Metropolitan Water Plan and Water Sharing Plan fail to protect and secure extra healthy water for the needs of the Hawkesbury - Nepean River system.

DISCUSSION

Population Growth for Sydney

The Growth Centres Commission was formed to guide the progress of the planned 30-40% housing developments in the North and South West growth centres; the remaining 60-70% allocated to existing urban areas. The Central Coast is also in the Governments growth objectives. The Central Coast water supply from Mangrove and Mooney Mooney Dams are within the Hawkesbury-Nepean Catchment, they influence the health of the Lower Hawkesbury River and aquatic ecosystems including migratory species.

Population growth will require increased potable water and subsequently will have impacts in effluent disposal. Changes to allow privatisation and public access to harvest effluent from existing sewer systems and storm water harvesting is proposed but fails to be assessed as a total water cycle management for the whole catchment and Hawkesbury-Nepean River system at this time. The productivity of aquatic species and fish migratory patterns is not realistically considered or understood.

All water and effluent harvesting has the potential to significantly impact the Hawkesbury-Nepean River aquatic ecosystem due to extraction and disposal locations, volumes, timing and treatment processes.

The Hawkesbury Trawl Fishery

The Hawkesbury Trawl Fishery operates between Box Head and an imaginary line across to Barrenjoey Headland in Broken Bay upstream to Lower Portland Ferry. The fishery utilises less than 4% of the river and estuarine system 5 days a week (except for regulated public holiday closures to allow exclusive recreational access) to harvest the school prawn (*Metapenaeus macleayi*) and Eastern King Prawn (*Penaeus plebejus*), Greasyback (*Metapenaeus Bennettae)* Broad squid *(Photololigo etheridgei*) and Bottle Squid *(Loliolus notiluca)* The Hawkesbury prawn trawl fishery is the second largest estuarine prawn trawl fishery and the only estuarine squid trawl fishery in NSW. Both products command top prices for their quality and texture at market outlets as a food and as bait for recreational fishing.

Value of the Trawl Fishery

Due to discrepancies in the process for valuing the Hawkesbury Trawl Fishery no value is listed here for the specific fishery. Officially Sydney Market prices are utilised to value the fishery. There is a significant discrepancy between Sydney Market price and actual selling price received by fishers in the fishery. Historically many fishers have sold their produce external to the Co.Operative and Markets. Deregulation has increased this activity. In 2008/2009 prices for green Hawkesbury Prawns consistently more than doubled the price recieved by the Clarence River prawns on the Sydney market auction floor.

Essentially what price do you put on the importance of a species integral to the food chain of all species in the aquatic ecosystem? It is not appropriate to manage a river system on the value of the commercial catches of fishermen. The regulatory imposts placed on each fishery dictates the number of fishers and the earning capacity of the industry irrespective of external environmental influences.

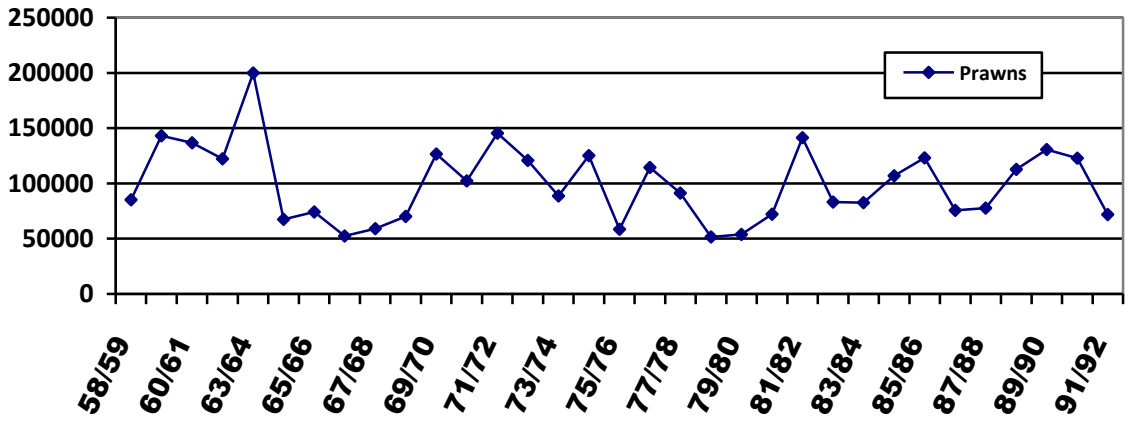
There has been a steady decline in catches over the period 1958/59 to 2006/07 (see graphs 1 and 3 below) and fisher numbers likewise have dropped. It may be argued that catch has declined due to fewer fishers harvesting, however fishers clearly argue that the reverse applies because there are not the prawns available, and the frequency of flushes is reduced due to the number of dams in the catchment and constant draw down of those dams in conjunction with drought and population growth.

Fishers in Broken Bay now target squid when prawns are not available. In the Estuary Prawn Trawl 2002 Environmental Impact Assessment the fishery was identified as fully fished i.e. current catches were sustainable and close to optimum levels.*(EIS Estuary Prawn Trawl Fishery (EPT)2002).* It is clearly demonstrated in the graphs that increased rainfall in the catchment has delivered increased catches for the periods 2007/08 and 2008/9. The number of fishermen fishing the estuary for prawns has not increased however there is a significant rise in catches for the 2008/09 period (graph 3) The catchments delivering flows to the Colo River and Mac Donald River received good rainfalls over this period, which are not picked up in the RAAF rainfall graphs.

The following graphs 1 and 2 compare prawn species catches with rainfall recorded at Richmond Royal Australian Air Force Base (RAAF) from 1958/59 to 1991/92

Graph 1

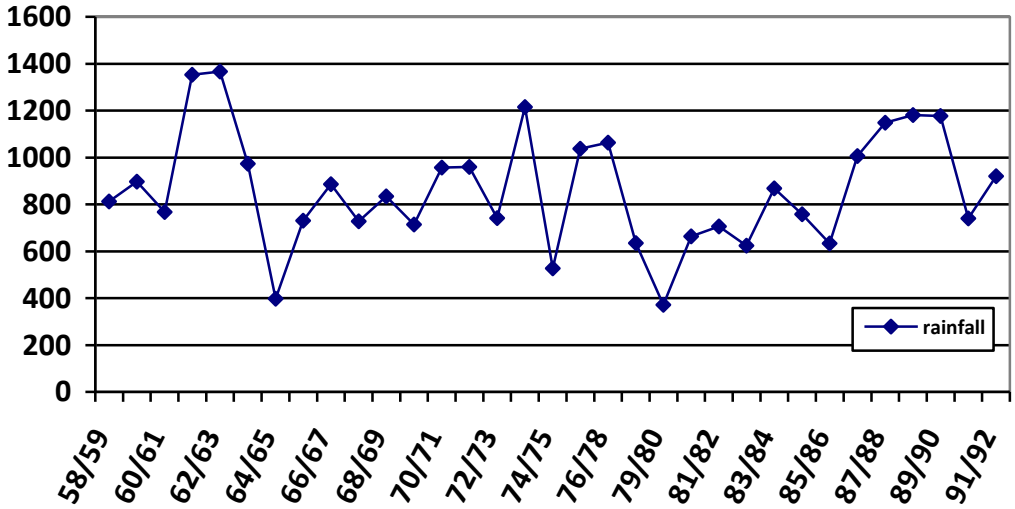
Hawkesbury River and Broken Bay Prawn Catches July 1958 to June 1992 *(NSW Fisheries)* by weight in kgs (combine methods).



