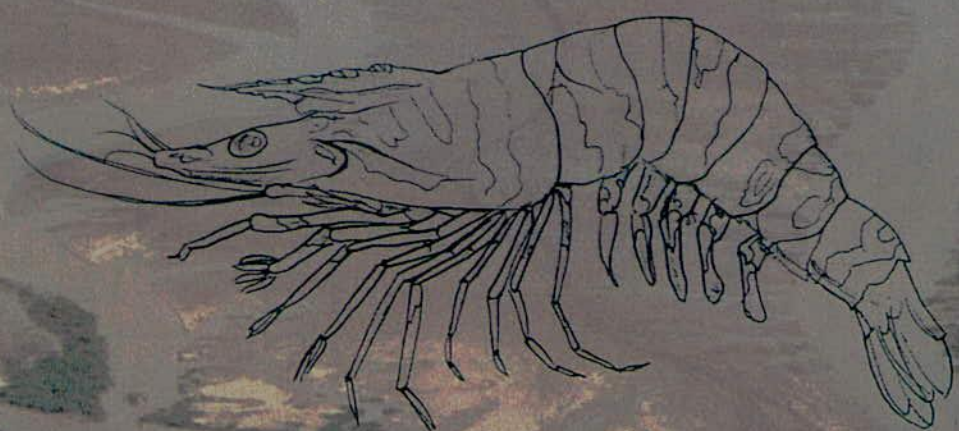
KIMBERLEY PRAWN COMPANY



CONSULTATIVE ENVIRONMENTAL REVIEW

CONSULTANT ; DIAMOND ISLAND Pty Ltd.

DOCTOR'S CREEK DERBY WA

Kimberley Prawn Company.

Kimberley Prawn Farm, Derby. W.A.

Consultative Environmental Review.

Prepared by Diamond Island Pty Ltd.
November 1997

CONSULTATIVE ENVIRONMENTAL REVIEW

The Environmental Protection Authority (EPA) invites people to make submissions on this proposal.

The Consultative Environmental Review proposes the development of the Kimberley Prawn Project outside Derby.

In accordance with the Environmental Protection Act, a consultative environmental review has been prepared which describes this proposal and its likely effect on the environment.

The report will be available for public comment for five weeks from Monday 1 December 1997.

Following the receipt of comments from government agencies and the public, the EPA will discuss the issues raised with the proponents and may ask for further information. The EPA will then prepare its assessment report with recommendations to government, taking into account the issues raised by the public submissions.

Why write a submission?

A submission is a way to provide information, express your opinion and put your suggested action - including alternative approaches.

It is useful if you can suggest ways to improve the proposal.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the CER or with specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal more environmentally acceptable.

When making comments on specific proposal in the CER:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable; and
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed.

Attempt to list points so that the issues raised are clear. A summary of your submission is helpful. Refer each point to the appropriate section, chapter or recommendation in the CER. If you discuss sections of the CER, keep them distinct and separate, so there is no confusion as to which section you are discussing.

Attach any factual information you wish to provide and give details of its source. Make sure that your information is accurate.

Please indicate whether your submission can be quoted, in full or in part, by the EPA in its assessment report.

Remember to include:

Your name;
Your address; and
The date of submission.

The closing date for submission is:

Monday 5th January 1998.

Submissions should be addressed to:

The Chairman
Environmental Protection Authority
8th Floor "Westralia Square"
141 St George's Terrace
PERTH WA 6000

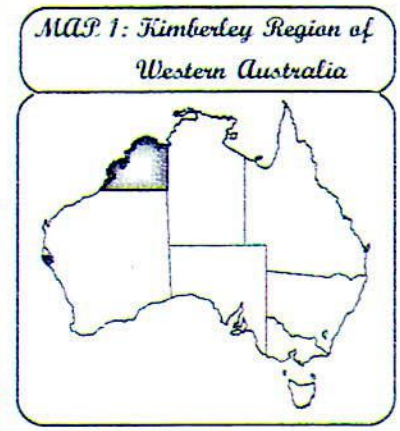
Attention: Mr Ben Hollyock

KIMBERLEY PRAWN COMPANY (AUST) PTY. LTD.

TABLE OF CONTENTS

Map 1 : Kimberley Prawn Company Derby W.A.

Kimberley Prawn Company lease area



Christine Point

Amur Point

DOCTORS CREEK WEST BRANCH

DOCTORS CREEK EAST BRANCH

Derby

DERBY HIGHWAY

Airport

Creek

Colac Shoals

exposed at low tide

wharf

tanks

causeway

disused pipeline

tanks

caravan park

racecourse

golf course

aboriginal camp site

cemetery

aboriginal camp site

meatworks

rubbish tip

waste water treatment works (under construction)

disused gravel pits

aboriginal camp site

speedway

gravel

DCA Bores

yard

Myall Bore

Boab Tree

Prison

gravel

gravel

gravel

Yabbagoody Well

Mowanjum Community

Yabbagoody Claypan

telephone line

Home Bore

Stuart Bore

numerous causeway

causeway

1.0 INTRODUCTION

1.1 Background.

Japanese biologists worked on culturing the Kuruma prawn *Penaeus japonicus* from the 1930's. Success with this species led to the expansion of prawn culture in both Japan and Taiwan principally with the black tiger prawn *Penaeus monodon* . Over the ensuing decades, prawn farming has expanded throughout Asia and in Ecuador in South America. In Asia generally, low density stocking rates of prawns were practised while in Japan and Taiwan, semi-intensive and intensive culture was practised.
In Australia, in 1970, the New South Wales government commenced construction of the Port Stevens Brackish Water facility. The greasy back prawn *Metapenaeus bennetae* and the School Prawn *Metapenaeus macleayii* were hatched and culture trials undertaken. The first prawn farms were in northern New south Wales and some in Queensland. Initially school prawns were used and then black tiger (alternatively known as giant tiger, or leader) prawns which now form the majority of production.

The prawn farming industry in Australia is now centred in Queensland but competition for coastal land and pollution from other human activities there means that green field sites in Western Australia may have some real advantages in developing a sustainable prawn farming industry.

1.2 Responsible Authorities.

Interdepartmental Committee for Aquaculture (IDCA) receives submissions for aquaculture projects. Department of Environmental Protection are represented on this Committee. All agencies represented must comment on proposals received by the IDCA. DEP will comment after consideration of the Proposal by EPA.
The following agencies are represented on the IDCA:
Fisheries Department (Chairman and Aquaculture Development Officer)
Aboriginal Affairs Department
Aquaculture Council of Western Australia
Aquaculture Development Council
Bernard Bowen Fisheries Research Institute

Conservation and Land Management
Department of Agriculture (Agriculture WA)
Department of Commerce and Trade
Department of Environmental Protection
Department of Land Administration
Department of Transport
Ministry for Planning
WA Marine Research Laboratories
Water and Rivers Commission (formerly Water Authority)

1.3 Statutory Requirements and Approvals.

Inter Departmental Committee for Aquaculture, Environment Protection Authority, Shire of Derby/West Kimberley, Conservation and Land Management, Department of Land Administration, Department of Minerals and Energy, Water and Rivers Commission of WA, Kimberley Land Council, have all been requested to give approval to the Project proposal.
The Shire of Derby/West Kimberley has given approval for the project, as have Conservation and Land Management, DOLA, Department of Minerals and Energy, Waters and Rivers Commission, Department of Fisheries. Negotiations are currently being finalised with the Kimberley Land Council and Native Title claimants.

Kimberley Prawn Company will be required to operate under an Aquaculture Licence which is granted by the Fisheries Department. The *Fisheries Resources Management Act 1994* is the legislation that grants a licence to operate a fish farm in this State. This licence controls the operation of the farm and details the requirements that control the species to be farmed, where they are obtained and how, the control of feed quality, disease monitoring and water quality control including the discharge of water back to the King Sound. These are all inspected by Fisheries officers regularly. The licence is to be renewed annually on the understanding that the completion of reports and the monitoring of environmental standards are achieved.

1.4 The Proponent.

The proponent for development of the proposal is Kimberley Prawn Company (Aust) Pty Ltd a corporation with one of the principle shareholders being a resident of Derby, Mr Ian Crimp and another shareholder being the Thomson Antipodean Trust which is involved in other

aquaculture ventures including oysters. The Kimberley Prawn Company was formed to develop a viable prawn farming venture in the Kimberley region of WA.

1.5 Details of Timing of Proposal.

First application to Interdepartmental Committee for Aquaculture November 1994.
EPA request for Consultative Environmental Review September 1995.
CER March 1996 returned June 1996 for modification
CER August 1996 returned for further information November 1996
CER modified February 1997, returned May 1997, further requirements regarding licences and ISO 14000 standards for environmental management August 1997.
CER August 1997.
CER modified October 1997.
Public comment on CER, December 1997.
Government requirements detailed to project applicants December 1997.
First ponds June 1998, First harvest 1998/9.
More ponds, expansion to 20 ha June 1999.
Expansion to 100 ha May 2000 - 2002.
Expansion to 1000 ha May 2003-2007.

1.6 Scope and Purpose.

The purpose of this document is to allow scrutiny of the project by both public and government to allow for suggestions as to improvements to the proposal.

2.0 CONCEPT DESCRIPTION

Prawn Farm Doctor's Creek, Derby.

In Australia, the first prawn farms established were in northern New south Wales and some in Queensland. The black tiger (alternatively giant tiger or leader) prawn, *Penaeus monodon,* is now the major species in production. In other countries such as Taiwan, disease resulted in a collapse of the industry caused by stocking rates being too high and appropriate control measures not being taken. Similar problems have occurred in Ecuador, China and Thailand, with pollution of the intake water being a significant factor. In Queensland too, and the USA, viral diseases have appeared in densely stocked ponds, depressing production. Economic studies have shown that tropical rather than temperate environments are necessary for profitable prawn farming. Stocking density and survival rate are important in providing economic returns.

2.1 The Proposal.

Kimberley Prawn Company proposes to establish a prawn farm on Doctor's Creek outside Derby on the hyper saline mudflats with land based buildings on the site of an abandoned experimental brine shrimp farm. The project involves the growing of Black Tiger or Leader Prawns (*Penaeus monodon*) and other secondary species found within the King Sound area to act as biological filtration systems in the discharge water. The prawns will be bought as post larvae from either hatcheries at Exmouth, Nickol Bay or Broome Aquaculture Park. At some time in the future it may be necessary to include a hatchery at Derby to ensure the continual supply of prawn stock. Secondary species which grow in the King Sound will be sourced in conjunction with the Fisheries Department of WA. This proposal will provide a new industry in the Derby West Kimberley Shire and additional employment opportunities for Derby residents.

The major elements of the project are:
Experimental phase - Year 1 will require the construction of a bund wall, six ponds, inlet settlement canal, distribution channel, discharge channel, secondary species ponds and water return channel plus sheds and pump house, power lines and roads.
Consolidation phase- Year 2 increase to 20 x 1 ha ponds.
Commercial phase: depending on the results of the first two phases, expansion to 100 ha of ponds will take place in years 3 and 4 (2000 - 2001).
Expansion Phase - progressive expansion of the farm to 650 ha of ponds will take place from years 6-10 (2003-2007).

After approximately six months of use, each pond will be harvested by emptying the water through drainage of the ponds, the prawns will be trapped in cod end nets at the drainage point. The emptied ponds will be allowed to dry and then the built up sediment will be removed by mechanical extraction. When dry, this sediment will be placed along the outside walls of the canals and ponds to assist vegetation of the site to ensure that the walls are not eroded during the "wet" and to enhance the aesthetics of the area.

Water discharged from the ponds during grow out of the prawns will pass through the secondary species ponds where oysters and scallops will act as biological filters. These shellfish will remove the algae and consequently the nutrients from the water before the water is discharged back into the East Doctor's Creek.

Most buildings will be constructed on the old *Artemia* site. A processing shed, mechanical workshop, feed storage, site office, laboratory and site management housing will be needed. Two concrete pads remain from the *Artemia* venture and will be utilised for two of the sheds required. All buildings will be built according to the Derby/West Kimberley Shire council guidelines and cyclonic zone requirements. The only buildings to be built on the actual pond grow-out area will be a pumping station and later a hatchery. The pumping station will be a low shed, housing an electric motor and centrifugal pump to lift the water into the distribution channel from which all water is gravity fed into the ponds and secondary species ponds and the return canal and then through the flood gates into East Doctor's creek. Construction of the first six ponds will commence as soon as the dry season allows.

