Urban Wastewater Re-Use and Integrated Aquatic Production Project No. 32R-3007 FINAL REPORT

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Victoria
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Urban Wastewater Re-Use and Integrated Aquatic Production

Project No. 32R-3007

FINAL REPORT

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Introduction

Australia's water resources are coming under increasing pressure through the effects of prolonged drought and increasing urban populations. The fact that Australia has one of the highest per capita water consumption rates in the world (Anon, 2003) has compounded the problem and in Victoria water restrictions have been imposed in many areas in recent years to conserve scarce supplies. The severity of recent conditions has prompted many Victorian Water Authorities to actively pursue opportunities for water reclamation, recycling and re-use as part of their water and wastewater management strategies.

Treated urban wastewater is increasingly being recognised as a valuable resource, but only a small proportion of it is currently recycled in Victoria. There is a wide range of potential uses of recycled water, the actual use being a function of the standard to which it is treated (Radcliffe, 2004). Common uses of recycled water in Australia include:

- Agricultural and horticultural irrigation;
- Irrigation of golf courses;
- Irrigation of parks and public areas.

In Victoria, several key policies have been developed to underpin the role of recycled water in the long-term sustainable management of Victorian water resources (Alloway and Corlett, 2006). The *White Paper on Water* (DSE, 2004) signalled the Government's intention to promote the beneficial uptake and re-use of recycled water and sets a specific goal to increase the amount of recycled water from wastewater up to 20% across the state by 2010. In addition, State Environmental Protection Policies (SEPPs) set high level environmental quality objectives and attainment programs. These policies envisage that increased re-use of treated urban wastewater will reduce waste and provide triple bottom line (environmental, social and economic) benefits to the community. Specifically, the benefits on increasing the volume of water recycled include (Angelakis and Bontoux, 2001 as cited in Po *et al.*, 2004):

- Protection of water resources,
- Prevention of coastal pollution,
- Recovery of nutrients for agriculture,
- Augmentation of river flow,
- Savings in wastewater treatment,
- Enhancing groundwater recharge, and
- Sustainability of water resource management.

This project investigated the commercial viability and social acceptability of an innovative approach to the re-use of Class C treated urban wastewater – the production of fish using aquaculture technologies. This concept differs from conventional, stand-alone aquaculture production systems as aquaculture would be integrated into the recycled water distribution system (Figure 1) and the nutrient-rich wastewater would be the primary source of nutrition for the target culture species, rather than artificial diets. In this aquaculture production system (known as Integrated Wastewater Aquaculture or IWA), the fish feed on plankton biomass and biosolids that are generated naturally when the recycled water is ponded and exposed to sunlight. The feeding activity and harvesting of the fish can lead to a reduction in nutrient levels in the recycled water and the natural disinfection processes that occur in the aquaculture pond can produce an effluent that is better quality than that of the influent. Since this form of aquaculture is generally a non-consumptive use of recycled water, the effluent water is available for re-sale to downstream users.

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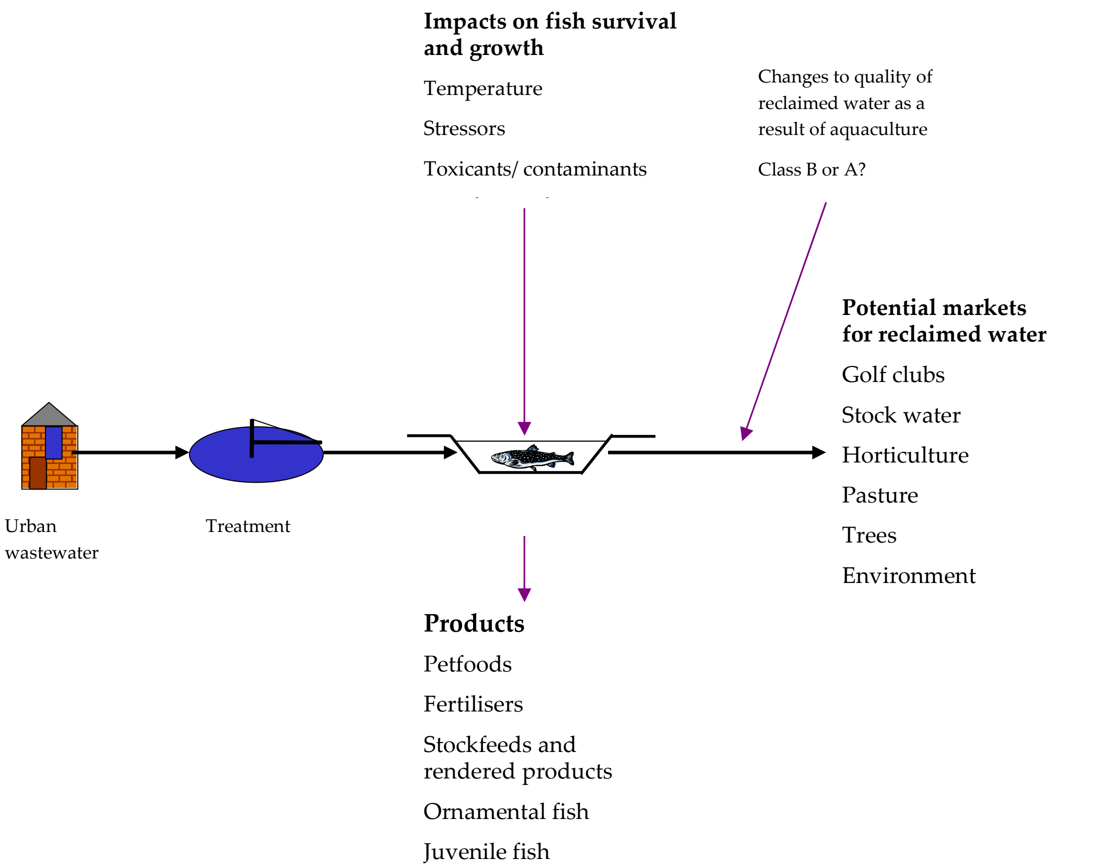