GRAPH 2:

Rainfall in millimetres at Richmond RAAF base from June 1958 to July 1992

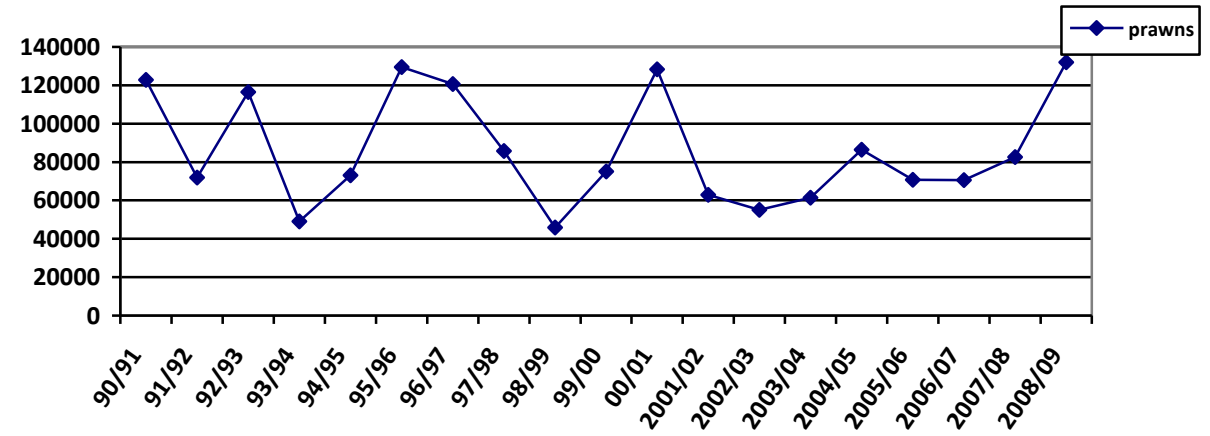
(Office of the Bureau of Meteorology)



The following graphs 3 and 4 compare prawn species catches with rainfall recorded at Richmond Royal Australian Air Force Base (RAAF) from 1990/91 to 2008/09.

Graph 3

Hawkebury River and Broken Bay Prawn Catches July 1990 to June 2009 (*NSW Fisheries)* By weight in Kgs.



Collective fisher months worked…

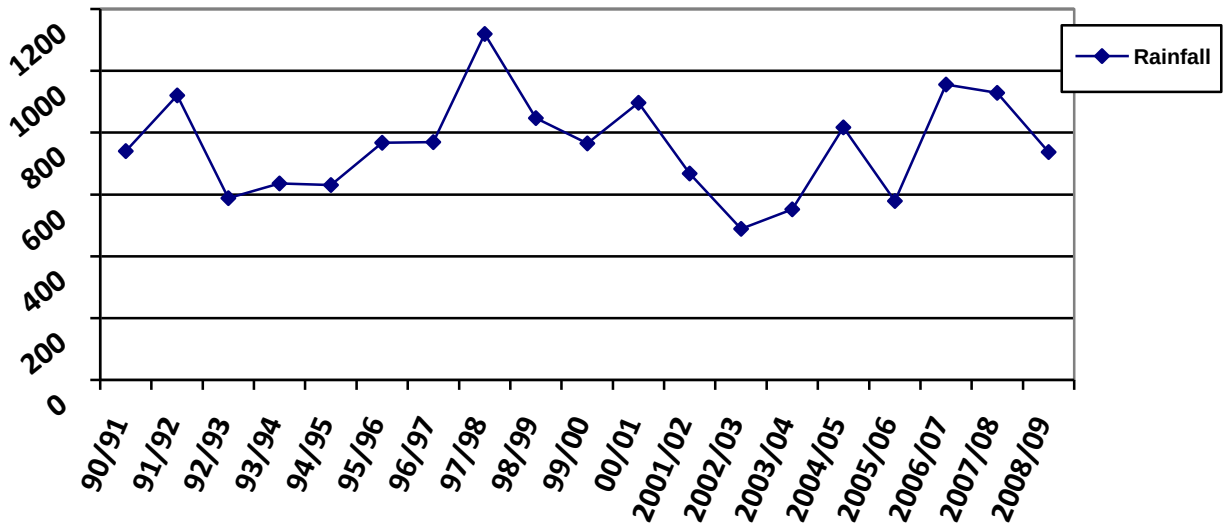
1997/98	304	2000/01	317	2003/04	239	2006/07	235
1998/99	263	2001/02	258	2004/05	259	2007/08	224
1999/00	270	2002/03	238	2005/06	230	2008/09	206.

Fish record returns received each month indictes number of fisher months worked

Graph 4

Rainfall in Millimetres Richmond RAAF Base from June 1990 to July 2009.

(Office of the Bureau of Meteorology)



It should be noted there was a return to normal pre drought water flow releases from Warragamba Dam in February 2008.

Traditionally many fishers only worked one tide in a day, many, now work both tides. Latent effort does exist in the fishery, from 2006/07 to 2008/09 fiscal year in every month at least 54% of the EPT FB did not report prawn catches for that month *(Makin D. NSW Department of Primary Industries figures 2009)* There are approximately 56 endorsed (licences) fishing business with less than half of these working full time. It should be noted that fishers trawling for squid do so under their endorsement for Hawkesbury Estuary Prawn trawl (EPT) . Some fishers have endorsements for alternate methods of fishing, they can then select which method to fish to maximise their returns. It is therefore not possible to define the actual latent effort from the figures provided in this document.

Fish do not breed or grow without the appropriate water conditions for survival. It is not new science that fish breeding capabilities are linked closely to salinity, temperature, oxygen, Ph, tidal movement (moon phases) and rainfall events.

The State Government plans for the growth of Sydney mean more and more demand is made on water extractions and less for the environment in the Hawkesbury-Nepean rivers and estuary. Increases in effluent disposal and high nutrients continue from all sources, dam storages consistantly draw down resulting in less spills and subsequently the trigger reactions do not take place. The life cycle of the *M Macleayi* is estimated to be a 15 month cycle where the prawn travels from the ocean into the estuary. The *M. Macleayi* can be found up stream as far as North Richmond. It clearly is able to travel through a range of salinity levels in its travels through the river. The Hawkesbury trawl fishery does not harvest above Lower Portland Ferry crossing, this is considered to be one of the prime nursery areas for the fishery. Tributories such as the Colo River, Macdonald River, Webbs Creek, Cowan, Berowra, Brisbane Waters, Pittwater have access closures. Hawkesbury Trawl Association members have assessed that 56% of the river is closed to trawling. In these regions water management affects the survival of juvenile prawns and subsequently affects the overall productivity of the species.