The development will provide modest employment in its first two years (4 FTE's) rising to become a significant employer in phases 3 and 4 (40 and 100 FTE's respectively).
It is planned to market the produce in the Asian region and in Australia. Accordingly the size of the development must be sufficient to obtain priority on aircraft for freighting live and chilled product to market.

2.2 Sea Water Extraction.

Sea water will be obtained from West Doctor's Creek via an intake canal. Due to the naturally occurring high turbidity of the sea water in the Doctor's Creek system an inlet canal will be used to settle the suspended clay sediments and other solids before the water is pumped into the distribution channel for supplying the ponds. Water in the ponds will be augmented depending

on evaporation and build up of nutrients and depletion of oxygen. Water discharged from the ponds will be taken by transfer canals to secondary species ponds where nutrients and their associated phytoplankton blooms will be removed by the filter feeding scallops and oysters. After passing through these ponds nutrient reduced water will be allowed to return to East Doctor's Creek.

2.3 Ground Water Extraction.

Some ground water may be required in the grow out ponds to counteract high evaporation which will cause the salinity of the pond to rise. Any use of ground water will be from the unconfined aquifer and will have a lower priority than the township of Derby and will be used in accordance with Water and Rivers Commission guidelines and licensing conditions. Salinity figures monitored to date indicate that ground water may not be required and that rising salinity in the ponds can be counteracted by flushing with more sea water from West Doctor's Creek. The extraction of ground water will be in accordance with the "Water & Rivers Commission Guidelines for Acceptability of Aquaculture Projects". The Water Resources Manager in Karratha was contacted in 1995 regarding this matter and informed the proponents that they would need a groundwater well licence. The Water & Rivers Commission has no objection to the project nor any conditions necessary for the stated installation and effluent discharge subject to other Government agency requirements.

2.4 Regional Value of the Proposal.

The Derby /West Kimberley Shire has a high unemployment rate particularly among the young and the aboriginal community. Commercial activities in the town are declining due to the closure of meat works, use of Broome as a regional centre by government in preference to Derby and the closure of the port due to difficulties with the large tidal range in King Sound and declining port usage. This proposal will address each of these problems once it reaches the commercial stage (phase 3). Transport rates are reduced if the volume of freight is increased, so the proposal will have benefits to the general community other than employment, the multiplier effect and provision of a fresh seafood for the tourist trade.

While prawn farms are common throughout the tropical world and are now a significant industry in Queensland, there are as yet no commercial prawn farms yet in WA.

2.5 Location.

The location chosen is in an appropriate climate regime with unpolluted water, namely Derby in the King Sound in northern W.A. The disadvantages are distance from domestic markets and source of food and only modest potential for shop-front sales. The proximity of Singapore and Jakarta is offset by a lack of regular air services from Derby to these centres, but there are two airports available to fly product out, and road services to Darwin and Perth. Air services are currently via Broome to both Perth and Darwin, but once production is sufficiently large, aircraft will be used to ship product direct from Derby or Curtin airports. Road transport will also be used for local marketing of product.

The proposed site is 27 km by road from Derby. The location of the project is between the two arms of Doctor's Creek to the east of Derby. Seawater will be taken from the western arm and returned to the eastern arm. (Figure 1A). The selected site is part of the special purpose Aquaculture area acknowledged by the Kimberley Development Commission.

2.6 Current Land Status.

Part of the lease area is on Meda pastoral station which has agreed to the excision of the area. The rest is Vacant Crown Land although some of the area was part of an experimental Artemia aquaculture lease in 1989. Map 1 and Figure 1 & 1A show the location and details. Currently the land intended for the growout ponds has no usage as it is tidal inundated mudflat devoid of any vegetation. (see Figures 2,4,16). The buildings are to be built on the Pindan promontory on the existing concrete pads to the south - east of the pond site.

2.7 Preferred Site Summary.

The actual site for pond construction requires an adequate supply of salt water of suitable temperature. A three phase electricity supply is required. In the Derby area, the tidal amplitude provides a good water exchange but the amplitude makes it difficult to choose heights for ponds and canals. In the spring when evaporation is high, a source of fresh to brackish groundwater may be required to keep prawns growing. This water would be sourced from the unconfined aquifer which flows from the inland towards the headwaters of the Doctor's Creek system and has passed through Derby and the surrounding habitat before reaching the prawn farm site. The amount of water allowed to be used will be determined by the Waters and Rivers Commission

licensing arrangement.
Prawn farms must be sited near a pollution free arm of salt or brackish water. In Ecuador and Asia, mangroves were cleared to create the ponds with consequent degradation of the foreshore. In this proposal at Doctor's Creek, construction will have little or no impact on the mangrove and samphire communities of the Doctor's Creek system as the ponds will be dug on the existing bare mud flats with the walls of the ponds and the canals being made from the excavated clay. The site in question is shown by the photographic plates in Figures 2-4 and 15,16.

In south-east Asian countries, problems have occurred because many prawn farms are sited close to each other with the discharge water from one farm being taken in by the next; problems occurred when diseases appeared in the farms with rapid transfer to neighbouring farms. The Doctor's Creek site was chosen so that the inlet water is remote from the discharge water, it is remote from other aquaculture ventures and there is room at the site to treat both inlet water and discharge water to minimise nutrient build up and to prevent any spread of contamination should a disease occur in the prawns.

Because of the high sediment load (1-2%) of water in the King Sound, the sediment must be allowed to settle from the water before the water can be used in the grow out ponds, this will be done via the inlet canal. The tidal range of King Sound and Doctor's Creek is both an advantage and disadvantage in that the tidal flood can save pumping but it can also hinder the drainage of pond water until the tide recedes.

Electric power is used on prawn farms in pumping water to the ponds, circulating water in the ponds and aerating that water when required. A chiller or freezer is also required for the product so reticulated power is an advantage. A power line from Derby to Bungarun (old leprosarium) passes over the site and is one of the factors that made this site the preferred one.

2.8 Evaluation of Alternative Sites.

Alternative sites in the King Sound were considered including one at the old Derby airport, at Christine Point, at the Blue Holes, at Point Torment and at Old Kimbolton Station. The selected site offers the proponents the best opportunity to be successful by :

Being close to the town of Derby, for labour and supply of construction materials for sheds etc (27 kms approx from the centre of Derby to the ponds via the Bungarun road, currently the only

access to the site).

- Close to both airports, Curtin is suitable for large cargo aircraft to land.

- Seawater suitable for aquaculture.

- Utilisation of the existing internal road and previously used concrete pads and power lines, the project will not interfere with bush at the land base site in stage 1 or 2 and sites for more buildings will be carefully chosen in order to interfere with the vegetation as little as possible.

- The availability of suitable mudflats which are devoid of any vegetation for grow out ponds. The mudflat clay will be used for construction of the ponds, roads and canals. The mangal system on the edge of the arms of Doctor's Creek will not be interfered with.

- The close proximity of available power. (3 km from Sutherland St. to the pumping station)

The ability to utilise ground water from the unconfined aquifer without interfering with the Derby ground water supply.

The current site was chosen because it interfered less with recreational fishing activities of the community, the land is partly on the pastoral lease of Meda Station, it has previously been used for experimental brine shrimp culture (*Artemia* sp.) and there are two existing concrete pads which will be used for buildings associated with the Project (see Figure 15).
The proponents deliberated over the site and although this site has some drawbacks associated with the high tidal range and high sediment load of the waters of King Sound, the site also has clear advantages:-

it is over 3 km from the township and any noise from the farm would not be heard in the town. Apart from earth-moving machinery in the construction stage, the only noise from the operations will be the electrically driven pumps, and vehicles driving at feed times.

Commitment 1 :
Public access to the area between the two arms of Doctor's Creek will be maintained by a permanent raised crossing over the inlet canal.

3.0 PROJECT DESCRIPTION

Site Selection Criteria

Parameters	Criteria	Doctor's Creek
	(see also Site Details)	
Soil		
Clay content	Compaction suitable	Excellent
pH	>5.0	7.0 - 8.5
Heavy metals	Below seawater concentration	Acceptable
Sea Water		
	Adequate volume of clean sea water	Yes
pH	7.5 - 8.5	8.0
Salinity	30 - 35 ppt	32 ppt
Temperature	25 - 30°C	30°C
Fresh Water	Adequate supply	Licensed bore extraction
Locality		
Labour	Labour intensive	Available
Power	Power needed	At site
Feed	Readily available	Available
Transport to Market	Available	2 airports within 40 km, wharf within 30 km, road transport 3 days per week
Predators & poachers	Control	In control
Hatchery	Less than 6 hours away	Exmouth gulf, Nickol Bay or Broome will be used

3.1 The Site.

The site is shown in Map 1 and outlined in Figure 1 and Figure 1A to the east of the township of Derby some 3 km from the town by direct line across West Doctor's Creek but is 27 km when accessed from Bungarun road (formally the Leprosarium). Power lines run over the land at the land base site. The first work to be done on site will be to construct a bund wall around the boundary to ensure that the tides are kept away from the construction area whilst the ponds are being constructed. The bund wall will be made out of the existing clay of the mudflats and will be built approx 1/2 a metre high initially and compacted to form a road on the top for ease of machinery movement. The bund wall closest to West Doctor's Creek may later be used by Derby Hydro power for access to their turbine site. The inlet canal will be dug from the existing clay using scrapers and excavators. The walls of the inlet canal will be 2 metres above the ground level and the canal will be approx 1.5 km long by 10 m wide and 7 m deep.

The ponds will be constructed from the existing clay. The ponds will be dug to a depth of 1/2m by 100m square with walls to a height of 2 m above the existing ground level. The anticipated depth of the water will be 2 m which gives 1/2m of wall above the water. The floor of each pond will slope towards the outlet for ease of draining. The floor will also be compacted ensuring that the clay will return to a hard surface once the pond is drained and dried.

The distribution canal will be constructed from the existing clay on top of the pond wall opposite the drain outlet. The top of the distribution channel will be 1.5m above the top of the pond and 3m wide with a slope of 1:10,000. The drain outlet return canal is also to be built from the existing clay of the mudflats and will be contained by a 2 m high wall and have a slope of 1: 5,000.

Secondary species ponds will also be built from the existing clay with an above ground wall height of 2m and a depth of water approx 1.5m deep. Sea water is to be obtained from West Doctor's Creek and returned to East Doctor's Creek. The flow pattern is via the inlet canal and then pumped up to the distribution canal, the water is then gravity fed via the distribution channel into the ponds where it is circulated and aerated before being partially exchanged. The exchanged water will flow to the secondary species pond via the return canal. The land has been set aside as a Derby special aquaculture development site, as part of the State government's commitment to aquaculture. The area requested by Kimberley Prawn Company has been set aside by DOLA subject to negotiations with the native title claimants and EPA being satisfactorily completed.

SITE DETAILS

NECESSARY PARAMETERS	DOCTOR'S CREEK SYSTEM
Quantity of sea water	Although turbid the water is free of pollutants and phosphates.
Tidal variation	The King Sound is subject to large tidal variations but the proponents see this as an advantage due to the following reasons ; (a) Complete exchange of water in the tidal creek system every tidal cycle. (b) Easy ability to drain outflow water at low tides.
Pond water pH	Approx 8.0 with some slight seasonal variation.
Salinity	Varies from the wet season to the dry but is an average 32 °/oo over the expected grow-out season of 8 months. (January - October)
Water Temperature	Surface temp approx 30 °C.
Freshwater	Ground water available.
Soil Type	The grey / blue clay has good compaction rates and can be considered impermeable using standard dam construction compaction rates. (a) PI (Plasticity Index)29.9%. (b) PL (Plasticity Limit) 25.5%. (c) LS (Linear Shrinkage) 13.8%. (d) LL (Liquid Limit) 55.4%. 100% of clay particles passed through a sieve size of 0.6 mm. Soil classification test conducted by MRWA Derby
Soil pH	7- 8.5

3.2 Farm Description.

In 1995 the Australian industry average was around 10 ha with farms ranging from 1 to 100 ha. The farms are generally earthen ponds on shore. Pond sizes vary but 1 ha is the norm with depths ranging from 1-2m. Stocking densities range from 5 post larvae (PL)/m^2 to 35 PL/m^2. The low stocking density farms tend not to have aeration and therefore have larger ponds. It is proposed to follow the model of North Queensland farms of medium stocking density (semi-intensive production) Figures 5-14 were photographs taken on Queensland prawn farms.