Figure 1: IWA, integrated into the recycled water distribution system and producing value added products from both aquaculture and horticulture.

Fish production using various types of wastes is one of the oldest forms of aquaculture, originating in Asia around 2,000 year ago. It is still practiced in many Asian countries as an efficient means of integrating on-farm waste disposal with the production of fish for both commercial and subsistence purposes (Little and Muir, 1987; Edwards and Pullin, 1990). However, the key differences between traditional systems and the commercial-scale IWA systems being considered in this study are:

- Traditional systems are focussed on food production whereas IWA is designed to facilitate multiple-use of treated urban wastewater through the production of fish;
- IWA can therefore achieve multiple triple bottom line benefits through value-adding to currently under-utilised resources;
- Traditional systems mostly operate in sub-tropical or tropical climates, their performance in temperate southern Victoria was unknown.

The integration of aquaculture into recycled water distribution systems has the potential to provide the following benefits to conventional uses of reclaimed water:

- Add economic value to an undervalued resource;
- Provide cost-effective bioremediation to offset existing management costs;
- Improve water quality for third party users; and
- Reduce the external impacts of wastewater disposal to the natural environment.

This project "*Urban Wastewater Re-Use and Integrated Aquatic Production*" (Project No. 32R-3007) was funded by the Victorian Smartwater Fund to investigate the potential for aquaculture technologies to add value and bio-remediate recycled water on a large scale in southern Victoria. Specifically, the objectives of this project were:

- To develop the concept of integrated aquatic production systems re-use of Class C wastewater through selected case studies designed to facilitate product, market and industry development at a regional scale.
- To communicate and extend the concept of commercial scale, wastewater fed aquaculture systems to stakeholders in regional Victoria.

In order to implement this project a conceptual IWA business was developed so that the scale and nature of a commercial venture could be illustrated. A series of conceptual case studies were then developed around this IWA venture to investigate factors related to industry development and socio-economic issues.

Case Study 1: Socio-economic analysis, stakeholder and community engagement

Case study 1 investigated the technical and economic feasibility of IWA in southern Victoria and identified economic, environmental and social risks associated with commercial-scale developments of this nature. It focussed on the area of Barwon Region Water Authority (or Barwon Water's) operations around Geelong, the Bellarine Peninsula and the Surf Coast as this authority has demonstrated a pro-active approach to the development of recycled water schemes and was a partner in this project. The outcomes of this case study are reported in full in Milestone Report No. 2 (Gavine, 2007a) and are summarised below.

Conceptual IWA business

The key characteristics of a commercial-scale IWA business operating in Barwon Water's region in southern Victoria would include:

- It could be sited anywhere in the Barwon Water service area within a reasonable distance of treatment plant or recycled water pipeline;
- The primary focus would be the production of low-value fish biomass using species that feed at low trophic levels (e.g. European carp);
- The development would cover a large area. 100 Ha of production ponds would be required (filled with Class C recycled water) due to the low value of fish produced. The production ponds would range from 0.5-2.0 Ha in surface area and 1.5-2.0m deep;
- At full capacity would produce 1,300-1,500 tonnes of fish biomass per annum. This figure has been estimated using the results of recent experimental trials (Gavine *et al.*, 2006a) and a bio-economic model developed by DPI (Gooley *et al.*, 2006).
- Water use would depend on pond management and fish harvesting and stocking regimes. With a culture volume of 2,000 ML (100Ha ponds @ 2m deep), approximately 7,440 ML of recycled water would be used per year - assuming 3 harvests/yr and a water exchange rate of 1%/day (Gooley *et al.*, 2006).

- The quantity of water available to downstream users would depend on evaporative losses and would be site specific depending on the location. It was estimated that the volume of water available to downstream users in this part of Victoria would be around 6,250ML/year.

Economic viability

The economic viability of the conceptual IWA venture was initially analysed using a model specifically developed for IWA (Gooley *et al.*, 2006). The model assumed two revenue sources: fish biomass and sale of bio-remediated water to downstream users. Capital costs associated with the development were difficult to estimate where no specific site had been selected and the business structure was unknown. Large variations in capital costs could occur depending on assumptions made about land ownership and the resources already available on the site. Similarly, operating costs were difficult to estimate for a conceptual business, but reliable estimates could be made for labour, seedstock, harvesting, utilities and administration costs.