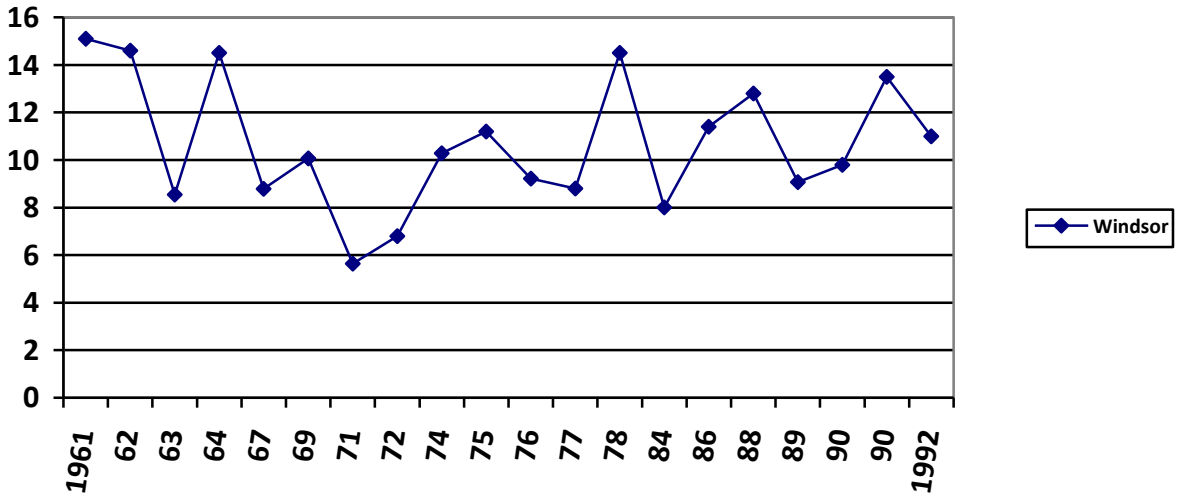
The *M.Macleayi* periodically sheds its shell to grow, but most importantly the female must be in a soft shell state for breeding (after moulting) moulting is triggered by water temperature, moon phase and the time of year.

The *M.Macleayi* migrates to the ocean where it breeds and fertilized eggs are shed onto the bottom of oceanic waters where they remain for a short time before they hatch. The first larval stage called a nauplius emerge and swim upwards towards the surface. There are several moult stages and between each stage an increase in size occurs before it becomes a protozoea. Similarly the protozea moults several times before becoming a mysis it is at this stage that it starts to resemble a prawn. *(NSW Fisheries State Leaflet No8)*

Changes to flows, nutrients, temperature, Ph, salinity and chlorophyl a, are just some of the essential components that have the potential to inhibit zooplankton survival (including prawn larvae) seasonally in Broken Bay, e.g. the new Brooklyn Sewerage Treatment Plant outfall in the main river channel.

Graph 5. Flood frequency and levels of the Hawkesbury River recorded at Windsor Bridge 1961 to 1992. There have been no floods recorded between 1992 and 2007 at Windsor bridge however it should be noted that in 2007 the MacDonald river flooded and a rise in the river occurred down stream of Windsor.

Height in Metres.



Lost Hydrology Expands Impacts

Two species of Macrophytes, namely *Egeria densa* and *Elodea canadensis* are spreading rapidly in the river both upstream of Penrith Weir and down stream *(Expert Panel 2004 Eleni Taylor-Wood).* In 2005-06 Salvinia spread through the Hawkesbury-Nepean River above Sackville to Penrith, establishing itself also in creeks lagoons and farm dams in the flood plain area. de oxygenating water, reducing nutrients and shading the river and creek surface. Over a million dollars was spent harvesting the Salvinia from the River. In the same section of river *Egeria densa* and *Elodea canadensis* is spreading. In 2004 fishers were concerned with the bulk of weed (*Egeria densa*) floating down stream as far as Lower Portland and disrupting fishing activities. In February 2008/09 following increased rainfall in the catchment, the weed has again been flushed down stream and now disrupts fishing at Laughtondale and can be found at Sentry Box Reach, but not to the same extent. Both species of weed develop long fragile strands to the top of the water that easily break off. Tonnes of weed now exists adrift instream in the tidal flow, rotting and dropping to the river bed.

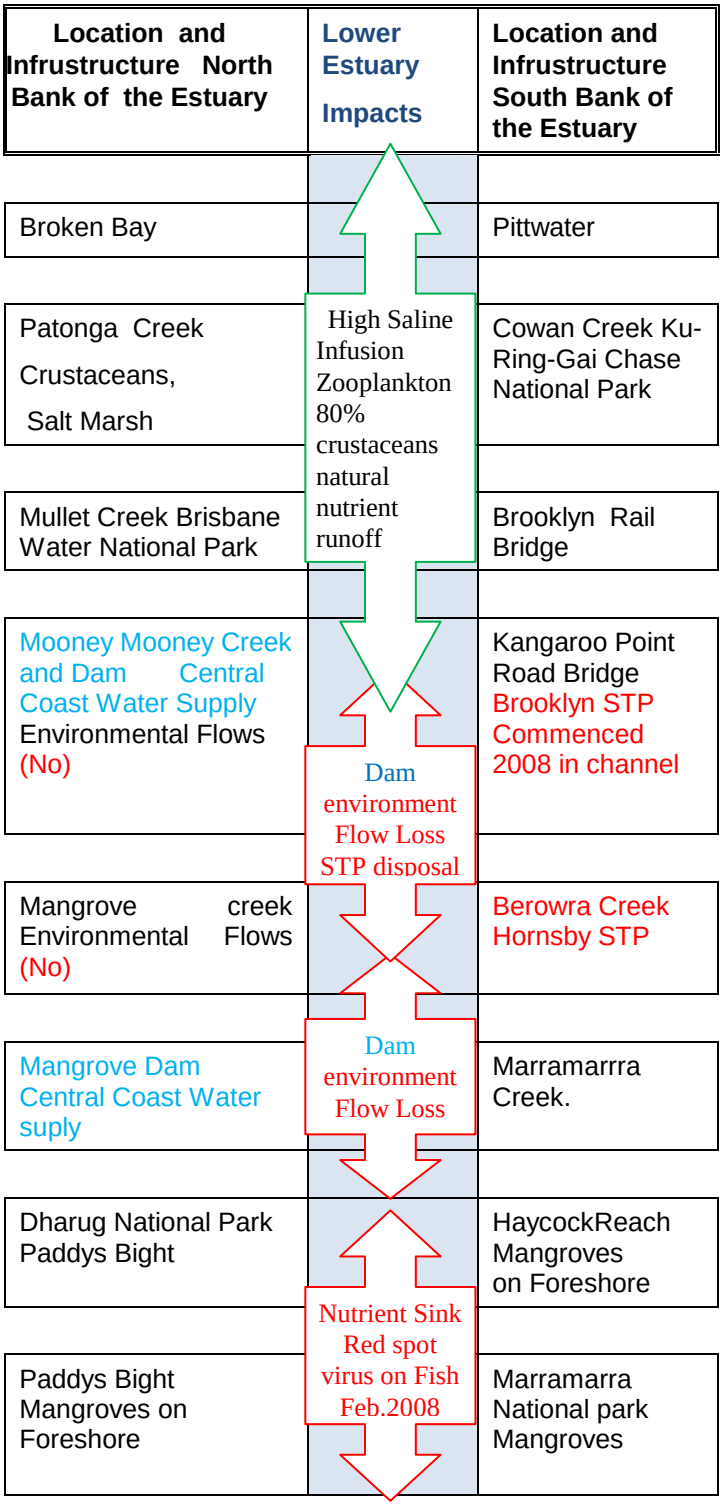
Environmental Impact Studies and Sydney Water Infrustructure proposals.