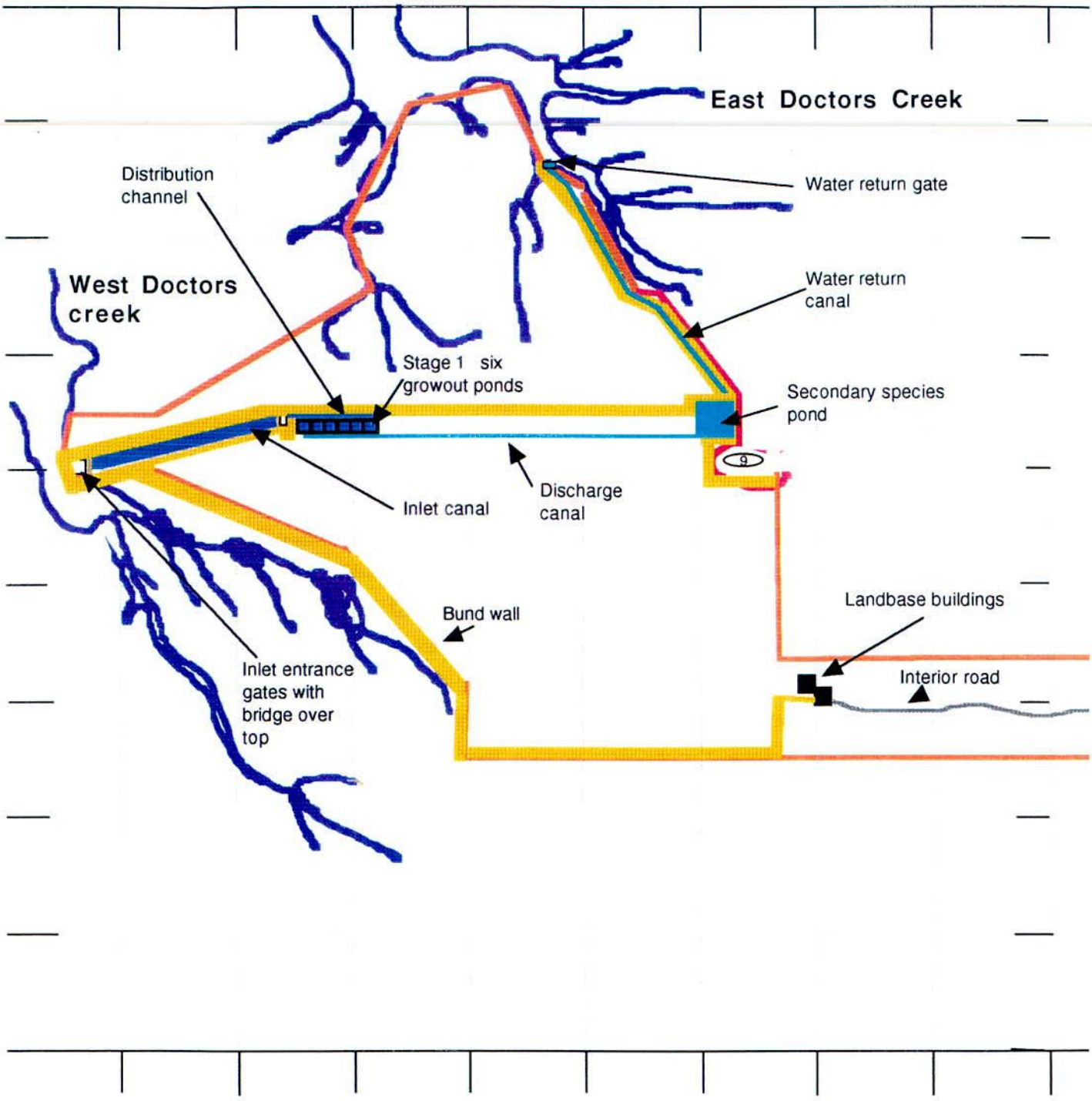
The farm will consist of the following:

3.2.1 Bund wall.

It will be necessary to construct a bund wall on the mudflat as close to the West and East Doctor's Creeks boundaries of the lease area as soon as the "wet" and tidal movements allow. (see Map 1, page 17) The bund wall will be constructed from the existing clay of the mudflat by using an excavator, grader and vibrating roller to compact the built up roadway. It is necessary to build this wall behind the mangrove line on the flats so that construction of the intake canal, ponds, discharge canal, secondary species ponds and return canal can be constructed without the problem of tidal inundation of the mud flat which occurs through out the year making it impossible to drive machinery on the mudflat itself during this time. Pipes with one way gates will need to be laid on the mudflat at ground level through the wall to allow water to drain from the inside of the wall to the creeks so that any rainfall or run off water does not create pools.

Dimensions - The bund wall will be built 6 metres wide by 1/2 m high. Later a covering of gravel 150 mm thick may be put on top of the clay to allow all year access to the ponds.

MAP 1: Position of Bund Wall , to allow construction t
commence.



Legend : The yellow line depicts the bund wall. This will secure the mudflat from tidal inundation whilst construction is taking place. During the construction phase the bund walls will be incorporated into the walls of either the ponds or channels.

3.2.2 Sea water intake system.

A sea water intake system will consist of sluice gates with a fine mesh screen frame attached to prohibit entry of wild fish stocks. The sluice gate will have one directional filling of the inlet settlement canal.

Dimensions - concrete wall with rock surrounds to protect against erosion. Stainless steel sluice gates with windlass type opening mechanism. On the outside will be positioned frames of fine mesh screens, these will be removable for cleaning.

3.2.3 Inlet settlement canal.

The water that passes through the seawater intake system will enter the inlet settlement canal where the suspended sediment of the King Sound water will be allowed to precipitate (see Figures 2,4). The flow of water into the inlet canal will only continue while the water in West Doctors Creek is above the bottom of the sluice gate, so will be subject to the rise and fall of the tide. Water should flow into the canal for one half of the tidal cycle.

Dimensions - The canal will be approx 1.5 km long by 10m wide by 7 m deep. Walls either side of the canal 2m high by 6m wide will be built above the ground level from the excavated clay of the canal and compacted to allow vehicle access. The water in the canal will be allowed to settle before usage to allow the suspended clay particles to drop out. Occasional dredging of the bottom of this canal will have to be done to remove a build up of silted clay particles, the dredged silt will be used to consolidate the bund wall.

3.2.4 Distribution channel.

Sea water at the inland end of the inlet canal will be pumped through a 16 or 20 inch centrifugal pump. This size is necessary to allow a pumping ratio of 50% of total pond volume per tidal cycle. It will be necessary to place a removable fine mesh screen over the outlet pipe to ensure no small fish of wild stocks of prawns enter the ponds. Water will be pumped up into the distribution channel and will flow by gravity to the growout ponds (see Figures 7,8,11,13).

Dimensions - The distribution channel will be constructed from compacted clay 1.5 m high by 3 m wide. The side walls will have slope of 1: 1.5 with a gradient of 1:10,000 to ensure that there is no erosion of the channel.

3.2.5 Growout ponds.

The ponds will be constructed using the clay already found at the site. Pond floors will be constructed with a slope towards the outlet gate at the discharge canal. This will ensure that when the pond is drained for prawn harvesting all the water is drained from the pond into the discharge canal and subsequently returned to East Doctors Creek via the secondary species ponds (see Figures 5,6,7,9,16) after monitoring.

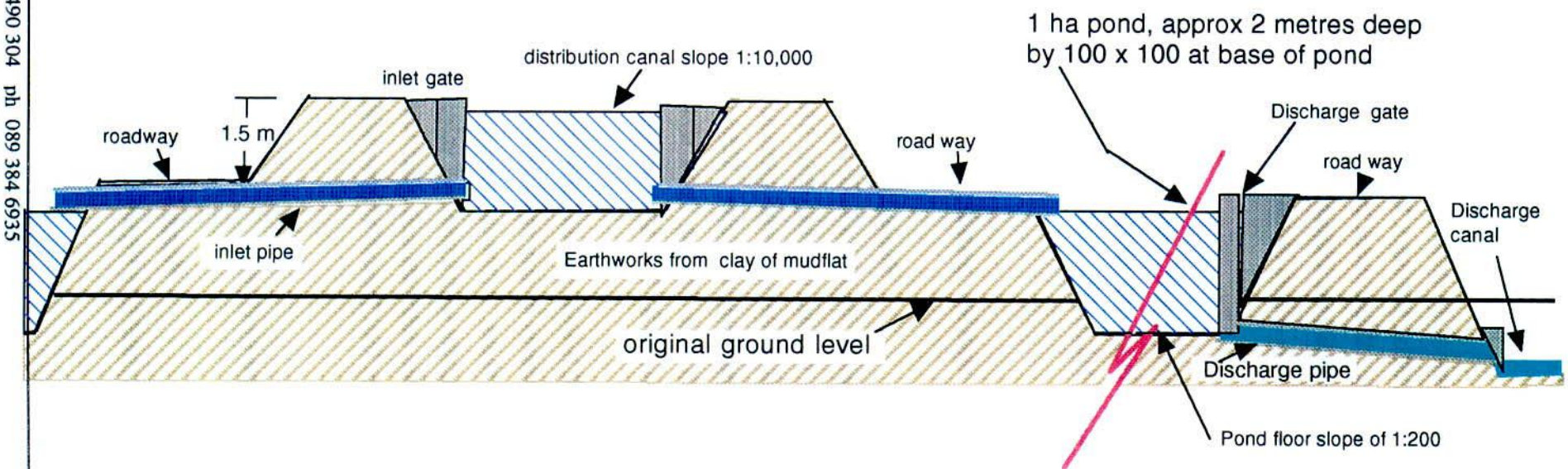
Dimensions - The construction of the inlet and outlet will allow passage of water without erosion. The inlet and outlet gates will be constructed from concrete and have sluice gate mechanisms. At the inlet gate a fine mesh screen will be used to trap any foreign species before the water enters the pond. The growout ponds will be constructed by scraper, excavator, grader and roller. The bottom of the ponds will be dug to a depth of 1/2 m below the existing ground level and the floor slope will be 1:200. The excavated material will be used to construct the walls of the ponds. The slope of the walls will be 1:1 with a height of 2m above the ground level. The top width will be 5m for three of the walls but where the distribution canal sits on the wall the width will be increased to 7 m. The tops of the walls will be graded and compacted to allow them to be used as roads. Artificial aeration will be created by use of paddle wheels or air jet rams.

DIAMOND ISLAND PTY LTD ACN 009 490 304 ph 089 384 6935

KIMBERLEY PRAWN COMPANY

DRAWING : 1

Typical pond & distribution channel layout



3.2.6 Discharge canal.

The outlet gate of the pond controls the depth of water and subsequently the amount of exchange of water in conjunction with the inlet gate. Harvesting the prawns is achieved by placing a "cod end" net over the outlet pipe and allowing the water to flow through the net. Water from the grow out ponds will be taken by discharge canals to secondary species ponds (see Figure 10). The water will contain varying concentrations of faeces and uneaten food, algae, dissolved nitrogen and phosphorous and some suspended clay particles.

Dimensions - Although built below ground level these will also have a 2 metre high by 3m wide above ground level wall on either side of the canal. The canal bottom width will be 2m with a wall grade of 1:1.5. The gradient of the canal will be 1:5,000.