To provide some rigour in the analysis, RMCG a Melbourne-based economic consultant group were contracted to validate the estimates of capital and operating costs for the conceptual business. RMCG's estimate of capital costs were significantly higher than those estimated in the PIRVic analysis, primarily due to high pond construction cost estimates and different assumptions on the requirement for freezing and processing infrastructure. A cost-benefit analysis (CBA) framework was used to determine the economic feasibility of the aquaculture venture and associated risks to viability (Table 1). Both scenarios showed a net profit and positive profit margins, but NPV was negative and IRR rates were less than those that could be earned by less risky investments (RMCG, 2007). In the multiple harvest scenarios (which would be undertaken in a commercial venture), however, the IRR increased to 10% and NPV was positive (Gavine, 2007b).

Table 1: Model results for conceptual IWA business.

	Net Profit	NPV	PM	IRR
RMCG 2007 (single harvest)	$977,200	-$1,670,334	36.06%	5%
PIRVic Costing (single harvest)	$501,410	-$536,377	23.18%	5%
PIRVic Costing (multiple harvest)	$644,250	$38,000	25.99%	10%
(Gavine, 2007b)				

The sensitivity of the economic model to changes in input variables was tested under a range of conditions (RMCG, 2007). The key points raised by the sensitivity analysis of the single harvest scenarios were as follows:

- Revenue – at current cost estimates the operation would need to generate a revenue of approximately $3 million to be profitable.
- Capital expenditure. With a single harvest of fish biomass and under the current set of assumptions, capital expenditure must be kept below $6.4 million for the business to turn a profit. If revenue was increased, the capacity for capital expenditure would also increase.
- Supply of recycled water to IWA. The price of Class C recycled water supplied for the production of fish was an important variable as it was the largest ongoing operating cost. The sensitivity analysis indicated that for a single harvest scenario and a revenue of $2.7 million, the price for Class C recycled water needed to be below $90/ML. RMCG (2007) estimated that the price of this water can vary between $69 and $200 ML – with an average price of $136 ML used in the model. Given the large volume of water to be used and treated by the IWA venture, it is possible that a long-term supply contract could be negotiated at a reduced price.

Stakeholder engagement

There were two main stakeholder groups targeted in the engagement process:

- Regulatory agencies and local councils who would determine if the venture would proceed on the basis of legislative and policy compliance; and
- Community members whose acceptance of the scheme would be vital from a social perspective.

A communication plan was developed to engage the main stakeholder groups and communication materials were developed in consultation with project partners. A series of meetings, seminars, workshops and presentations were held to communicate with the various stakeholder groups.

The stakeholder engagement process found that to proceed to commercialisation, IWA developments would need approval from a variety of local, state and Federal agencies. Case Study 1 detailed the likely requirements at each level of Government for a development in Barwon Water's area. However, the specific approvals required will be site specific depending on the location and sensitivity of the site selected. Since IWA is a relatively new concept it is likely that most approval agencies would require a high level of information prior to approval. The culture of a noxious species may also involve additional permits and other conditions will be applied.

The community consultation undertaken in this study aimed to identify any latent issues in the community in relation to the use of recycled water for aquaculture. The fact that the fish produced were not destined for human consumption and that the effluent from the fish ponds was destined for agriculture or horticulture use meant that the proposal was not as contentious in the eyes of the community as some other re-use projects. Most people thought that the concept was a good idea, that it would probably be technically feasible and viewed aquaculture positively. They were less certain about the economic viability and if it would bring jobs to the area. Although they were generally supportive of the concept, they would not necessarily want to live near to a development of this nature. Major concerns about IWA development included: odour problems; increased traffic; inappropriate use of land; and the culture of carp.

Case Study 2: Product and market analysis

Product analysis

Fish and reclaimed water samples were collected during a four month fish production trial at Black Rock Treatment Plant (Gavine *et al.*, 2006a). The fish (carp, mullet and goldfish) had been cultured in Class C recycled water and carcass analysis aimed to ascertain the quality of the product in terms of attributes that make it attractive for markets (proximate analysis, amino acid content and fatty acid profile). The analysis also investigated the extent to which pathogens and/ or contaminants may have accumulated in the flesh of the fish (heavy metal residues, pesticide/herbicide accumulation and pathogens). These factors could make the product unsuitable for certain markets.

The results of the analysis showed that the three fish species under consideration exhibited different attributes in terms of proximate composition, fat and amino acid profiles. This is to be expected given their various feeding habits and genetic pre-disposition to certain characteristics. The analysis of pathogens and accumulated contaminants did not give cause for concern when compared with the Food Standards Code.

It should be noted that these results are specific to the treatment plant and time when the fish were grown. When considering the application of IWA in other areas and treatment plants an independent assessment of pathogens and accumulated contaminant in the product and water would be required. Indeed, for quality control purposes and to assure potential markets of product integrity, analysis of selected contaminants and pathogens may have to be carried out on a regular basis.

The analysis shows that some parameters were higher in the dam (DO, EC, pH and turbidity) than in the recycled water stream, while others were lower (notably micro-organisms, total phosphorus and total nitrogen). These changes alter the nature of the resource for use in agriculture and horticulture and could reduce or remove the requirement for pre-treatment or disinfection. The one-off comparison of a wide range of parameters showed that pesticides and herbicides were below detection levels in both the dam water and recycled water (Gavine *et al.*, 2006a). Some heavy metals were higher in the dam than in the recycled water (*e.g.* arsenic, barium), whereas others were lower (*e.g.* boron, chromium, iron). None were at a level that would give caused for concern. These changes alter the nature of the resource for use in agriculture and horticulture and could reduce or remove the requirement for pre-treatment or disinfection. The increase in turbidity and salinity, however, could constrain its use for some plants, soils environments or irrigation systems.