Due to the bulk of work being carried out by Sydney Water with its priority sewerage programs and Western Sydney recycle scheme affecting the Hawkesbury-Nepean River, fishers are continually grapling with the failure of Sydney Water to adequately assess and complete various studies to verify their statements of impacts on commercial fishing in environmental impact assessments.

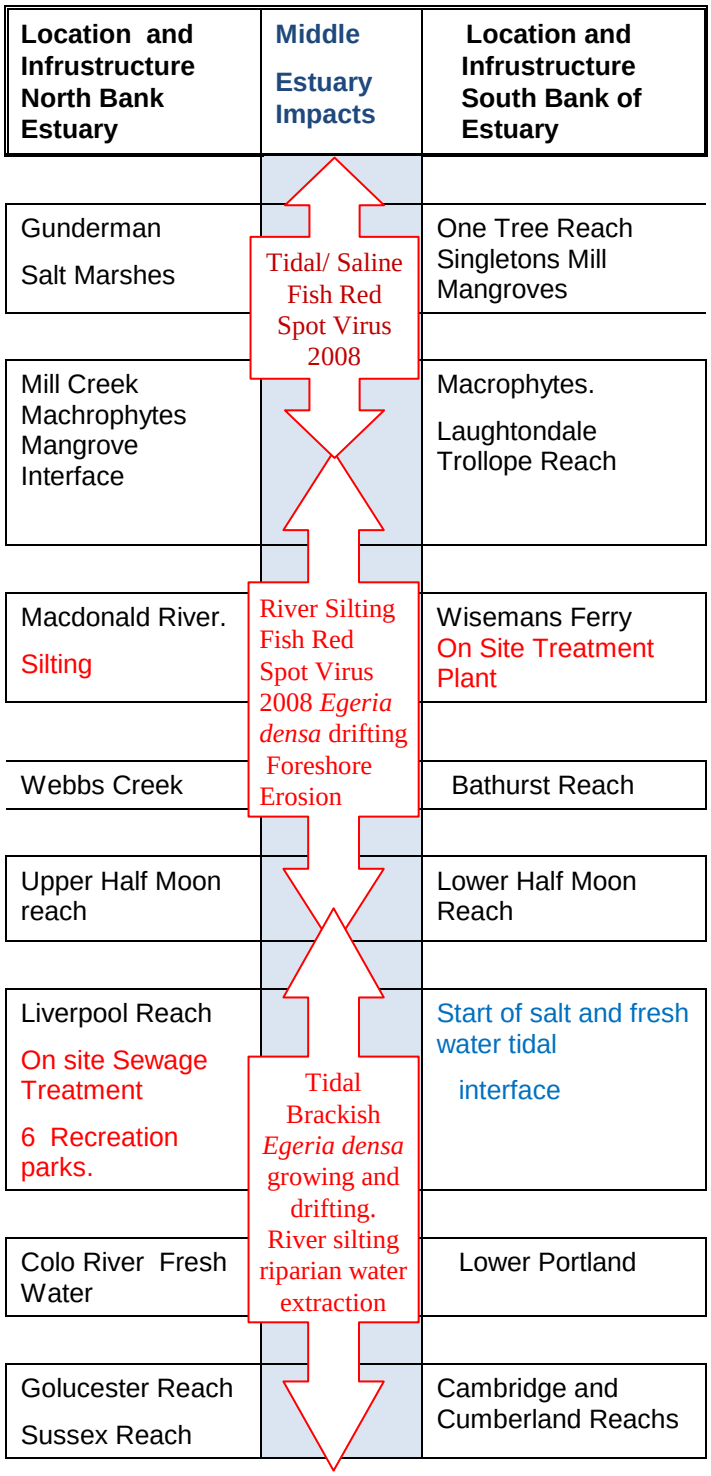
External scientific studies agree that the bouancy of fish larvae is linked to salinity and temperature and currents (*Effect of biotic and abiotic factors on biochemical composition of wild eggs and larvae of fish species. C. Guisande, I. Riveiro, A. Sola, L. Valdes.)*

The Brooklyn sewerage treatment plant and outfall remains a conern. Sydney water failed to adequately assess the impacts of this outfall on migratory species such as the *M Macleayi* while in the Zooplankton stage or for that matter fish larvae that may well be trying to make their way seasonally upstream. (See Schematic diagram 1.)

Schematic Diagram 1 Of Hawkesbury Nepean River to Sentry Box Reach STPs and DAMS



Schematic Diagram 2 Of the Hawkesbury River from Sentry Box Reach to Sackville North.



Trollope Reach: 2 recreation parks with onsite effluent reatment requirements

2 Golf Courses.

Bathurst Reach: 6 recreation parks with onsite effluent treatment requirements.

Lower Half Moon Reach: 1 recreation Park with onsite effluent treatment requirements.

Upper Half Moon Reach: 1 recreation Park with onsite effluent treatment requirements.

Liverpool Reach: 6 Recreation parks with onsite effluent treatment requirements.

Gloucester Reach: 1 recreation Park with onsite effluent treatment requirements.

Sussex Reach: 2 recreational parks with on site effluent requirements.

Cambridge Reach: 1. Recreational park with onsite effluent requirements.

Cumberland Reach: 1 recreation park with onsite effluent treatment requirements

Total Number of Parks this section of the river: 21 Parks with peak use in Summer.

Schematic Diagram 3 Of Hawkesbury-Nepean River, Kent Reach to Windsor.

Location Reaches and Infrustructure	Upper River Impacts	Location of reaches and infrustructure
Kent Reach		
		Sackville Ferry
Portland Reach		
		Lower Cresent Reach
Upper Crescent Reach		
		Swallow Rock Reach
Clarence Reach		
		Cattai Creek Castle Hill STP
Canning Reach		
		York Reach
Wilberforce Reach		
Buttsworth Creek		Windsor Reach Windsor Bridge
Turf farms Market gardens Irrigation Golf courses		Riverstone, Quakers Hill, St Marys STP 66ML Day +Mc Graths Hill and South Windsor STPs Flow into South Creek.
Richmond Lowlands		Salvinia
		Tidal Pools reliant on wet weather
Rickabys Creek		South Creek extraction 9.3ML/day
Richmond Drinking Supply		Argyle Reach
Cooley Creek		Richmond Lowlands

Foreshore erosion *Egeria densa* growing and drifting Brackish to fresh water Riparian Water Extraction (in excess of 150 pumps) River Silting Salvinia

2009 Fresh water flow reduction downstream of South Creek confluence **63 ML/day**

Kent Reach: 2 Recreation Parks with onsite effluent treatment requirements.