3.2.7 Secondary species ponds.

Secondary species ponds will be constructed as required through each of the construction stages to hold oysters and scallops or other species to remove the nutrient build up in the discharged pond water (see Figure 3). The particulates from the discharge water will settle out with reduced water flow and the oysters will remove the phytoplankton or algae from the water. Although not yet commercially tried, Jones and Preston (1996) demonstrated that Sydney rock oysters could remove 88% of bacteria, 80% of Chlorophyll-a (algae) and 81% of total soluble solids after three circuits of a race system.

Dimensions - Built below ground level and with a depth of water around 1.5m these ponds will be around 3 hectares in area and have a wall gradient of 1:2 and a 2 m high wall built at ground level around them. At the opposite end to the inlet of each pond will be a outlet sluice gate, built out of concrete with a one way valve and fine mesh screens to allow only the water to pass through when the nutrients and other matter have reached the acceptable level required to return the water to the East Doctor's Creek system.

3.2.8 Water return system.

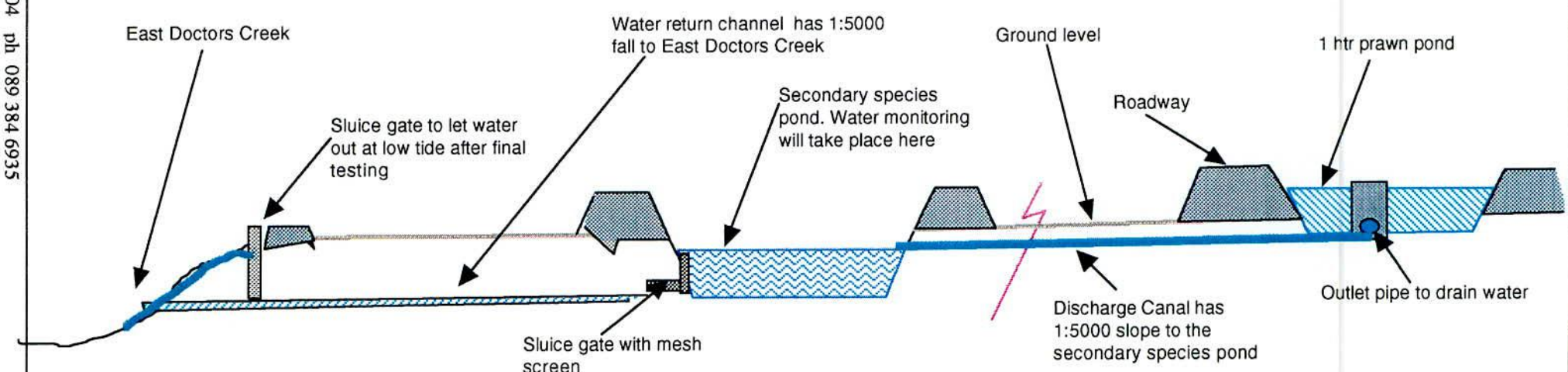
Water from the secondary species ponds will be returned to East Doctor's Creek via a canal (see Figure 3). A sluice gate and one-way valve will be necessary to

stop storm surges and extremely high tides entering the return system. The one way sluice gate will be used at the seaward end of a canal. It is in this canal that final monitoring will be done before returning the water to East Doctor's Creek.

Dimensions.- The canal will also be excavated from the clay and walls 2m high by 3m top width will be constructed above the ground level. The canal will be 2m wide at the base and have a slope of 1:1.5

DRAWING : 2

Side view of ponds and drains to East Doctors Creek



Construction is of the existing clay on the mudflat.
1/2 m deep excavation will give enough fill for walls of 2 m high
Some gravel may have to be used to create non slippery road surface

3.2.9 On-site buildings.

At the inland end of the inlet canal a pumping station will be built. At a later time the hatchery may be built in this area. Power to this will be sourced from either the Bungarun power line or from the existing line at Sutherland street near Numbala Nunga or from the Derby Hydro power line which may run across the site. The pump house will be a low shed built of steel and colour bond cladding with an electric motor and a 16 or 20 inch centrifugal pump.

The other sheds will be built on the land base (the old *Artemia* brine shrimp site) and will include a laboratory, feed shed, workshop, general storage, power generation, prawn processing shed, staff room, manager or caretakers residence. At the land base site will be stored any fuel or chemicals far removed from the ponds. All buildings will be constructed to region C, terrain category 2, wind speed 57 m/s cyclone certification (Derby/West Kimberley Shire requirements). The processing works will need to comply with AQIS export standards.

Commitment 2 :

In accord with the Code of Practice and Best Practices for Prawn Farms the Kimberley Prawn Company is dedicated to ensure that protection against erosion, storm surge, cyclonic flooding and dust and noise protection are incorporated into all stages of the project. Management measures to be taken include -

- All earthen constructions will be designed to minimise erosion and run off and stabilisation will be incorporated into design plans.
- All internal drainage will be directed into the settling ponds to protect the health of the mangrove zone.
- Drainage from the workshop will be routed through oil interceptors.
- Oils and fuels will be stored in such a manner as to preclude accidental spillage effecting the groundwater table.
- Drainage from the processing shed will be placed into a settling pond.
- All buildings will be constructed to region C, terrain category 2, wind speed 57 m/s cyclone certification (Derby/West Kimberley Shire regulations).
- The processing works will need to comply with AQIS export standards.

3.3 Feed Requirements.

The cost of food for the growing prawns is the largest operating expense (Hardman et al, 1990), followed by labour and electricity. All quality feeds used in the Australian prawn farming industry are imported. The imported feeds give lower feed conversion ratios and are more consistent in quality. The growth of phytoplankton for prawn food will have to be supplemented by a water stabilised pelletised food source. The size and quantity of feed used varies with the growth and size of the prawns, the main requirements are proteins, vitamins and

minerals. Supplementation with crushed lupins may be used to increase protein and carbohydrate levels. Ideally the feed conversion ratio will be 1.7: 1 but this will vary with different conditions. In the first year of production it is expected that around 180 tonnes of prawn food will be needed. As processed fish meal quality will deteriorate quickly the feed will be imported from Asia on a monthly basis via sea container. Each consignment will be subject to quarantine inspection by the Australian Quarantine Inspection Service. (AQIS). AQIS recently undertook a review of the importation of prawn feed and found that prawn feed is not seen as a potential source of disease. Other supplementary feeds will be sourced locally as needed. The secondary species will not need any processed feed as their purpose is to clean up the nutrient enriched discharge water.

Commitment 3 :
All imported prawn feed will be held under strict import and quarantine arrangements under AQIS quarantine regulations.

3.4 Acquisition of Stock.

Although there are hatcheries in Queensland which have a greater capacity than the current industry's requirements and post larvae could be obtained there, some of these hatcheries have had viral diseases in them and each batch of post larvae brought to WA would have to be certified as disease-free before import. Discussions with the Fisheries Department indicate that import from interstate is not a viable option. Proposals are currently being put forward to start hatcheries at Exmouth, Nickol Bay and the Broome aquaculture park and KPC would source post larvae (PL) from one or more of these. The use of local *P. monodon* will ensure that diseases will not be introduced from outside the area. It is impossible to say whether there are diseases in the local brood stock at this stage but should problems arise contingencies will be set in place to control the spread. Failure to supply sufficient quality or quantity of PLs by the local Western Australian hatcheries may necessitate construction of a hatchery in Derby. A higher quality of intake water will be necessary for this to be successful. The Kimberley Prawn Company recognises the desirability of having its own hatchery and planned to do so in year 4 or 5.

Commitment 4 :
Kimberley Prawn Company are committed to ensure that quality of both the stock and the environment are sustained. The prawns will be acquired from hatcheries with quality assured product.

3.5 Marketing.

The major markets for other Australian prawn producers is the Australian domestic market. There is some export to Japan which is the largest importer of prawns and takes 80% of Australia's exports which accounted for only 5% of Japan's imports in 1989 (Battaglene and Kingston 1990). China is the largest producer of cultured prawns but there are rapid increases in production in both Thailand and Indonesia. Japanese consumption of prawns is around 3 kg per person per annum. The bulk of cultured prawns are black tigers and they command a price ranging from $12-20/kg depending on size. Price is sensitive to supply and Australian prawns are usually harvested out of phase with northern hemisphere prawns. Ecuador is the major exporter of prawns to the USA.

With low harvests from all wild prawn fisheries in Australia in 1994, there was a supply shortage, and prawns were fetching $21/kg on the Sydney market (7 October 1994).

3.6 Implementation of Project.

The first requirement is suitable land on which to construct ponds. Following negotiations with the pastoral leaseholder, the State government and traditional land claimants, applications were made to WA Fisheries for the appropriate fish farm licence. The application was referred to the Inter departmental Committee on Aquaculture (IDCA). The EPA, a member of that committee through the Department of Environmental Protection has required the developers to prepare this CER before recommending action to the IDCA and the WA government. The Department of Land Administration (DOLA) needs to ascertain whether the land can be leased to the Company. Part of the land applied for is vacant Crown Land while a small portion of it is part of the pastoral lease of Meda Station. This portion of land would need to be excised from the pastoral lease. The pastoral lease holder has given permission for the land required to excised from the pastoral lease. DOLA has ascertained that there are no mineral tenements over the area requested through the agency of the Department of Minerals and Energy. DOLA has also advertised for any Native Title claims over the area and negotiations are currently being concluded between the proponents and native title claimants. The heritage survey will be undertaken shortly.

Commitment 5 :
Kimberley Prawn Company will ensure that clearance is obtained under the *future act* clause in the *Aboriginal Heritage Act.*

Once approval is obtained, the site will be surveyed and construction commence. The first phase is planned to be six x 1 ha ponds with the first harvest expected six months after stocking. The second phase will be expansion to 20 ha and then depending on the success of the project to that time, expansion to 100 ha will be undertaken. At this point some 40 employees are expected. A fourth phase depending on world markets and success of the husbandry to date, will be expansion to around 650 ha of ponds. The industry would by then be a substantial employer and assist in maintaining the necessary transport infrastructure for both import of food and export of product. At each phase the expected production of saleable prawns will be, 30 tonnes, 100 tonnes, 500 tonnes, 4,500 tonnes annually.

FARM PROJECT DETAILS

Proponent		Kimberley Prawn Company Aust. Pty Ltd PO Box 867 DERBY WA 6728
Site area		Doctor's Creek, Derby WA
Lease area		2,000 ha. Approx 300 hectares is on the Meda Pastoral Lease the remainder is Vacant Crown Land, part of which was previously leased as a Special Purpose Aquaculture, Artemia lease.
Area utilisation	Stage 1-	50 ha (6 ha ponds, inlet canal, distribution channel, outflow canal, secondary species ponds, return canal, roads, workshop, process shed, office, accommodation *Pilot commercial*
	Stage 2-	70 ha (20 ha ponds) *Moderate expansion*
	Stage 3-	250 ha (100 ha ponds) *Commercial*
	Stage 4-	1800 ha (650 ha ponds) *Possible hatchery and full expansion.*
Workforce	Stage 1-	Contractors (local contractors for site buildings and flood gate system, tenders will be called for pond construction and canals), site manager and one marine biologist and 3 FTEs and some casual labour during harvesting.

Farm Project Details.
(continued)

	Stage 3- Pond construction contractors. Two site managers, two pond supervisors, maintenance officer, Secretary, bookkeeper, truck driver/ storeperson. 30 to 35 FTEs and casual labour during harvest. Stage 4- To be determined.
Stock requirements	Black leader prawn (*Penaeus monodon*) From Western Australian hatcheries (Broome, Exmouth and Nichol Bay) King Sound rock oyster (*Saccostrea echinata*) Local collection in conjunction with WA Fisheries Officers Saucer scallop (*Amusium balloti*) Local collection in conjunction with WA Fisheries Officers Brine Shrimp (*Artemia salina*) From suppliers
Feed requirements	Pelletised fish meal, lupins, super phosphate (for phytoplankton production), the quantity of feed is to be determined.
Feed Conversion rate	A feed ratio conversion of 1.7:1 is expected.
Water requirements	Sea water from King Sound via West Doctor's Creek. Fresh water from unconfined aquifer under Rivers and Waters commission licensed extraction. Ground water usage will be for general use at land base facilities, processing of product and supplementation of pond waters when needed due to pond evaporation and seasonal increase of salinity in the King Sound water.