Market analysis

Potential markets for IWA fish products identified and explored in this analysis included:

- Petfood;
- Fishmeal and fish oil production;
- Aquaculture diets;
- Stockfeeds; and
- Fertilisers.

Each of these markets were examined with reference to potential customers; quality standards; and projected quantity and value of the market. On the basis of the analysis conducted in this study, IWA products appeared to be technically suitable for the target markets identified. In addition, IWA products would have a market advantage over the traditional sources of fish used for these purposes (*e.g.* wild caught pelagic fish, processing wastes and trimmings and other trash fish or by-catch).

Case Study 3: Value chain assessment

Case study 3 added to the analysis conducted in Case study 2 by providing further detail on the supply chains and logistics for accessing potential markets (reported in Street-Ryan, 2008). The objective of this case study was to assess the potential for commercialisation of identified supply chains for fish products from IWA and to determine the circumstances under which IWA products could be incorporated into these commercial supply chains. The status of a number of industry sectors was reviewed and industry sub-sectors with the greatest potential for successful commercial supply chain development at present were identified as:

- Aquafeeds;
- Stock feeds; and
- Dry pet food.

Each one of these sectors would require the product to be rendered and processed into fishmeal. A "Farm-gate" price of $0.25 to $0.50 per kilogram would be required for IWA products in order to develop long term supply chain arrangements and relationships. IWA project viability may be enhanced by sale of recycled water from the IWA system and other environmental credits. A joint venture arrangement with a downstream value chain partner (probably in aquafeeds or stockfeeds) could also enhance the viability of the project.

Final report

The case-studies were designed to produce information that would provide more certainty around the business opportunity presented by IWA for proponents that decide to proceed to commercialisation. This final report aims to use the information collated in the case studies to:

- Undertake a SWOT analysis of IWA commercialisation opportunity;
- Develop an industry development strategy to support the growth of commercial-scale IWA in Victoria.

SWOT analysis

Strengths

- IWA involves the multiple and sustainable use of resources, with demonstrable environmental benefits;
- Production of fish in waste water systems through IWA has the benefit of the cost effective utilisation of nutrients;
- IWA has the potential to add economic value to otherwise under-utilized or wasted resources;
- Fish production in pond-based aquaculture systems provides natural disinfectant processes for recycled water with could offset existing management costs;
- IWA may provide an alternative to the costs of implementing other engineering solutions to upgrade recycled water to Class A or B;
- IWA improves the quality of recycled water available for some downstream users;
- IWA reduces the external costs and impacts of wastewater disposal to the natural environment;
- Public perceptions about the concept were generally positive;
- IWA would provide a positive nutritional component to a range of aquaculture and stock feed diets;
- IWA production has the potential to offer reliable supply and consistent quality fish biomass, to compete with imported product in the Australian aquafeed, stockfeed and pet food industry sectors;
- If the necessary costs of production can be achieved, IWA would deliver a positive fishmeal option to Australian feed manufacturers.

Weaknesses

- Perceptions of product quality issues due to the potential uptake of wastewater contaminants and pathogens into fish tissue;
- Corporate perceptions may be negatively affected by the production process and concept, even though the value chain is somewhat removed from the human food chain ("Yuk" factor);
- The IWA system does not yet have access to suitable waste water storage areas in order to offer potential quantities or consistency of supply to potential value chain partners;
- Hatchery capability to produce seedstock for IWA is currently unavailable;
- The proposed IWA species is European carp, which is classified as a noxious species in Australia, and would require specific licensing and bio-security measures to be implemented;
- Public perception of the use of carp also was a negative during the stakeholder consultation process;
- Other concerns included odour problems, increased traffic and more appropriate land use options;
- Large area of land are required for cost-effective biomass production;
- Uncertainty in the regulatory/ approval process – a variety of local, state and federal agencies involved and there are currently no commercial scale precedents;
- Uncertainty about economic viability due to difficulties in determining capital and operating costs, particularly costs related to the supply and re-sale of recycled water;
- Although the costs of production of IWA fish from fingerling stock is competitive, the proposed capital equipment and infrastructure costs at each site are likely to imply an unattractive return on investment, based on the commercial value chains investigated to date.
- Key data on optimal management of production, best practice guidelines and operational risk management frameworks are currently not available to potential investors.

Opportunities

- There is a vast wastewater resource available for use throughout Australia – 1824 GL/Yr (Radcliffe, 2004), only a small proportion of which is currently re-used;
- In Victoria, there was an estimated wastewater volume of 448 GL in 2001-02 of which only 30.1GL (or 6.7% was re-used). There is therefore potentially a huge resource available for the IWA opportunity to exploit;
- IWA has the potential to capture and utilize nutrients in wastewaters that would otherwise be discharged to the aquatic environment at an environmental cost;
- IWA is conducive to the development of vertically integrated businesses, joint ventures between Water Authorities and industry and regional business networks.
- IWA can offer a cost-effective approach to upgrading traditional engineering wastewater treatment solutions to "polish" wastewater to meet new environmental standards;
- Government policy environment at regional, state and federal level now conducive to innovative approaches to the use of recycled water;
- IWA offers new agribusiness opportunities with significant triple bottom line outcomes;
- Bio-remediated water from IWA offers an alternative nutrient-rich water source for irrigated horticulture operators with reduced water allocations;
- Socio-economic multipliers, including enhancement of regional employment, would result from large-scale commercial development of IWA and its support industries in regional areas.
- Production of fish biomass from IWA will reduce the pressure on wild fish resources that are currently used in the targeted markets.
- Replacement of imported finfish biomass will benefit the national balance of payments therefore the local economy.