Portland Reach: Houses on Western bank with numerous riparian water pumps.

Lower Cresent Reach: 1 Recreation Park with onsite effluent treatment requirements.

Upper Crescent Reach: 1 Recreation Park with onsite effluent treatment requirements.

Swallow Rock Reach: 1 Recreation Park with onsite effluent treatment requirements. Housing Subdivision and 1 Golf Course.

Canning Reach: 1 Recreation Park with onsite effluent treatment requirements and subdivision.

York Reach: 1 Recreation Park with onsite effluent treatment requirements and subdivision.

Wilberforce Reach: 1 Recreation Park with onsite effluent treatment requirements. Golf Links (New)

Total Number of recreational parks this section of the river 8. There are at least 29 recreational parks between Trollope Reach and Wilberforce Reach with peak summer daily activities.

Many of the Small Treatment Plants are below the I in 100 Flood levels and below tertiary treatment.

Existing Flows South Creek receive tertiary treated effluent 66ML / day.

New Flows 2009
Quakers Hill 19 ML
St Mary's 5 ML
Riverstone unknown
Natural flow 1 ML
Less 9.3 ML/day extraction allowed.
Tidal exchange to South Creek keeps Flow equivalent to existing Flows.
STP flows will still be dominant flows into South creek in Dry weather.

Schematic diagram 4 of Nepean River from Redbank Creek to Wallacia Weir. War (Sy

Location Reaches and Infrustructure	Upper Impacts	Location of reaches and infrustructure
Redbank creek	Nepean	Turf farms
		Richmond
North Richmond	*Egeria densa* Silting, Erosion Shallow Slow Flow	
		Richmond Bridge
Grose River 60ML per day.		Yarramundi Lagoon
Mahons creek		
Rivatts Creek		Agriculture
Lynches Creek		
Shaws creek	Shallow Pools *Egeria densa* Pumps Riparian Access Irrigation Salvinia Nutrients	
Frazer Creek		**Penrith Lakes**
Waterside Green developments		Boundary Creek existing Penrith STP 22ML/ day
Operational rules regulate flows over the Penrith weir.		existing 50ML per day. Penrith Weir
Wallacia STP 1.5 ML /day.	18 Kms between	Weir PoolProtection extraction proposed Drought
Wallacia Weir		Gorge

Comparisons Existing Drought flows between Warrragamba, Penrith Weir and Boundary Creek
(Sydney Water Recycled Water Initiative 2006)

Existing Flow **Proposed 2009**

Drought Dominated

Richmond Drinking Supply extraction. **50ML per day**

Richmond Drinking Supply extraction. **50ML per day**

Grose River 60 ML and Winmallee STP **13.9 ML/day**

Grose River 60ML and Winmallee STP 13.9 **ML/day**

Low 63ML Median 147ML downstream **Penrith Weir**

Low 117 ML Median 239 ML a day downstream **Penrith Weir**

Penrith Lakes Development no flow variation included. Penrith Lake Plans include pumping requirements.

Existing Flows drought dominated Penrith STP Boundary Creek **22ML/day**

Proposed Western Sydney Recycle scheme constant environmental **Flow 50 ML/day**

Low 41 ML Median 125 ML 95 (percentile) 50

Low 67ML Median 189 ML Relies on cease to pump rules up stream Weir modifications

Drought Flow Warragamba Dam Low **22ML** Median **43 ML**

No Environmental Flow from Warragamba at all. Flow loss 18 Billion liters a year.

Western Sydney Replacement Flow Project
The upgrading of treated effluent from South Creek to reverse osmosis via Western Sydney Recycle Scheme, will provide environmental flows below Penrith Weir pending cease to pump rules in drought conditions. (See Schematic Diagrams ,3,4). It will lower effluent flows and nutrient loads down South Creek except in dry times, when effluent flow will remain the dominant flow in South Creek. There is no evaluation of the future water requirements of Penrith Lakes and Waterside Green development provided in the flow regimes.

No change is expected to the continued weed growth in the Hawkesbury- Nepean river, because of the loss of environmental flows from Warragamba, the reliance on the Nepean Dam (ie no flows from Upper Nepean more than 40% of the time)(*Sydney Water Chapter Seven River health and Water users*) and the completion of the Penrith Lakes Scheme which will require water continually.

It is also expected that Macropyhes such as *Egeria densa, Elodea canadensis* Salivina and alligator weed will proliferate in South Creek due to flow changes. River, estuary and creek depths, temperatures, nutrients and flow are all significant factors in the proliferation of exotic weeds being experienced in the area. There is a management regime required that provides variable flows in conjunction with climatic conditions to continue to disturb exotic weed and to restore normal aquatic ecosystem health requirements. *(Eleni Taylor –Wood January 2003).*

The Western Sydney Recycle scheme EIA claimed that there would be no impacts to commercial fisheries. No modelling of South Creek was provided. A constant reverse Osmosis flow does not provide a solution to the water problems currently being experienced in the river from Penrith to Sackville, an area where juvenile prawns are found along with Eels, Bream, Bass, Mullet, and where Macquarie Perch once lived. Sydney Water do not consider they have a threatened species issue because they are no longer there. King Prawns are decreasing in numbers in the commercial catch in Broken Bay, from the mouth of the Estuary, King Prawns are not the most significant species targeted in the Hawkesbury River, the most obvious species for monitoring impacts would be the (*M Macleayi)* no apparent monitoring or assessment of impacts appears to be considered in either the Brooklyn STP (that has now commenced disposal of highly treated effluent) or the Western Sydney Recycle Scheme except to conclude that there would be no expected impacts to the fishing industry.

When queried on the impacts of endocrine disruptors on the fish population in Broken Bay Sydney Waters response was that the STP was to cater for a domestic market. In studies on common pharmaceuticals (*Colleen Flaherty 2002)* found that the cholesterol – lowering drug clofibric acid; and the anti depressant, fluoxetine were fatal to freshwater zooplankton (Daphnia) when combined. The cumulative impacts from the Mouth of the River to the top of the catchment all link together, each slowly compounding on the river ecology in different locations. The present method of assessing impacts on river ecology is not working. Clear evidence of this is the condition of creeks that receive STP loads and in the costs to maintain harvesting of weeds in the river from Penrith to Windsor, fixing the problem not the cause.