Farm Project Details.
(continued)

Site Power	Electrical power will be taken from the existing power line at the land base site (Bungarun power line) and from the power line which is closest to the pump station (East end of Sutherland Street, Derby). Electrical power is needed for the general running of the farm and the elevating of sea water from the inlet canal to the distribution canal and also aeration of the ponds (paddle wheels and air rams).
Vehicle fuel storage	All fuels for on farm machinery will be stored at the land base facility. All fuels and chemicals will be stored as per state government by - laws pertaining to the storage of same in the area of Derby.
Marketing	Prawns will be sold on the domestic and export markets. Oysters will be selectively sold for the local market as will the scallops. Organic and waste matter when dry (drying will take place in the ponds) will be extracted by mechanical harvesting and stored temporarily in a bund walled storage area. The extracted material will be used mainly on the external walls of the ponds to encourage growth of grasses and trees but some of this material will also be sold locally as fertiliser.

4.0 DESCRIPTION OF THE ENVIRONMENT

4.1 The Existing Environment.

The existing environment is inter - tidal hypersaline mud flats, Mangroves line the arms of the tidal creeks required for seawater intake and egress. On the landward side of the mud flats, samphire vegetation occurs. Ponds will be built on the bare mud flats. It is not proposed to disturb the mangal or samphire scrub zones. The Pindan vegetated dunes occur to the east of the area above the effect of spring tides. The buildings will be sited on and near the existing concrete pads on the old *Artemia* (brine shrimp) experimental site. The site is accessed by the Bungarun road and an internal track. An overhead three phase power line to Bungarun Aboriginal Educational Centre (formally Derby Leprosarium) passes over the land base site.

The Derby region has a semi-tropical arid climate with a pronounced summer maxima of rainfall. The rainfall varies between 400-800 mm per annum with a mean of 621 mm. The rain falls mainly December to April inclusive with a dry season for seven months of the year. The average number of rain days per year is 45. Evaporation rates are high with an average of 3300 mm per year. Monthly maximum air temperatures range from 29°C in July to 36°C in December. Minimum monthly air temperatures range from 14°C in July to 26°C in December.

Kimberley Prawn Company has monitored the temperatures and salinities in Doctor's Creek with water temperatures ranging from 20°C in July to 28°C in both December and April. Salinities have ranged from 6.5 °/oo in February/March to 41 °/oo in September. Average is 33 °/oo. The readings were taken over a three year period at Derby wharf and Doctor's Creek. Average salinity of sea water at Doctor's Creek is 32 °/oo. Derby has a tidal range of up to 10.8m.

4.2 Cyclones & Storm Surge Movement.

Cyclones are a feature of tropical Australia. They are not as frequent over Derby as in some other regions of WA, but cyclone tracks have passed within 5° latitude and longitude of King Sound in 1910-11, 1949-50, 1950-51, 1969-70, 1970-71, 1987-88 and 1995-96. Two cyclones entered the King Sound in 1997 but neither made a discernible difference to the tidal

range at the Derby wharf. The main effect of a cyclone would be possible increased height of high tide and a decrease in salinity of water at Doctor's Creeks if the Fitzroy River water entered the Doctor's Creek system. Floods could threaten the banks of the ponds but the walls of the ponds and canals should be sufficiently high to prevent inundation. The estimated peak tidal surge is 1.2m above published tidal data. With the vast expanse of mudflats at the headwaters of the King Sound the tide would need to be above ten metres to rise onto the land, the area of mudflats to be covered before storm surge takes effect would be around 2/3 the area of the King Sound covered by water (3,985 sq. km). This vast expanse of flat tidal mud flats is bordered by a fairly flat expanse of pindan sand ridges. In other coastal regions of Western Australia, the land bordering the ocean has low to high sand dunes immediately inland. This is the case at Geographe Bay where the sand dunes acted as a wall when cyclone Alby (1978) forced a tidal surge into the bay and sea water eventually flooded over the top into the low land immediately behind the dunes.

As the tides are fast moving in the King Sound (5 knots on neap tides, 8 to 10 knots on spring tides) it is reasonable to assume that there would not be enough time for a cyclone to build up enough water to flood the mudflats (approx 2600 sq km in area) to any significant depth before the effect of a receding tide would alter the depth of sea water. If the cyclone were to enter the area at low tide it may pass into the upper reaches of the sound where there is often no water beyond the Derby wharf (over 200 sq. kms). In his work on the Derby mudflats, Semenuik (1980b) postulated that for a storm surge to occur the coincidence of a spring high tide, gale force winds from the north west and the severe flooding of the Fitzroy River would be needed. No weather records show this effect having occurred at Derby since settlement (1883). Indeed there is no evidence to show that a storm surge of 1.2m height has ever occurred in the King Sound. The top of the ponds will be 2 metres above the ground level which is well above the usual level of mudflat inundation in the area of the pond construction.

4.3 Hydrology Of Doctor's Creek Mud Flats.

The clay is described by Semenuik as composed of clay minerals, quartz silt and older Holocene period silt particles contained in the sediment as laminated and viscular mud. The Doctor's Creek formation is found to be 10-12 m thick and overlies the Christine Point Clay. The salt flat is vegetation free with a gradient of less than 1:2000. It is covered by water to a shallow depth by tides higher than MHWS. Groundwater hypersalinity precludes biota over most of the flat. On the seawater side of the flats is the Mangal flat, samphire grasses occur toward the landward side of this zone. The surface is mud and shelly mud.

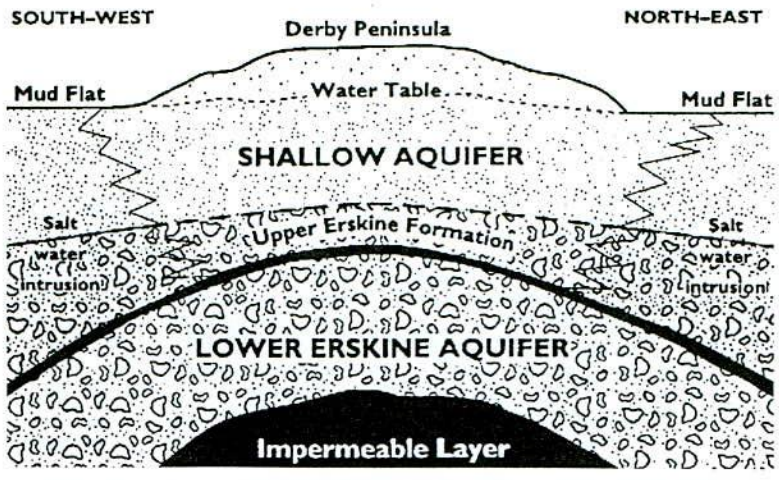
On the landward side the higher parts of the flats are vegetated by terrestrial grasses and other low-growing angiosperms, which occur above EHWS. The lower parts of the flats are vegetated by samphire grasses and are inundated by EHWS tides. (EHWS equinoctial high water spring, MHWS = mean high water spring). During spring high water , seawater covers the mudflat to a shallow depth which leaves a low cover of water on the mudflat on the receding tide. This water can pool and take time to dry. Mosquitoes (*Aedes vigilax)* breed in the small amount of water left on the mudflat. In 1996 there was a MHWS on at least one occasion per month throughout the year which covered the mudflat.

There is however normally a *window of opportunity* in each year whereby a bund wall can be constructed to keep the tidal inundation out of the ponds and channel construction area. During heavy rainfall periods the mudflat is covered by shallow amounts of water. This causes boggy conditions on the mudflat for some time after the rain has finished. It will be necessary to incorporate drainage pipes into the bund wall to ensure that this water can drain to the Doctor's Creek system.

4.4 Groundwater Details.

Two ground water zones occur on the Derby peninsular.
The Shallow Aquifer is described as unconfined and is the supply for privately licenced bore users. It is recharged by a small amount of rainfall which percolates from the surface to the water table in the Pindan land area. Generally the groundwater flows outwards from the peninsular discharging along the ocean floor beyond the coastline.
The Lower Erskine aquifer underlies the entire groundwater area but the top of the aquifer exists at depths greater than 100m below the surface and is situated between impermeable materials both above and below the aquifer. The Lower Erskine Aquifer is the chosen town water supply for the town of Derby. The clay on the mudflat is impermeable to surface water percolation to the unconfined aquifer and soil tests of the mudflat by the proponents have shown hypersaline readings of between 180 ppt and 240 ppt.

Water supply aquifers

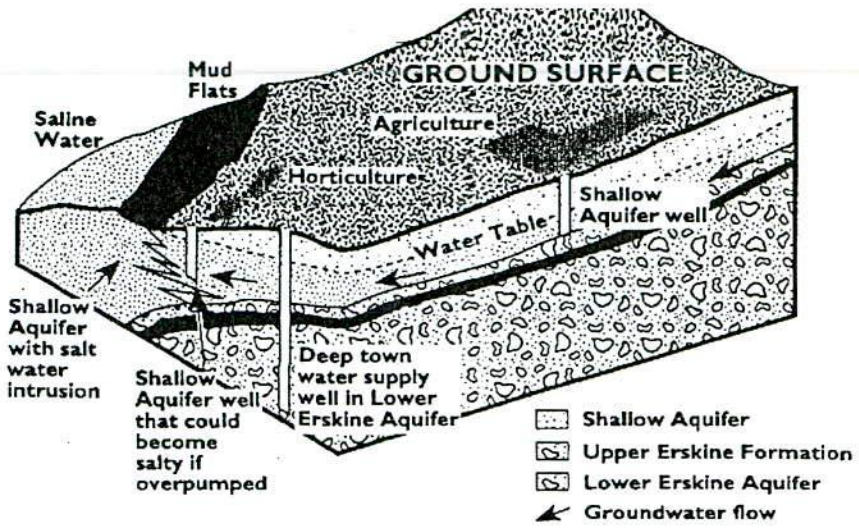


Cross section of Derby peninsula showing main water supply aquifers

There are two significant water supply aquifers underlying the Derby peninsula and these are referred to as the Shallow Aquifer and the deeper Lower Erskine Aquifer. The Shallow Aquifer underlies the entire Groundwater Area. A number of town water supply wells and many private wells rely on this resource. The Shallow Aquifer system includes the upper Erskine Formation. The Lower Erskine Aquifer also underlies the entire Groundwater Area but the top of the aquifer exists at depths greater than 100m from the land surface. It constitutes what is termed a confined aquifer, as it is situated between impermeable materials both above and below. This resource is utilised by three town water supply wells and only a few private wells which existed prior to the policy of reserving the Lower Aquifer for public water supply.

"Derby Groundwater Management March 1993 . Water Authority of Western Australia".

Groundwater flow system

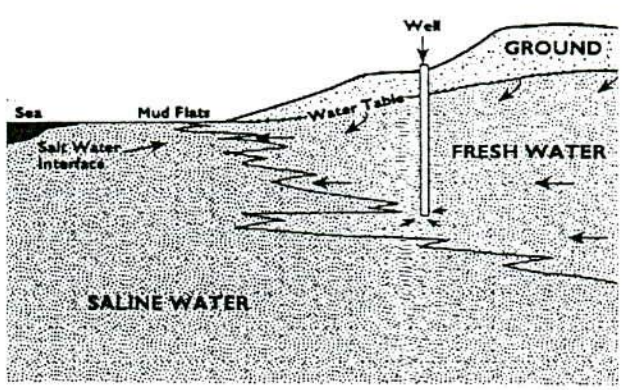


Schematic representation of groundwater flow in the Shallow Aquifer

The Shallow Aquifer at Derby is recharged by a small amount of rainfall which percolates from the land surface to the water table (the top of the aquifer) Generally, groundwater flows outwards from the centre of the peninsular discharging along the ocean floor beyond the coastline. The Lower Erskine Aquifer is recharged by rainfall where it is exposed at the land surface near the Erskine Ranges about 90 kilometres south-east of Derby.

"Derby Groundwater Management March 1993 . Water Authority of Western Australia".