Threats

A risk analysis of IWA was conducted by DPI as part of a study that investigated the potential Victoria-wide application of integrated aquaculture and horticulture re-use of urban wastewater (Williams, 2006). Other risk assessments were conducted as part of IWA R&D projects (Gooley *et al.*, 1999; Gavine *et al.*, 2006a). All of these risk assessments were completed using a modified version of the DPI Risk Assessment Framework (DNRE, 1999). The most important risks identified are summarised in Table 2.

Table 2: Risk analysis for IWA – "High" risks.

Specific risk	Risk Rank	Contingency Plan
Economic risks – regulatory		
Planning permission refused (by local councils or a referral agency).	High	Provide Councils with information about IWA. Ensure site sensitivities are considered and incorporated into the documentation.
Aquaculture licence not granted.	High	Ensure proposed facility is bio-secure.
Economic risks – production/ technical		
Lack of harmony between wastewater treatment plants and aquaculture operations (compromise core business).	High	Conduct IWA externally to WRP (along distribution system).
Limits on input water supply.	High	Negotiate long-term supply contract with WA.
Limitation of nutrient supply.	High	Negotiate long-term supply contract with WA.
Target species cannot tolerate conditions.	High	Conduct pilot trials prior to development.
Fish yields are below projected levels.	High	Conduct pilot trials prior to development.
Predation by birds impacts on fish yields.	High	Investigate bird scaring methods.
Climatic conditions not suitable.	High	Conduct pilot trials prior to development.
Change in characteristic of influent water impacts on fish.	High	Negotiate long-term supply contract with WA.
Over-expenditure on capital infrastructure could constrain the viability of the venture.	High	
Operating costs too high.	High	Conduct pilot trials prior to development.
Economic risks – market related		
Market demand falls.	High	Identify other markets for development.
Projected revenues for fish and bio-remediated water not attainable.		
Target species not marketable.	High	Conduct commercial scale pilot with candidate species prior to full investment
Target species not marketable – product quality.	High	Ensure product quality issues are evaluated and monitored
Aquaculture water not compliant for horticulture use (decrease in market).	High	Monitor aquaculture effluent to ensure compliance.
Environmental risks		
Escape of noxious species from IWA to wild.	High	Ensure facility is bio-secure.
Seepage of recycled water into groundwater.	High	Ensure facility is designed to prevent this.
Social risks		
Negative community perception about use of wastewater for aquaculture.	High	Develop pro-active communication campaign prior to development.
Loss of public confidence in Water Authorities.	High	Manage operation well to restore confidence.
Community will not accept the use of carp.	High	Investigate other options for target species

Industry development Strategy for IWA

Strategy 1: Develop IWA Production Technologies and Best Practice Guidelines

Recent research has clearly demonstrated that the IWA concept is technically feasible in Victoria and fish can grow and survive in recycled urban wastewater (Gavine *et al.*, 2006a, Gooley *et al.*, 1999). However, there are still major scientific and technical information gaps that exist in relation to IWA and they must be addressed in order to progress the concept to the implementation and commercialisation phase.

A commercial scale pilot IWA production system is required to adequately assess the economic viability of an IWA business in Victoria. This pilot system would:

- Validate the results of R&D trials that were used to estimate fish growth, survival and yields from production ponds.
- Develop criteria for optimal system design including optimal pond configuration, bio-security measures, water flow rates, pond size, aeration techniques, and harvesting methods.
- Conduct year round trials to assess the influence of temperature on fish growth at different life stages.
- Provide information on the constraints to fish growth and bird predation of all species, with an emphasis on determining the impacts of different methods of bird predation.
- Provide more accurate data on the capital and operational costs involved in setting up a custom-built IWA facility. This information is required before progress to commercialisation can be made.
- Investigate other species that could have potential (e.g. eels & other native fish).
- Compile IWA development guidelines for local government planning departments and other approval Agencies so that informed decisions can be made regarding planning applications. This should assist investors with the licensing and approvals process.
- Provide technical information for the development of optimal “Best Practice” operational guidelines.
- Collate water quality and product quality information to underpin the development of product quality guidelines.

Strategy 2: Develop product quality standards and QA processes.

As IWA is a relatively new concept there are no quality standards available for IWA products. This could lead to uncertainty in potential markets about the quality of the products supplied by IWA. There is also a perception in many markets that products may be contaminated with a variety of residues as a result of the use of recycled urban wastewater for fish production. In order to address those concerns, the onus is on IWA operators to be pro-active in setting up processes and collecting data to develop quality standards and reassure customers that they are purchasing a safe, quality assured (QA) product of consistent quality.

QA processes should begin prior to the design of the IWA facility so that the risks inherent in a specific recycled water source can be assessed (Gavine *et al*., 2006b). QA processes should be ongoing throughout the operation and the cool chain to market. Some sources of recycled water will present a higher risk to the IWA operation and its products than others due to the composition of the catchment area from which the treatment plant receives sewage (i.e. relative contribution of domestic, industrial and stormwater to the influent) and the extent and efficacy of treatment at the plant. Prior to development of IWA the proposed reclaimed water source should be characterised using historical data and sample analysis to identify biological and chemical hazards specific to that source.