The loss of the Sydney Rock Oyster Industry requiring a replacement with Pacific Oysters. Frequent but unrecorded, outbreaks of 'Red Spot' disease (*Aphanomyces invadans*) in fish, 'Lordosis' deformaties in Bream and Mulloway are all symptons of a river under stress. There comes a time when any impact is more than the river can tolerate because of the cumulative affect of all impacts. The Critical Infrustructure Act., Sydney Water and State and Local Government Environmental Impact Assessments, Department of Environment and Climate Change licensing and monitoring, Department of Planning and the Department of Water and Energy guidelines are not sufficient to deter the decline. (The precautionary principle is not applied.) The timing of the proposed review of Environmental Flows 2009 and 2015 is unacceptable due to the impacts of development already occuring along the River foreshore and catchment and discrepancies in the proposal for Replacement Flows.

Irrigators presently extract the Environmental Flows released from Nepean Dam. It requires a 60th Percentile flow to maintain flows over Wallacia Weir (Sydney Water Recycled water Initiative 2007).

Modelling and proposed Flows For Penrith Lakes

It is apparent that modelling by Sydney Water is not clear and the overall impacts to the aquatic ecosystem are not assessed appropriately in modelling assumptions. The developments in the catchment impacting water quality are continually changing and the river requires continual remediation by environmental flows as well as variation for climatic influences.

In March 2005 the Independent Expert Panel (*Penrith Lakes Water Committee report*) for Penrith Lakes in its evaluation of the Penrith Lakes Waterplan were of the view that the only reliable alternative water supply in the long term for Penrith Lakes and Waterside Green developments was treated effluent from the Penrith Sewerage treatment plant (STP) provided it was treated to a similar level as the Rouse Hill STP development. There appears to be a volume discrepancy in the Sydney Water Environmental Impact Assesment for the Western Sydney Recycle Scheme including Penrith STP flows.

Clearly the Western Sydney Recycle Scheme proposal must play a part in the Water Plan for Penrith Lakes and could also be a vehicle to lengthen the holding time of water before it reaches the river and can in fact facilitate a variability in flows by holding water and releasing water in different capacities. (ie wet weather events)

Optimum modelling assumptions are not being utilised, environmental flows provided will not improve river condition below Penrith weir unless proper modelling assumptions are made and flows are delivered in accord with the best outcomes from the modelling process and are variable according to climatic occurances. Lesser values are not acceptable and will lead to a collapse of riverine condition which is in fact what is occuring in the Penrith to Sackville region now.

Protected transparent and translucent variable flows need to be provided from Warragamba Dam in appropriate volumes to support human health as well as the aquatic ecosystems. Humans eat fish and fish eat fish and ironically fish stop multiplying and growing with deteriorating water quality and low flows. Overall aquatic productivity is reduced through the system to the sea. The management of the resource concentrates on restriction and reduction of commercial fishing and a bandaid resolution for remediation and improvement to the environment, by recreational fish stocking and weed harvesting.

Sydney Catchment Authority

Sydney Catchment Authority (SCA) was established in 1999 under the Sydney Water Catchment Management Act 1998, they are responsible for 21 dams under regulation and must protect and enhance these catchments identified as drinking water catchments. SCA's customers include Sydney Water, two local councils and 61 retail customers. 18 of these dams are located in the Hawkesbury Nepean River Catchment.

Within the catchment there are also numerous irrigation dams and bores as well as regulated and riparian pumping direct from the river. There is a failure to have historic pumping records in many cases because 'volume' has only recently become a requirement for accountability.

In 2005/06 it was reported that 80% of Sydneys water supply came from Warragamba Dam *(SCA Annual report 2005-06).* The existing town water suppliers that are reliant on the Hawkesbury Nepean Catchment provide water to more than just the Greater Sydney Metropolitan region. Sydney Water purchases its bulk water from SCA.

Main Dams affecting the Hawkesbury Nepean River

The lower Hawkesbury River is affected by the Mooney Mooney and Mangrove Dams that have not provided 'environmental flows' except for 1991, 1992, 1993 and 1994. Flows during this period resulted because of the changes required with dam construction works and the 1 in 100 flood in 1992.

The Nepean, Avon, Cordeaux, Cataract and Warragamba Dams are significant to 80% of Sydneys water supply along with Broughtons Pass Weir and Pheasants Nest Weir. Wingecarribee Reservoir, Fitzroy Falls Reservoir, Bendela pondage and Tallowa Dam, they are crucial components of the water supply system. These Dams are located above the Hawkesbury flood plain and confluence of the Nepean and Warragamba River.

The Blue Mountains water supply for Blackheath, Mount Victoria, Katoomba, Luera, Orchard Hills and Lithgow relies on the Fish River Dam, Greaves Creek and Medlow Dams, the three Cascade Dams and Woodford Dam.

North Richmond water supply is pumped direct from the River at Richmond. There is a regulated commitment for SCA to supply 50 megalitres a day over the Penrith Weir for (compensatory) irrigation and domestic purposes.

This was reduced to 33.3 megalitres a day due to the drought. Flows have recently been restored (February 2008) to existing pre drought levels. This flow is not a protected variable environmental flow it was previously insufficient to maintain the river in a healthy condition.

There are numerous gauging weirs and thirteen irrigation and compensation weirs. *(FORUM Report 2004)* These weirs are situated between Maldon and Penrith and restrict the availability of environmental flows to the lower estuary. Weirs slow the velocity of water flow, affect water quality and subsequently impact water condition as well as the flow. Fish are not catered for in many of these weirs.

Sydney Water (SW) customers were using in excess of 634 GL per year in 2004. They have however reduced their consumption in conjunction with water savings targets and water restrictions due to the drought conditions prevailing for the past decade. (SW has a target of 329 litres per capita per day by 2011, a reduction from 416 litres per capita per day June 2003) SW is the largest water manager in Australia. Sydney Water also manages the subsequent disposal of effluent from the Greater Sydney Metropolitan area including the Blue Mountains.

Numerous centralised Sewage Treatment Plants below the threshold of 2500 person operate under the small wastewater plant Code of Practice.

At least 29 recreational parks (*Schematic diagram 2 and 3)* that are not connected to Sydney Water or Hawkesbury Councils treatment works are operating along the Hawkebury River in the Windsor to Wisemans Ferry reaches. These parks have peak use in summer and holidays.

It is estimated that in excess of 180 megalitres of tertiary treated effluent a day is entering the Hawkesbury Nepean River System. Studies completed in 1995-1997 (*G.P. Bickford; SV Smith)* identified that above Sackville the major source of dissolved inorganic Phosphorous is Sewerage treatment plants, with a relative small contribution from non-point sources and is taken up either organic or inorganic particulates close to sewage treatment plants with 20% reported as introduced to the river below Sackville. Nitrogen on the other hand 90% is from STPs 20% reaches the estuary the rest is interpreted to be lost to dentrification. It was determined that there was a strong nitrogen presence from an internal source in the lower estuary possibly from mangroves.