Salt water intrusion



Pumping from the well could cause movement of the salt water interface resulting in salination of the well supply

Saltwater intrusion occurs when excessive pumping in a localised area induces inland migration of the saltwater interface. The saltwater interface that surrounds and underlies some of the peninsula is quite complex and irregular in nature due to variable groundwater flow characteristics, extreme tidal influences, and groundwater pumping history. Because of the nature of the interface, saltwater intrusion may occur either vertically or horizontally and be indicated by a slow or rapid rise in groundwater salinities.
"Derby Groundwater Management March 1993 . Water Authority of Western Australia".

This matter was discussed with the regional manager of Water & Rivers Commission, Karratha and it is felt that there is a possibility that by extracting saline water from the Unconfined Aquifer in the vacinity of the grow out ponds of the prawn farm, the inland migration of the interface may be halted.

5.0 BOTANY & ZOOLOGY

5.1 Flora.

Parallel to the coast the mangroves form a wide belt dissected by many small creeks. The main creeks have the most complex marginal vegetation towards the seaward side (Johnstone 1990). Landward, the major creeks become shallower, tributaries more numerous, and their marginal vegetation less diverse. The sources of the creeks can be discerned on the mud flats as mere gutters.

The mangrove vegetation grows on a long gently sloping mud bank which has allowed the trees to form zonal belts of *Rhizophora*, *Camptostemon* (along creeks), *Bruguiera exaristata* , *Avicennia* and *Aegiceras* on the seaward zone. These grow to a height of between 1-6 m The central zone is mainly *Avicennia* and *Bruguieria* with some *Ceriops*, *Camptostemon* and *Rhizophora* . The landward zone is mostly scattered *Avicennia* , *Excoecaria* and *Ceriops* , and open to dense thickets of *Ceriops*. The substrate is dark grey mud. The mangal is backed by samphire flats with *Sporobolus virginicus* , further to landward there is a thin belt of *Melaleuca acacoides* (Semenuik 1980a; Johnstone 1990).

Inland of the mangrove belt along the creeks is the bare mud which is subject to inundation at spring tides and is devoid of vegetation because it is hypersaline. Fisheries officer Colin Ostle and the proponent Ian Crimp tested a drill site at Christine Point where the salinity was found to be 180 ppt at 2 metres deep. These mud flats are between 2-4 km in width. On the landward margin of the mud flats are the samphire flats which also sometimes occur in small pockets between the mangroves and the saline mud flats. Species found in the samphire flats are (Semenuik 1980a): *Arthrocnemum halocnemoides* , *Arthrocnemum leiostachyum* , *Batis argillicola* , *Halosarcia halocnemoides*, *Halosarcia indica* , *Hemichroa diandra*, *Sesuvium potulacastrum* , *Sueda arbusculoides* , *Sueda australis* , *Threlkeldia diffusa* , *Trianthema turgidifolia* , and the saline tolerant grass *Sporobolus virginicus* . All of these species are common and are neither rare nor on an endangered species list.

5.2 Fauna.

In the mangrove communities, a diversity of animal life is supported. Mangrove leaf litter supports shrimps, amphipods, isopods, polychaete worms, clams and insects. On the stems

and leaves of the mangroves are found barnacles, oysters, snails, insects etc. Xanthid and grapsid crabs are found near the roots of the mangroves. Fish and crustaceans swim into the mangroves at high tide and retreat at low tide. Gobi fishes burrow into the mud to survive low tides. Birds feed on the fish and invertebrates among the mangroves.

Birds usually found in the mangroves include (*Johnstone, 1990*) :

Common name	**Scientific name**
Great-billed heron	*Ardea samatrana*
Mangrove heron	*Butorides striatus*
Chestnut rail	*Eulabeornis castaneoventris*
Bar-shouldered dove	*Geopelia humeralis*
Little bronze cuckoo	*Chrysococcyx minutillus*
Mangrove robin	*Eopsaltria pulverulenta*
Mangrove golden whistler	*Pachycephala melanura*
White breasted whistler	*Pachycephala lanoides*
Mangrove grey fantail	*Rhipidura phasiana*
Broad-billed flycatcher	*Myiagra ruficollis*
Mangrove fly-eater	*Gerygone levigaster*
Dusky fly-eater	*Gerygone tenebrosa*
Yellow white-eye	*Zosterops lutea*
White-breasted wood swallow	*Artamus leucorhynchus*

No evidence of marine birds using the mudflat for nesting has been seen, migratory marine birds predominantly nest outside Australia before travelling to the feeding grounds in Australia. In the Kimberley only a few forest dwellers nest after migration, Oriels and dollar birds are two such species.

5.3 Terrestrial Mammals.

Due to the effect of tidal inundation there are no mammals to be found within the mud flats or mangal tree line of West or East Doctors Creek. Terrestrial mammals commonly found in mangals are the Flying Foxes. There are three possible species which roost during daylight and feed on mangrove blossom or elsewhere during the night.

These are :

Northern Blossom Bat	*Macroglossus lagochilus*
Black Flying Fox	*Pteropus alecto*
Little Red Flying Fox	*Pteropus scapulatu*

5.4 Reptiles and Sea Life.

In the sub-tidal areas of King Sound there are crocodiles, (*Crocodylus porosus*), sea snakes, turtles, dugongs (*Dugong dugon*). The crocodiles could follow the fish onto the tidal mud flats at high tide and could find their way to the prawn farm in the inlet canal. Fences will be constructed around the ponds to keep crocodiles out. Snakes could be found in the mangal and samphire communities.

6.0 ENVIRONMENTAL IMPACTS AND MANAGEMENT

Some of the potential environmental impacts are a possible nutrient build up in the discharge water before being removed in the secondary species biological extraction ponds. A visual change of the mud flats for those driving on the mud flat within 300 metres of the ponds. Because of the mirages on the mud flats, any visual impact beyond that distance would be blurry but could be extended in distance by the elevating effect of the mirage above the horizon. This slight visual effect could be reduced by vegetation of the pond and canal margins. With good monitoring procedures and the careful management of the project there will be no adverse impact on the mangrove or samphire communities.

6.1 Mangroves.

Mangroves are generally an opportunistic species and will alter their distribution and zonation in response to changes in available water, tidal range, sediment distribution and their growth rate can be attributed to the availability of saline, nutrient-enriched water. The large tidal range in the Doctor's Creek system is helpful in maintaining a healthy well developed mangrove community. Mangrove communities prefer locations where organic matter and nutrients collect and regular tidal inundation with surface run off to produce a flushing effect therefore limiting the amount of salinity in the soil. Kimberley Prawn Company intends to build the bund wall and associated pond structures beyond the inland extent of the mangrove community to ensure that there is little or no direct impact on the communities (*see Figure 17*).

It is the intention of the proponents to protect the mangroves at the discharge site from any indirect or direct impact during the construction of the inlet canal and the discharge canal. No mangroves will be cleared in the construction of these and although the increased water flow from the discharge canal will extend the occurrence of time that water is in the upper reaches of East Doctor's Creek the near-continuous flow of water from the secondary species ponds will keep the watercourse well-oxygenated. Potential impacts of the discharge water would be an increase of potentially suitable habitat for the mangroves to grow in and some slight scouring of the creekbed. The tidal flow rates are as high as 10 knots, in comparison therefore the small volume of discharge water will have little impact.

6.2 Samphire

Samphire vegetation to be found on the project site area are highly salt tolerant species of succulent nature. It is not expected that there will be any impact on them through construction of the ponds and other infrastructures such as the bund wall as there is no need to disturb the area that they grow on. It is possible however to propagate these species by cuttings and the proponents intend to use this method to stabilise areas at risk of minor erosion. Research will also be undertaken into the possibility of direct transplantation of the samphire vegetation into other areas such as pond and canal walls (*see Figure 17*).

Commitment 6 :
No mangrove or samphire will be cleared during the construction phase. Photographic monitoring will be used before and after construction to satisfy the DEP.

6.3 Rehabilitation of Disturbed Land.

The mudflat will be stabilised against erosion where necessary and as there is no vegetation on the proposed grow out area samphire and salt water couch grass will be encouraged to grow on the walls of ponds and channels The land base will be landscaped to ensure that the Pindan is protected against erosion and the aesthetics of the area are protected.

Commitment 7 :
Rehabilitation will be carried out to the satisfaction of the DEP and monitored annually to ensure that the vegetation approaches pre-construction amounts.

6.4 Decommissioning.

By following the Code of Practice and Best Practices for the prawn industry which adhere to the principals of good housekeeping and quality control procedures, the project is deemed to have an indefinite lifetime. Therefore there are no plans currently to decommission the project or to abandon the site.

Commitment 8 :
If in the future it is found that it is necessary to rehabilitate part of the operation, the decommissioned area will be rehabilitated to pre-construction conditions, in accordance with Best Practices for the prawn industry and the West Kimberley region and the DEP.

6.5 Public Concern Issues & KPC Response.

From interaction with the public to date, there are some perceptions that need to be corrected and some fears need to be allayed.

Claims have been made that the prawn farm would :

1; increase dust in Derby.
2; increase atmospheric humidity at Derby.
3; increase mosquitoes in Derby.
4; adversely impact on wildlife particularly mangal nesting birds.
5; increase salt content of the water.
6; adversely impact on the Derby ground water supply.
7; affect the nest habits of migratory birds.
8; interfere with the class "A" nature reserve.
9; impact on the Yabbagoody area.

The following are explanations of why these points are believed to be insignificant -

6.5.1: Dust Management.

The prevailing winds in Derby are principally onshore in summer and from the south in winter, so any dust created during construction will blow away from Derby and is not expected to carry 3 km to town even if the wind came from the east. Dust already impacts on the town of Derby principally in May and October, the dust mainly blows from the south-east over the town from the mudflats from the south. After the construction phase, the surface of the mud will be resealed by water and salt to the same surface consistency as already exists on the mud flat. The

type of construction is shown in Figures 5-7. Figure 5 shows the amount of dust to be expected. Once water is placed in the ponds this will have a dampening effect on the dried soil and less dust will rise from the area than at present.

KPC Response:
The KPC will monitor dust levels during the construction stage and grow out stages to ensure that there is no increase of dust from the farm.

6.5.2: Humidity.

The evaporation expected from the ponds is expected to be less than an equivalent tidal inundated mud flat as the temperature in the shallow water on the mud flat would be much higher than in the ponds. The area the ponds cover will be the same as that which is already covered by tidal inundation and is very small when compared to the total area of mud flats and the surface water of King Sound so the ponds will not increase the humidity of the town.

Response:
The proponents will implement procedures to ensure that pooling of water on the unused mudflats of the lease will be kept to a minimum to reduce the possibility of humidity increase.

6.5.3: Mosquitoes.

Most mosquitoes lay eggs in stagnant, fresh to brackish still water but prawn pond water is saline and constantly in motion; any mosquito larvae which venture into the ponds will most likely be eaten by the prawns. Pooling of surface water on the mudflats occurs at present due to tidal inundation, *Aedes vigilax* breeds in grass, trees and shallow stagnant fresh water ponds. Occurrences of Ross River virus and Australian encephalitis are found to be from the mosquitoes which breed in the fresh water pools and in the grasses and other vegetation of the pindan grasslands.

Response:
The farm management will monitor levels of mosquitoes and take appropriate action where necessary should a problem arise.

6.5.4: Mangrove Birdlife.

The site is predominantly a mud flat devoid of vegetation, birds do not nest on the mud flats as there is no shelter for them and the area is subject to flooding by spring tides. It is not proposed to enter or disturb the mangal or samphire communities other than for siting the water intake and outflow (see Figures 2-4, 15,16).

Response:
The mangal and samphire communities will not be disturbed. Photographic surveys pre and post construction will be used to verify a lack of disturbance to the mangal and samphire zones. Workers will be discouraged from entering the mangal zone and hence disturbing the local bird life.

6.5.5: Salinity Levels.

Evaporation of water from the pond surfaces will increase the salinity levels in the ponds; this is a phenomenon common to all prawn farms; this increase in salinity can be alleviated by :
an increase in through flow of seawater entering the ponds to dilute the pond water to the salinity of the inlet water;
adding lower salinity water or fresh water from an estuary, stream or ground water; in this case ground water could be used that would be too 'hard' for domestic use;
waiting for seasonal conditions to change; high salinities will slow the growth particularly of the juveniles so this is the least preferred option;

From temperature and salinity readings taken so far from this area, any increase in pond salinity can be reduced by an increase in the intake of seawater from the King Sound. If ground water is required it will be taken in accordance with instructions from the Water and Rivers Commission who have made it clear the Derby town ship has priority for water use.