Once the IWA facility is operational, QA processes should be developed to monitor the following areas:

1. Inputs to the aquaculture system (such as the quality of recycled water inputs, seedstock and/or any supplementary feeds used). Procedures should also be developed for labour inputs associated with fish handling and processing.
2. Parameters that could impact on fish growth and survival. Processes should be developed to monitor water quality components that may be toxic or stressful to fish.
3. Parameters that could impact on the quality of fish or bioremediated water products. Components of the recycled water that may accumulate in fish and have an adverse impact on product quality or public health.
4. Quality of bio-remediated water destined for downstream users. Storing and using water for aquaculture may alter the quality of the resource and impact of its suitability for downstream users.
5. Harvesting, storage, processing and cool-chain transport procedures (including traceability). Fish are a perishable commodity and post-harvest handling is critical in ensuring that IWA products reach their destination in as good a condition as possible. Issues that must be taken into account prior to delivery for processing (after Thomas, 2005):
   - Freshness - harvest to chill time must be kept to a minimum;
   - "Belly-burst" – this is an issue when fish start to decompose and can cause the potential for microbiological spoilage;
   - Cool chain handling processes must be correct for the intended market.

Strategy 3: Develop markets and address value chain issues

Fish biomass

Fish biomass produced through IWA has significant market advantages over traditional sources of fish biomass (Table 3) which is traditionally sourced from wild fisheries and as such is subject to vagaries in supply, price and quality. IWA has the potential to produce a reliable supply of quality assured product at a size specified by the market.

Table 3: Market advantage of IWA products over traditional sources of fish biomass (adapted from Thomas, 2005).

	Traditional sources	Advantage of IWA products
Quality of fish	Variable due to the vagaries of capture at source and how the fish was subsequently handled. Key issue here is rancidity.	Fish from known conditions with known harvest times and regimes and controlled storage.
Type of fish	Variable depending of the source fish. Wild captured fish will be small pelagic species. Other sources (by catch and processing wastes) could vary between consignements	IWA produced fish rely on natural productivity rather than protein from commercial diets derived from wild fish sources. The product will be more consistent in size and quality and can be grown to the required size for the target market.
Contamination	Fish from wild sources is often contaminated with fish hooks, plastics and stones. Once the product is frozen, it is difficult to filter out the rubbish. Wild fish often have green and red gut problems caused by plankton and krill and this can appear in the product.	The quality of IWA can be more easily controlled through washing prior to freezing. The diet will control the gut content issues.
Availability of fish	Imported from wild fisheries in Thailand, South Africa, South America and North America. Supply impacted by the vagaries of ocean capture, currency and shipping. Defined fishing season – fish captured and stored frozen until required.	Harvested in Australia with minimal freight. Available all year round in commercial quantities of known and acceptable quality.
Storage of fish	Frozen.	Could be supplied fresh or frozen.
Transport of fish	Frozen international freight.	Minimal domestic freight.

Markets for IWA products considered as part of this project are shown in Table 4. These markets were then considered in the context of their value chain, so that factors that could be an obstacle to their exploitation or commercial development could be explored. The value chain analysis found that industry sub-sectors with the greatest potential for successful commercial supply chain development at the present time are: aquafeeds, stock feeds and dry pet food (Figure 2). Each one of these sectors would require the product to be rendered and processed into fishmeal.

Table 4: Summary of potential markets (estimated volume and value) for IWA products

	Volume (tonnes/annum)	Value	Estimated $/kg
Petfood – current	17,900	$5.2-9.6 million	$0.3-0.8
Petfood - Import replacement	15,700		$0.3-0.8
Fishmeal	25-32,000	$21 million	$0.10
Aquaculture – tuna	50-60,000	$25-30 million	$0.50
Aquaculture diets	12,250		$0.85-1.10
Stockfeeds	?	?	?
Fertilisers	300	$120,000	$0.40