Sydney Water completed a strategy in the late 1980s to reduce STP phosphorus levels, oxygen demand and ammonia levels of effluent. *(NSW EPA 1994 G.P. Blockford;S.V. Smith)*

Several Priority Sewerage programs have been completed since this report, Brooklyn/ Dangar Island STP commenced in the main channel at the Brooklyn Road Bridge February 2008. Silverdale has been connected to the Warragamba /Wallacia outfall and the Bluemountains outfalls have combined to be released from Winmallee.The West Camden Sewage Treatment Plant, a fifty million dollar upgrade that can provide recycled water to Elizabeth Macarthur Agricultural Institute. It has the potential to pump five million litres a day for irrigation. The Three Towns program of Wilberforce, Glossodia and Freemans Reach Environmental Impact

Assessment has been to public consultation the effluent will be transferred to Richmond treatment plant. Effluent disposal will continue to increase with the growth plans for Sydney in particular Hornsby STP and Castle Hill STP both flow into the Hawkesbury River.

Table 1. Sydney Water inland Sewerage Treatment Plants 2008-09 discharges to the environment Kilolitre per year.

Area	STP	*Volume (kL/year)
Inland	Brooklyn	52146.7
Inland	Castle Hill	2266586.9
Inland	Hornsby Heights	2326531.3
Inland	North Richmond	319620.2
Inland	Penrith	8391441.9
Inland	Picton	4997
Inland	Quakers Hill	13773180
Inland	Richmond	322818.3
Inland	Riverstone	665813
Inland	Rouse Hill	3863693.8
Inland	St. Marys	13386821.4
Inland	Wallacia	227099.1
Inland	West Camden	3115084.9
Inland	West Hornsby	4159498
Inland	Winmalee	6465731
	Total	59341063.5

The bulk of effluent discharge is occuring between Penrith to Sackville. The bulk of exotic weeds out of control are between Penrith to Sackville. A close look at Sydney Waters' environmental reports for creeks that are receiving constant tertiary effluent flows clearly demonstrates that they are unsuitable for aquatic life, South Creek, Eastern Creek and Cattai Creek just to name a few. These three creeks are all above Sackville Ferry.

Environmental Impact Assessments

Each new sewerage treatment plant proposed has an Environmental Impact Assessment (EIA) evaluating proposed impacts on the estuary or river before approval and histrorically each is appproved as an acceptable impact.

The Hawkesbury River has been under stress for at least thirty years with numerous studies and strategies developed to improve it. Unfortunately with the proposed new developments in the Hawkesbury catchment and present environmental guidelines the Environmental Assessments prepared and accepted will not deliver real outcomes because they fail in real terms to improve on existing conditions.

There is no established “how much is too much” tertiary treated effluent flow determined for any individual section of the river or estuary. The section of river from Penrith Weir to Sackville Ferry is a classic example.

The river is a drowned river valley and narrows above Sackville. This is generally where the salt water wedge is fluctuating and subsequently the fresh water moving down stream becomes a lense over the salt wedge. *(E.Wolonski, P Collis, Aspects of Aquatic Ecology of the Hawkesbury. 1. Hydrodynamical Processes.)*

This is also the drainage area for industry, urban development, agriculture, horticulture and pharmaecuticals and chemicals.This then brings about an area of river that is and has been predicted to be a source of concern for managers and also fishers using the river. The area that is a nutrient ‘sink’ that is also silting up with invasive weeds and reduced flows and experiencing higher temperatures due to this and changing climatic conditions.

Hydrodynamical Processes

In 1976 *E. Wolonski and P.Collis* determined that under wet weather conditions a thin freshwater lens is rapidly flushed to the ocean composed of ‘new’ runoff water floating passively over the underlying layer of ‘old’ saline water. Under dry conditions mixing occurs from tidal turbulance, but does not create complete vertical mixing. Strong density currents are generated by the longitudinal gradients of salinity. Their study predicted that by the year 2000, sewage treatment plants in the upper reaches of the estuary would result in a serious decline in river/estuarine condition. Their population prediction at that time was 1,150,000 people. The river is divided into two regions, one above the tidal head at Richmond and the other down stream to the mouth of the river and is defind as a coastal plain estuary 6km inland from Broken Bay it was observed that fresh water had not mixed with salt water in a fresh and in fact was a lens on the top. It was determined that the saline inflow was 16 times larger than the freshwater discharge and subsequently the currents accelerated to the sea.

Present Condition above Sackville

The river above Sackville up to and above the Penrith Weir has become invaded with a variety of aquatic weeds. Weeds that flourish in low constant high nutrient water regimes. In excess of one million dollars has already been spent on the removal and control of Salvinia that had spread uncontrolled through this section of the river 2005/06,07. The steps taken by Government had controlled the Salvinia in most of the river by 2008 however in this same section *Egeria densa* is spreading in the water column. *Egeria densa* over the last 4 years spread to below Lower Portland Ferry. This weed ‘strangles’ native grasses and can grow in water several metres deep. It breaks off and moves up and down with the tide. In February 2008 following several significant rain events *Egeria densa* could be found down stream as far as Sentry Box Reach, subsequently the deterioration above Sackville Ferry is impacting the river ecology to Sentry Box Reach.

Commercial Fisheries Future

A Background paper for NSW Fisheries *(Phillip Gibbs 2007*) found that Climate Change will have a significant impact on commercial fisheries in estuaries due to aquatic ecosystem changes as a result of the aquatic plant and animal species varying in parallel with habitat changes. Eastern King, School and Greasyback prawns were predicted to decrease because their lifestyle was reliant on estuarine wetland habitats and their reliance on the freshwater discharges through rivers and estuaries.

Recognition of the strategies required due to recruitment patterns for fish, crustaceans and molluscs from changes in physical habitats was recommended, highlighting the need to monitor and model existing fisheries to inform consultative governance and legislation.

The Hawkesbury River fishery is not only contending with climate change it is trying to hold its own with anthropogenic changes that lower freshwater events and compound nutrient loads resulting in a similar scenario. The impact is being felt by the commercial fishing industry, grounds now unworkable due to *Egeria densa,* floating in the water column and choking nets, they are excluded from fishing or cooking due to effluent disposalzones. Fishers who cook prawns have to stop due to blue green algae outbreaks at Lower Portland. There is lower productivity as a result of deteriating river condition and low flows.

Freshwater flows alone can affect estuarine communities independantly of nutrients, contaminants, or suspended sediments. *(Hayward, B.W., H.R. Grenfell, A.T. Sabaa, M.S. Morley and M. Horrocks. 2006 Effect and timing of increased freshwater runoff into sheltered harbour environments)*

In *2002, Stuart E. Bunn, and Angela H. Arthington wrote the Basic Principles and Ecological Consequences of Altered Flow regimes for Aquatic Biodiversity.* They stated quote ‘Firstly, flow is a major determinant of physical habitat in streams which in turn is a major determinant of biotic composition. Secondly, aquatic species have evolved life history strategies primarily in direct response to the natural flow regimes and thirdly, maintenance of natural patterns of longitudinal and lateral connectivity is essential to the viability of populations of many riverine species. Finally the invasion and success of exotic species and introduced species in rivers is facilitated by the alteration of flow regimes. The impacts of flow change are manifest across broad taxonomic groups including riverine plants, invertebrates and fish.’ End Quote.