The tidal exchange of water in King Sound varies from 8-37 km^3 for neap and spring tides respectively. The total water in the ponds will be 200,000 m^3 of water when there are 10 ha of ponds, 2 x 10^6 m^3 of water when there are 100 ha of ponds and 13 x 10^6 m^3 of water when there are 650 ha of ponds. The exchange required to reduce the salinity of 1000 ha of ponds from 38 to 26 $^0/oo$ is about 6,300 m^3 or 0.00008 % of the water exchanged each tide in King Sound at neap's and 0.000002 % at spring tides. The effects of pond water returned to King Sound on water quality of King Sound would be negligible even without the secondary species ponds. At an average daily exchange of 15% for each pond, there would be 18 ML per day in stage 1, 60 ML per day in stage 2 and 300 ML per day in stage 3 and 1950 ML in stage 4. The mean discharge to East Doctors Creek would be 0.75 ML/hr in stage 1; 2.5 ML/hr at stage 2; 12.5 ML/hr at stage 3 and 82 ML/hr at stage 4.

Response:
The proponents will monitor the inlet, pond and outlet salinity levels and take appropriate action to ensure that the salinity increase is within the guideline parameters.

6.5.6: Groundwater Usage.

The Water and Rivers Commission of WA expects the town of Derby to rely on the Lower Erskine Aquifer for its water supply, and the prawn farm to draw from the more saline 'unconfined aquifer'. The ground water would not be returned to the aquifer but would be released at the surface in East Doctor's Creek. It is possible that ground water used by the prawn farm will draw the more brackish water from the area allowing the fresh water to flow from the landward side ensuring that less saline water is available for Hamlet Grove residents. WA Water Commission documents show that the unconfined aquifer flows from south to north from an inland direction to the head of the Christine Point/Doctor's Creek area. There would be no detrimental effect on water quality of the aquifer due to the operations of the prawn farm, as all discharged water will be transferred to East Doctor's Creek via the secondary species ponds to remove phytoplankton and nutrients.

The clay at the site is some 10-12 m deep. That clay is impervious to downward percolation of the salt water from the mud flat. Water from the ponds will cover the same area of mud flats as is currently covered by the tides. There will be no addition to the salinity of the groundwater and as is indicated above (Section 4.4), the salinity of the groundwater may be reduced by the prawn farm withdrawing brackish water from lower layers of aquifer beneath the surface clay.

Response:

The KPC will abide by the Water and Rivers Commission licence conditions for bores and the allocation of fresh water that can be extracted for use in the operations of the farm. (see diagrams pages 33, 34)

6.5.7: Mudflat Migratory Bird Nesting Sites.

Most migratory sea birds nest in the northern hemisphere before flying to feeding grounds on the coast of Australia. As there are no nesting sites on the area of bare mudflats selected it can be reasonably presumed that the only activity the migratory birds may be involved in will be over-night roosting on the mudflat, when it is not inundated with water. It is rare also for migratory wading birds to fly inland for nesting. (Derby is some 140 kms from the coast).

Response:

The KPC will monitor all birds in the area of the prawn farm and ensure that disturbance is minimal.

6.5.8: Class "A" Reserve.

A class "A" reserve exists to the landward side of the prawn farm in the pindan area west of the Bungarun road. As this is well outside the prawn farm area there will be no interference. The reserve is at least two kms from the land base buildings.

Response:
There will be no interference by the KPC on this reserve.

6.5.9: Yabbagoody Well.

The area surrounding a water trough at Yabbagoody well is believed by some to be a significant flora and fauna reserve. As this area is well outside the influence of the prawn farm area it is more likely to be an impacted upon by the residents of Hamlet Grove and Mowanjum. This area is south of the lease at least 3 kms from the closest boundary of the lease area.

Response:
The proponents will take all precautions necessary to ensure that the project causes no impact on the Yabbagoody Well area.

6.6 Social , Cultural & Native Title Issues.

6.6.1 Social Issues.

The residents of Hamlet Grove were concerned that they would lose recreational space on the mud flat near their homes, and fishermen were concerned that they would no longer have access to fishing spots on the Doctor's Creeks. The northern boundary of the lease area requested was moved south to accommodate recreational fishermen on the East Doctor's Creek. The southern boundary was moved north to allow recreational use of the mud flat near Hamlet Grove and to avoid the 'A class' reserve near Bungarun Road. The proposed inlet canal from West Doctor's Creek would remove access to the mud flat to the north between the two arms of Doctor's Creek so the KPC has agreed to provide access over the inlet canal to maintain the present access to the mud flat and Doctor's Creek (see Figure 1&1A). If the tidal power proposal proceeds, then a road will need to be constructed along the edge of the Kimberley Prawn Company lease to provide access to the tidal power turbines. An "A" class reserve (lot 87 in Figure 1&1A) is some 3 kms from the nearest boundary. No other reserves exist in the area.

6.6.2 Native Title Issues.

Kimberley Prawn Company is currently completing negotiations with the Traditional owners and their representative body over Native Title issues. When Native Title negotiations have been completed a Cultural and Heritage survey will need to be undertaken.

Commitment 9 :

Kimberley Prawn Company will commission a heritage survey over the lease area and in compliance with the *Aboriginal Heritage Act of Western Australia,* will cease construction work in the immediate area until cleared by the Department of Aboriginal Affairs if any aboriginal artefacts or burial sites are discovered or inadvertently disturbed.

6.7 Environmental Impacts & Management Issues.

The CER guidelines raised environmental issues which the proponents were required by the Departmental of Environmental Protection to address. These "***Key Environmental Issues***" have been considered and their proposed management is contained in the following Table -

Topic	EPA Objectives	Possible Issue	Proposed Management	Relevant Standards	Standards of Success Achieved
Biophysical issues (Timing/Duration)					
Environmental Management System. (Ongoing)	Implement recognised environmental management system for prawn farming.	Covers all expected impacts.	Covers all management responses.	Code of Practice	Code of Practice implemented to satisfaction of Fisheries Department.
Terrestrial fauna. (Ongoing)	Protect significant and/or rare species.	Destruction of fauna habitat.	Minimal disturbance of mangal habitat.	Code of Practice.	Code of Practice implemented to the satisfaction of EPA.
Terrestrial environment (Ongoing)	Protect the environmental values of the area, including the proposed nature reserve near the Gibb River Road & Leprosarium Road	No significant impact expected by ensuring sound Environmental controls are in place.	Protect through monitoring the waters of the King Sound. Proposed nature reserve is not relevant to the project.	Code of practice & Best Practice for industry and the region.	Code of Practice implemented to the satisfaction of EPA.
Terrestrial vegetation. (Stages 1 to 4 of construction)	Minimise clearing and destruction of vegetation.	No clearing for ponds required and only low impact clearing for landbase.	All construction will take place behind mangal line on bare mudflat. Minimal disturbance of vegetation is intended at land base site.	Code of Practice & Best Practice for industry and the region.	Disturbed areas rehabilitated to the satisfaction of EPA.

Note "Code of Practice = Draft Code of Practice for Australian Prawn Farmers (Appendices 8.6).
"EPA Bulletin 771" Western Australian Water Quality Guidelines for fresh and Marine Waters (EPA 1993).

6.7 Environmental Impacts & Management Issues.
(continued)

Topic	EPA Objectives	Possible Issue	Proposed Management	Relevant Standards	Standards of Success Achieved
Samphire grasses. (Stages 1 to 4 construction)	Protect samphire communities.	Destruction of habitat.	Samphire will be propagated on outside banks and walls of ponds.	Code of Practice & Best Practice for industry and the region.	Stable wall profile and vegetation cover achieved.
Aquatic fauna. (Ongoing)	Protect significant and/or rare species.	Destruction of fauna habitat.	No significant or rare species identified.	Code of Practice.	Code of Practice implemented to the satisfaction of EPA.
Aquatic vegetation and flora. (Stages 1 to 4 construction)	Protect locally and regionally significant vegetation associations and habitats, including mangrove and samphires.	No physical disturbance. Expected increase of suitable mangrove and samphire grass habitats.	Ponds and road construction on bare mud flats, minimal disturbance of mangrove or samphires for inlet canal and pond construction.	Code of Practice.	No destruction of extent or health of mangroves in the Doctor's Creek system.
Commercial farming of crustaceans and molluscs. (Operation)	Ensure crustaceans and fish species proposed to be farmed are native to the King Sound area.	Minimise risk of disease introduction to the region.	All species found are native to the King Sound area.	EPA Bulletin 711. Code of Practice.	Implemented to satisfaction of EPA and Fisheries Dept.
Commercial farming of crustaceans and molluscs. (Operation)	Ensure that disease management, food sources and feeding regime are adequately managed so that there is no adverse impact on the adjacent marine or terrestrial environment.	Risk of introducing diseases through feed and stock.	Strict AQIS regulations control importation of feed. Disease control plan in place in case of disease occurrence.	Australian Quarantine Regulations. Code of Practice.	Compliance with Quarantine regulations. Code of Practice implemented to satisfaction of EPA and Fisheries Dept.

Note "Code of Practice = Draft Code of Practice for Australian Prawn Farmers (Appendices 8.6).

"EPA Bulletin 771" Western Australian Water Quality Guidelines for fresh and Marine Waters (EPA 1993).

6.7 Environmental Impacts & Management Issues.
(continued)

Topic	EPA Objectives	Possible Issue	Proposed Management	Relevant Standards	Standards of Success Achieved
Commercial farming of crustaceans and molluscs. (Operation)	Ensure that crustaceans and mollusc species farmed will not have an adverse impact on the adjacent marine and terrestrial environment.	Minimise risk of disease and escape by farmed species.	Fine mesh screens on control gates and secondary species pond and a long return canal will reduce the likelihood of escapees; also a one way flood gate at the release to East Doctor's Creek with fine mesh over the outflow pipe.	EPA Bulletin 711. Code of Practice.	Monitoring programme implemented to satisfaction of EPA.
Construction of fish farm. (Stage 1 to 4 constructin)	Ensure construction materials are obtained according to statutory requirements and with acceptable environmental impact.	Covers all expected impacts.	Construction of ponds and canals will be from material obtained on site, road gravel will be obtained from licensed quarries.	Code of Practice.	Code of practice implemented to the satisfaction of Fisheries Dept and EPA.
Pest Control. (Operation)	Ensure mosquitoes are appropriately managed.	No new breeding areas will be created.	Water circulation will prevent egg laying and prawns will eat mosquito larvae. Constant monitoring and appropriate control measures will ensure problems do not arise.	Code of Practice.	Mosquitoes controlled to minimise risk to Derby residents and workforce.
Bird Predation. (Operation)	Ensure that birds do not impact on or provide an avenue for disease to enter or be spread within the prawn farm	Injury to birds is not an acceptable control measure.	Deter birds by non injury causing deterrents such as human presence and "scare crow" effects. Pond depths allows prawns to be out of reach of most birds.	Code of Practice.	No significant concentration of birds at farm site.

Note "Code of Practice = Draft Code of Practice for Australian Prawn Farmers (Appendices 8.6).
"EPA Bulletin 771" Western Australian Water Quality Guidelines for fresh and Marine Waters (EPA 1993).