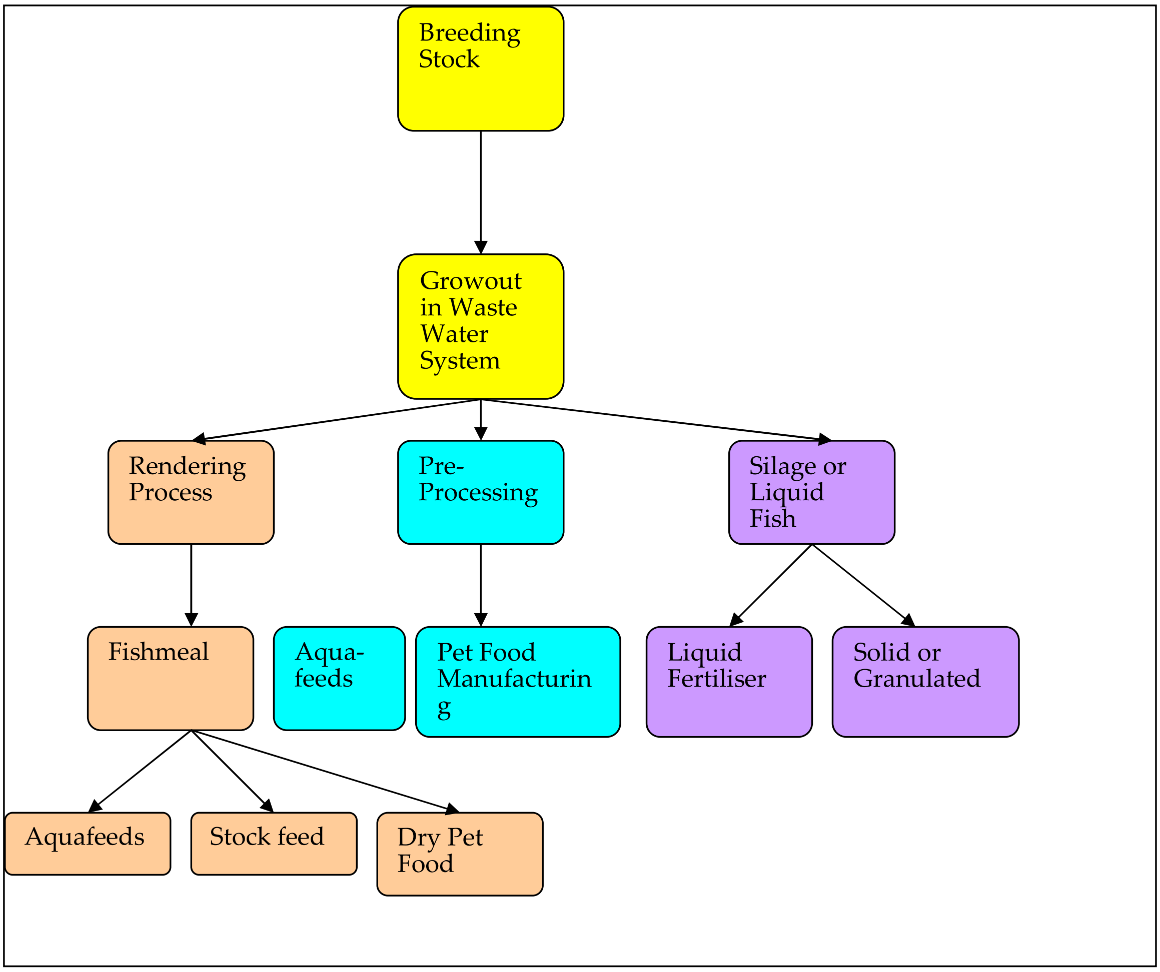

Figure 2: Potential IWA Value Chains (after Street-Ryan, 2008)

Table 5 summarises ratings and price structures for commercial supply chain partnerships with each market sector. A rating of *"high"* means that there is a reasonable short term prospect to develop a supply chain partnership subject to pricing and product quality. A rating of *"medium"* means that there are some prospects for developing a commercial supply chain relationship subject to a range of issues being addressed (including pricing, reliability of supply, quantity of supply, product quality and logistics). A rating of *"low"* means the prospects for developing a commercial supply chain relationship are currently poor. Out of all of the markets and value-chains assessed aquaculture pellets were rated most highly.

Table 5: Estimated value at each stage in the supply chain and chain development prospects.

	Stock Feed	Aquaculture		Pet Food		Fertiliser	
	Pellets (kg)	Pellets (kg)	Pieces (kg)	Wet (kg)	Dry (kg)	Liquid (kg)	Solid (kg)
Fresh Fish Inputs	30-50 cents	30-50 cents	30-50 cents	35-80 cents	25-35 cents	5-20 cents	5-20 cents
Rendering/Pre-Processing	75 cents	75 cents	30 cents	30 cents	75 cents	40-80 cents	40-60 cents
Fishmeal/Solid Fertiliser	80cents- $1	80 cents- $1.10	n.a.	n.a.	80 cents- $1	n.a.	70 cents - $1.15
Current IWA Value Chain Development Prospects	Medium	High	Low	Low	Medium	Low	Low

Value chain issues that need to be addressed before commercialisation can proceed are as follows.

1. **Production of Breeding Stock.**
   - Regulations and protocols associated with breeding a noxious species and bio-security provisions need to be developed.
   - Securing a regular supply of seedstock is an issue as there are currently no Victorian hatcheries that could supply the volume of fish required for commercial-scale IWA.
   - Choice of species may be important here (carp versus mullet) as it may be easier to get approval to culture native species. Mullet may offer more market potential due to high fish oil content.

2. **Growout in Waste Water System (addressed in other strategies)**
   - Infrastructure costs.
   - Return on investment required.
   - Site analysis and contaminants.
   - Perception of quality in human food chain.
   - Nutrients and growth rates.
   - Capacity to rollout to additional locations.

3. **Rendering Process/Pre-Processing/Silage**
   - Location of rendering plant relative to the IWA production facility could affect the viability of the venture.
   - Freshness and cool chain handling of product – see QA procesees.
   - Food safety security (from mammalian, ovine, bovine and poultry products)

Bio-remediated water

Bioremediated recycled water for sale to downstream users is also a product of IWA, however there is considerable uncertainty about the demand for the water downstream of some sites and the price. In some areas of Southern Victoria, Class C reclaimed water sells at an average price of $136 per ML and potable water at around $900 per ML. In general, farmers with high value crops like winegrapes, hydroponic tomatoes and turf farms can afford to pay higher prices for water than farmers in other areas due to differing equity levels and the types of crops produced (RMCG, 2007). More work needs to be done to reduce this uncertainty.