There are numerous studies quoted in the report that conclude that flows are significant to the productivity of fish and invertebrates. Prior to regulation, many species of fish in Australian rivers were thought to have used inundated floodplain wetlands of lowland rivers for breeding and juvenile habitat. *(Geddes and Puckeridge 1989)*

River regulation to prevent flooding has seriously affected such recruitments. Although fish species have been introduced into a wide variety of environments, the greatest success has been achieved in waters which have been dammed, diverted, and otherwise modified, creating permanent standing water (reservoirs) and more constant flows than previously existed (*e.g.,*

Moyle 1986, Arthington and other 1990.) Long term success of an invading fish speci es is much more likely in an aquatic system permanently altered by human activity than in a lightly disturbed system *(Moyle and Light 1966b)*

The greatest challenge to resolving the problem was determined to be the separation of direct effects of the modified flow regime from impacts associated with land use changes that often accompany water resource development. (e.g.conversion of forest to irrigated agriculture). *(Stuart E. Bunn and Angela H. Arthington 2002).*

This is the dilema that is now occuring in the Hawkesbury River. The failure of Government and its agencies to deliver accurate assessments of river flows in conjunction with the direct affects of development in the catchment. The need to recognise the deteriating health of the whole Hawkesbury-Nepean River aquatic ecosytem and the part flows play securing its health. The priority is not the health of the river, it is accomodating the growth of Sydney and securing its water supply and disposal of effluent.

Australia's legacy from the era of dam construction and floodplain modifications is highly modified flow regimes and degraded rivers *(Angela H Arthington and Bradley J Pusey* 2003) Flow regulation has the hydrology of rivers on three scales of temporal variation (Walker et al., 1995; the flood pulse (days to weeks), flow history (weeks to years) and the long term statistical pattern of flows and flow regimes (decades and longer).

To give policy to jurisdictions and water managers responsible for implementing the reforms, 12 National Principles for the Provision of Water for Ecosystems *(ARMCANZ,ANZECC,1996)* were formulated. The basic premise of the principles is that rivers and wetlands are legitimate 'users' of water and that the provision of water allocations is critically important to ecological sustainability . The goal of the principles is 'to sustain' and where necessary restore ecological processes and biodiversity of water dependant ecosytems by means of water allocations that are legally recognised and founded on the best scientific information available (ARMCANZ,ANZECC. 1996 p5) The principles further require that all aspects of water management must consider the implications for water–dependant ecosystems; monitoring systems must be established to assess the ecological outcomes of water allocations, and they must be amenable to adjustment on the basis of new knowledge and understanding gained through monitoring and research *(Angela H Arthington and Bradley J. Pusey)*

CONCLUSION

Population increases into the Sydney Metropolitan area have required the NSW Government to explore, plan an implement strategies to ensure water availability and security for the City of Sydney and suburbs. Critical infrustructure developments such as the Western Sydney Recycle Scheme have been designed to provide opportunities of disposing effluent into the river as an alternative flow so that 18 Billion litres of potable water from Warragamba can be retained to ensure security of supply.

The proposal will improve the quality of the transferred effluent from St Marys and Quakers Hill however does not improve the effluent that will continue to flow into South Creek and maintained for use by irrigators. In drought the predominant flow in South Creek will be from treated effluent.

The Sydney Water Environmental Impact Assessment for the Western Sydney Recycle project indicates that the variability will rely on the flows from the Nepean River and cease to pump rules in a drought. The Nepean Dam has had periods where it has not had a spill for 10 years. The environmental flows being released down the Nepean are not breaching Wallacia Weir and the Environmental Impact Assessment indicates a 60% flow would be required to maintain a flow over Wallacia Weir. There are discrepancies in the evaluations provided in the environmental impact assessment that fail to deliver clear flow outcomes.

The overall objective is not delivering increased flow to the Hawkesbury River in conjunction with climatic conditions, it is a constant flow from the recycle scheme and variability in line with hypothetical assumptions.

Unfortunately for the Hawkesbury – Nepean River modelling assumptions of river flows and nutrient loadings in the past have been obviously flawed. Prolific exotic weed growth feeding on high nutrients have been spreading down the river for over a decade, distorting nutrient levels and depleting oxygen. Constant flows made daily into the river from tertiary sewerage treatment plants from a variety of locations the length of the river will continue to increase nutrients even with the Western Sydney Recycle Scheme. Brine concentrations from reuse projects will need to be disposed of either to the ocean outfalls or various sewerage treatment plants.

The consolation is that at least reverse osmosis treatment is better than tertiary treatment for a small portion of the total existing effluent load and it is hoped most of the proposed new effluent loads expected from the planned growth of Sydney and greater metropolitan area.

The rivers problems will continue unresolved as population growth and water demand outstrips supply. The program of harvesting storm water will remove from the environment a further significant volume of water and flows will continue to be compromised for human priority.

The rivers ecology needs are still secondary and the needs of a very small fishing industry are negligible to that of a growing city. What is of significance and is ‘priceless’ is the value and survival of the Metapenaeus macleayi and its importance in the maintenance of the food chain in the whole aquatic ecosystem of the Hawkesbury-Nepean River from Broken Bay to Penrith.

This species is food for a multitude of species ie Bream, Mullet, Mulloway, Bass, Eels, Whiting, Hairtail, Stingrays, Sole, Squid, Bull Sharks, Crabs etc., utilising the length or part there of, of the Hawkesbury – Nepean River. The needs of the aquatic ecology remains poorly understood by the Department Of Planning and NSW Water managers. This is obvious by the assumptions made and subsequently challenged in the environmental assessments of the Brooklyn STP and outfall

and the Western Sydney Recycle Scheme. Pre monitoring and evaluating the impacts to fish productivity is not assessed appropriately in the reports made.

The management tool of NSW Primary Industries is to continue to blame Commercial Fishers for most of the depletions in fish populations and restrict remove or buy them out as a trade off for exclusive recreational fishing and restocking programs.

Along the NSW coast Fish Co.Operatives are closing their doors as one by one fishermen are being bought out and supplies cannot be maintained by the number of fishers remaining, while habitat loss, climatic conditions, acid sulphate soils and altered flow regimes are resulting in fish dying in our rivers by the tonnes from lack of oxygen, low or high Ph, high nutrients, polluted flows or no flows and poorly understood habitat maintenance requirements.

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ACKNOWLEDGEMENTS

I acknowledge the contributions of Geoffrey Rose, and Gary Howard; Hawkesbury Prawn Trawl Fishermen. Laurie Derwent from NSW Department of Primary Industries (Fisheries.) Anissa Lawrence, and staff of Ocean Watch for their advice and expertise. Disclaimer: The views expressed in this document are the views of the Author and not those of any affiliated organizations.

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Map 1 Hawkesbury -Nepean Catchment

(NSW Fisheries Hawkesbury – Nepean River and Catchment)

Figure 1: Map of the Hawkesbury-Nepean River System, showing the catchment boundary as well as the major tributaries and urban centres.

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