Strategy 4: Economic viability

The primary economic benefit from IWA is clearly from producing marketable aquatic products and on-sale of bio-remediated recycled water to downstream users. The sensitivity analysis presented in earlier reports identified three key areas that underpinned the economic viability of IWA:

1. Revenue – the sale price of both aquatic products and bio-remediated water are critical to economic viability. At the present time, the cost of production of IWA biomass is a barrier to market entry. Similarly more certainty is required around the volume and market price of bio-remediated water to be sold to downstream users.
2. Capital expenditure. This can vary enormously between sites depending on the resources already available on-site. Some Water Authorities already have large areas of ponds that could be converted for IWA at minimal cost – this would have a huge impact on the economic viability of the venture. Similarly, if the Investor has access to and is storing recycled water for another purpose (i.e. horticulture), then set-up infrastructure costs would be greatly reduced.
3. Supply of recycled water to IWA. The price of Class C recycled water supplied for the production of fish is an important variable as it the largest ongoing operating cost. RMCG (2007) estimated that the price of this water can vary between $69 and $200 ML – with an average price of $136 ML used in the model. Given the large volume of water to be used and treated by the IWA venture, it is possible that a long-term supply contract could be negotiated at a reduced price.

Secondary economic benefits from IWA stem from opportunities to deliver sometimes intangible, or difficult to quantify, benefits to Water Authorities or the community in general. Examples of secondary benefits of IWA that could enhance economic viability may include:

- Provide cost-effective bioremediation to offset existing management costs;
- Provide an alternative to costly engineering solutions to "polish" wastewater streams;
- Improve water quality for third party users; and
- Reduce the external impacts of wastewater disposal to the natural environment.

Strategies to quantify secondary benefits need to be developed on a site-specific basis.

Strategy 5: Identify the resource opportunity and appropriate business models for IWA commercialisation

Develop production capacity through resource inventory that identifies IWA opportunities

A wastewater resource inventory has been compiled that characterises Victoria's urban wastewater resource in the context of potential IWA reuse (Gooley *et al.*, 2006). This inventory lists the following information for each Water Authority:

- Volume of water available seasonally (Class A, B, C);
- Profile of Class A, B, C waters available for re-use;
- Upstream generators of wastewater (if applicable);
- Approximation of the area of land available at each site that could potentially be used for IWA; and
- GIS co-ordinates of the sites and effluent disposal lines.

This information can be used by potential investors to identify potential sites and assess the costs involved in providing infrastructure and capital equipment. It may be used to determine whether the necessary investment and the return on investment can be balanced with the demand end of the supply chain (including consideration of other environmental and saleable water benefits).

Develop appropriate business models for IWA commercialisation

To construct a realistic cost-benefit analysis, many assumptions had to be made about the business model that would be adopted by such a venture. The key feature of this business model in the analysis undertaken in this project was that the treatment of recycled water was the key driver. Discussions with other potential investors have, however, revealed that this was only one of several business models that could be adopted to commericalise IWA.

Table 6 shows some of the other drivers for IWA development and commercialisation. The business model adopted will have a dramatic affect on the cost-benefit analysis as capital and operational costs will be greatly different.

For example, where the driver is to use existing infrastructure capital costs will be drastically reduced as pond construction may not be required. If the driver is simply to secure a reliable supply of water for other crops, then IWA may be used to add value to an existing scheme and again capital and operational costs are reduced. Clearly the business model adopted will depend on the specific IWA opportunity identified as well as the circumstances of the investor (s).

Table 6: Alternative business models for IWA commercialisation

Driver	Characteristics
Treatment of recycled water	• Aquaculture and bio-remediation are the primary drivers • Alternative to engineering solution • Large surface area and volume • Low value species
Reliable water supply	• Water for horticulture is the primary driver • Aquaculture adds value to an existing scheme • Small scale • Potentially higher value species for niche markets
Use of infrastructure	• Use of existing pond infrastructure and land is the primary driver • Investor identifies opportunity for aquaculture • Limited infrastructure costs • Scale and species will depend on what is available
Water source for aquaculture	• Aquaculture is the primary driver • Reliable source of water • High value species grown

Strategy 6: Communication and extension

Once the technical and economic feasibility has been validated by a commercial pilot system in southern Victoria, the concept of IWA needs to be communicated to other Victorian regions. Po, *et al. (*2004) discussed strategies for implementing new recycled water projects and highlighted the need to involve the community prior to the conception of the projects. He argued that community empowerment was the key to allowing consumers to make an informed choice about the options available and allow for their concerns to be considered in the planning of projects. Although there is currently no formal standard framework for this process, *Wegner*-Gwidt (1998) (as cited in Po, *et al.*2004) recommended the following eight critical steps for successful community support programs:

1. Being upfront and pro-active;
2. Developing a basic information campaign that highlight environmental benefits and addresses key concerns of the community (odour, traffic, inappropriate land use, species *etc*);
3. Working with local media;
4. Using credible third party testimony;
5. Showing successful projects elsewhere;
6. Being visible and creative;
7. Increasing public awareness;
8. Using demonstration projects.

Given the lack of critical information to underpin commercial development, the communication and extension strategy should be implemented after technical and economic feasibility information gaps have been addressed. Probably in tandem with Strategy 5.

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