6.7 Environmental Impacts & Management Issues.

(continued)

Topic	EPA Objectives	Possible Issue	Proposed Management	Relevant Standards	Standards of Success Achieved
Flood management (Construction & Operation).	Ensure the effects of storm surge and/or flooding are taken into consideration during the design and construction of the proposed fish farm.	Protect against erosion and subsequent sedimentation of Doctor's Creek system.	Walls will be at least 1.2m above expected tide surges. Pond water will be 1/2m below top of pond.	Code of Practice. Best Practice for industry and region.	No erosion of earthworks.
Pollution issues					
Noise and dust control. (Construction & Operation)	Comply with statutory requirements.	Ensure existing seasonal dust levels are not exceeded. No noise impact expected.	Noise and dust controls in construction phase will comply.	Code of Practice.	Code of Practice implemented to satisfaction of EPA.
Water Quality of Doctor's Creek system. (Operation)	Manage nutrient rich waste water discharge into Doctors Creek to ensure that acceptable water quality within the Creek is maintained.	No significant impact on water quality.	Use of food consumption testing and secondary species ponds to remove nutrients before discharge to Doctors Creek.	EPA Bulletin 711. Code of Practice.	Monitoring programme undertaken to satisfaction of EPA and Fisheries Dept.
Salt water usage. (Operation)	Ensure that the quality of discharge water to East Doctor's Creek meets objectives of Bulletin 711.	Ensure low concentration of suspended solids, nutrients, algae and BOD before discharging water.	Secondary species ponds remove most of nutrients and solids. Monitor inlet, pond, secondary pond and discharge water quality.	EPA Bulletin 711. Code of Practice and Best Practice for industry and the region.	Water Quality monitoring plan implemented to satisfaction of EPA.

Note "Code of Practice = Draft Code of Practice for Australian Prawn Farmers (Appendices 8.6).
"EPA Bulletin 771" Western Australian Water Quality Guidelines for fresh and Marine Waters (EPA 1993).

6.7 Environmental Impacts & Management Issues.

(continued)

Topic	EPA Objectives	Possible Issue	Proposed Management	Relevant Standards	Standards of Success Achieved
Groundwater usage. (Operation)	Protect environmental values and groundwater resource quality.	No significant impact on groundwater quality.	Licensed extraction of ground water from unconfined aquifer only.	EPA Bulletin 711. Water & rivers Commission well licence.	Monitoring programme undertaken to satisfaction of W & R Com and EPA.
Storage of fuels and oils. (Operation)	Prevent spillage and soil contamination.	Significant spillage could impact on groundwater supply and mangrove and samphire communities.	Ensure that oils and fuels are handled in a manner in accordance with the Dangerous Goods Regulations of the Mining Act 1904.	Dangerous Goods Regulations of the Mining Act 1904.	Compliance satisfaction to regulations.
Social surroundings issues					
Land Usage. (Ongoing)	Ensure that proposed farming operations do not have an adverse impact on existing land use in the area.	No significant current usage.	Moved land boundary to avoid impact on reserve, local anglers and the Yabbagoody well area.		Access will be preserved to satisfaction of Shire of Derby / West Kimberley.
Heritage. (Construction)	Protect known and unknown heritage sites from physical disturbance.	No Aboriginal or European heritage sites are known or expected on site.	Monitor for sites during construction. If any found stop work and notify Dept of Aboriginal Affairs.	Aboriginal heritage Act.	Clearance for construction to be obtained under the Aboriginal Heritage Act.

Note "Code of Practice = Draft Code of Practice for Australian Prawn Farmers (Appendices 8.6).

"EPA Bulletin 771" Western Australian Water Quality Guidelines for fresh and Marine Waters (EPA 1993).

7.0 MONITORING & POTENTIAL DISEASE CONTROL

7.1 Environmental Monitoring and Management.

Prawn farms require daily monitoring of temperature, salinity, dissolved oxygen, pH, turbidity, chlorophyll a, phosphate and nitrate for the health of the prawns and their efficient feeding; these records will enable any increase in nutrients in discharge water to be known.

For successful prawn farming the pond water must be 'clean and green'. Prawn larvae are susceptible to degraded water quality. The design of the project includes raising secondary species (brine shrimp, oysters, scallops) in order to remove the nutrients and their induced phytoplankton loads from the egressing pond water before it is returned to the Doctor's Creek system.

Monitoring Details	
Water quality impact	Discharged pond water will contain algae, suspended solids, dissolved nutrients. To remove these from the water before the water is returned to the ocean, biological filtration systems will be employed. Levels of suspended solids, BOD, pH, DO_2, Phosphorus, Nitrogen, Chlorophyll -*a* will be tested before the outflow water is delivered to the biological filtration ponds and again after passing through the ponds before being returned to the East Doctor's creek system. The salinity of the water may be increased at this time but only by a small percentage.

7.1.1 Conclusions.

Although potential environmental impacts include increased nutrients in egressing water these nutrients are expected to be minimal. With ameliorating action, the nutrients derived from

excess food and prawn faeces would not increase the productivity of Doctor's Creek even marginally.

Commitment 10 :
Kimberley Prawn Company will monitor the water quality and physical appearance of East Doctor's Creek and the health of the mangroves to ensure that the discharge water from the prawn farm is having no adverse effects on the mangroves of Doctor's Creek. The monitoring programme will be implemented to satisfy the Fisheries Department and the DEP.

The proposal will have minimal disturbance to the mud flat environment as inlet canals will be sited to avoid removal of mangroves, ponds will be constructed in areas devoid of vegetation, and any ground water used will be at the discretion of the Waters and Rivers Commission and under their licensing controls. Saline water from the ponds cannot reach the groundwater through the clay and will return to the King Sound via existing creeks. The impacts to the environment will be minimal. The area is currently inundated at spring high tides, (in 1996 tidal inundation was monthly) and will continue to receive seawater under the farming regime. Species native to north Western Australia will be used for the project. Employment and increased commerce and employment are expected to benefit the local community.

7.1.2 Commitments.

The Kimberley Prawn Company has a commitment to maintain the environment in as near its present condition as possible both for KPCs own benefit and the benefit of the Derby community. The Company has a commitment to continue to allow community access to fishing areas between the two arms of Doctor's Creek by the provision of a road over the inlet canal constructed to bring sea water to the farm.

The Kimberley Prawn Company will abide by the guidelines set down regarding the Code of Practice for Australian Prawn Farmers currently being reviewed.

During production of prawns in pond culture, the following parameters are measured daily:

temperature, salinity, pH, dissolved oxygen, secchi disk;

The secchi disk readings are indicators of turbidity and/or phytoplankton density whose growth is dependent on nutrients such as nitrate, phosphate, silicate. These parameters are measured at less frequent intervals along with measurements of chlorophyll, nitrite and hydrogen sulphide.

Decisions on increased flow of sea water or dilution with ground water are made as a result of these measurements. Inlet water will be screened by suitable mesh to stop small fish and predator species from entering the intake water at the pumping station. This water will be again screened by fine mesh before being allowed to enter the grow out ponds and again before being allowed to return through the flood gates back to East Doctor's creek.
As there are currently no prawn farms in Western Australia the parameter guidelines are taken from the industry standard in Queensland and the Draft copy of the Code of Practice and best Practice for the prawn industry. It is expected that WA Fisheries Department Officers will oversee the administration of the water monitoring controls.

Commitment 11 :
Kimberley Prawn Farm will prepare a monitoring programme to the satisfaction of the DEP before commencing operation. The purpose of the monitoring programme will be to ensure that the impact on the quality of the East Doctor's Creek water is not compromised and that any adverse effects are detected and rectified quickly. The monitoring programme will set out the water quality criteria, details of monitoring sites, frequency of monitoring and further reviews of monitoring as required in consultation with the DEP and Fisheries department.

7.2 Sampling Checks For Water Quality.

Parameters	Times Tested			Location		
	05:00	15:00	22:00	Occasion	Where tested	Depth
Temperature,°c	O	O	O	daily	sluice gates	Bottom
Oxygen	O	O	O	daily	sluice gates	Bottom
pH	O	O	O	daily	sluice gates	Surface
Salinity, ppt		O		daily	sluice gates	Surface
Turbidity		O		daily	sluice gates	Surface
Water Colour		O		daily	sluice gates	Surface
Ammonia, ppm				weekly		Bottom
Nitrite, ppm				weekly		Bottom
H_2S, ppm				weekly		Bottom
Redox potential, mv				weekly		Bottom
Phytoplankton				weekly		Surface

It will be necessary to take daily measurements at the following:

(1) the inlet canal	salinity, water temperature, DO.
(2) the distribution canal	salinity, pH, DO (dissolved oxygen), water temperature.
(3) grow out ponds	salinity, pH, DO, water temperature, Secchi disk visibility.
(4) in the outflow canals before the water reaches the secondary species ponds	salinity, pH, DO, water temperature.
(5) at the outflow floodgate before return to East Doctor's Creek	salinity, pH, DO, water temperature.

Discharge waters from prawn farms contain total phosphorous of 0.05-0.3 mg/L, total nitrogen of 1-2 mg/L and particulate matter of 10-20 mg/L. In the Derby farm, the suspended material would be deposited in the secondary species pond where the nutrients will be used by the algae which will be eaten by the shellfish.

The following are suggested parameters for assessment of water quality

Parameter	Method of Measurement	Range of Tolerance
Salinity	Refractometer, Hydrometer	10 - 25 ppt
pH	pH Meter, pH paper	6 - 9
Dissolved oxygen (DO)	DO meter, Winkler Titration	> 3.5 ppm
Temperature	DO meter, Thermometer	26 - 32° C
Turbidity	Secchi disc visibility	> 30 cm
Total NH_3-N	NH_3 - Specific Electrode	
	Colorimeter Test using Nesslers	pH 7 - 8
	reagent	< 1.1 ppm
Nitrate -N	Colorimeter test using Sulphanilamide	< 0.1 ppm
H_2S	Colorimeter test using p - Phenylene	pH 6-7
	Diamine Hydrochloride	pH 7-8
	Redox Potential	pH 8-9

The Water and Rivers Commission of Western Australia guidelines for small scale aquaculture projects with discharge water that directly enters a stream or watercourse, express the following

(a) pH range 5-9
(b) suspended solids less than 80 mg/L
(c) BOD 5 day, less than 10 mg/L
(d) produce a salinity increase in the receiving stream of less than 20%
(e) nitrogen as ammonia less than 1 mg/L
(f) nitrogen as nitrate less than 10 mg/L
(g) total phosphorous less than 1 mg/L

(*Water Authority General Guidelines for Acceptability of Aquaculture Projects 1995*)

With the secondary species ponds and the discharge canals, the KPC discharge water will meet these criteria.

Other general discharge standards are contained in the EPA Bulletin 711: 'Western Australian Water Quality Guidelines for Fresh and Marine Waters' (1993). The bulletin gives ranges

within which discharge waters must fall:

Phosphate	5-15 µg/L.
Nitrate-N	10-100 µg/L.
Ammonia-N	<5 µg/L.
Chlorophyll-a	1-10 µg/L.
pH	<0.2 pH unit change.
DO_2	>6 mg/L (>80-90% saturation).
Particulates	<10% change from seasonal mean.

Commitment 12 :
The proponents undertake to maintain the level of phosphate and nitrate in the return water at levels acceptable to the DEP and Fisheries Dept. This will be done on the basis of the monitoring program in 8.1 and 8.2.

7.3 Weekly & Monthly Monitoring Checks.

◊ Readings to be taken at the grow out ponds and secondary species ponds

TSS (Total suspended solids), total nitrogen, total phosphorus, chlorophyll a.

◊ At the floodgate before water is allowed to re-enter the Doctor's creek system

all of the above the tests will be done.

7.4 Disease Contingency Plan.

Commitment 13 :
Kimberley Prawn Company will implement a disease contingency plan to control the possible escape of disease into wild stock should an outbreak of disease occur. The plan will be submitted to the Fisheries Department for assessment.

The main elements of the disease contingency plan are summarised below -

7.4.1. Daily visual checks will be made to inspect activity of prawns for early warning of potential disease problems. Samples will be checked.

7.4.2. Feeding will be monitored daily on "control" trays in the water to check whether too much or not enough is being fed. Overfeeding could cause problems with water control, underfeeding will stress animals which will affect the health of the prawns.

7.4.3. Growth rates, survival rates and feed consumption will be monitored for disease effects.

7.4.4. Movement of equipment between ponds will be controlled and effective methods of sanitation used to control the possibility of disease spreading between ponds.

7.4.5. Should disease enter into a pond a sample of the prawns will be sent to the appropriate laboratories for analysis. The pond will be quarantined and the ponds nearby closely scrutinised to ensure that the disease doesn't spread throughout the pond systems.

7.4.6. If a disease is found, the prawns will be immediately harvested by netting (not by draining the pond) and the pond chlorinated at 100 ppm to prevent spread of the disease.

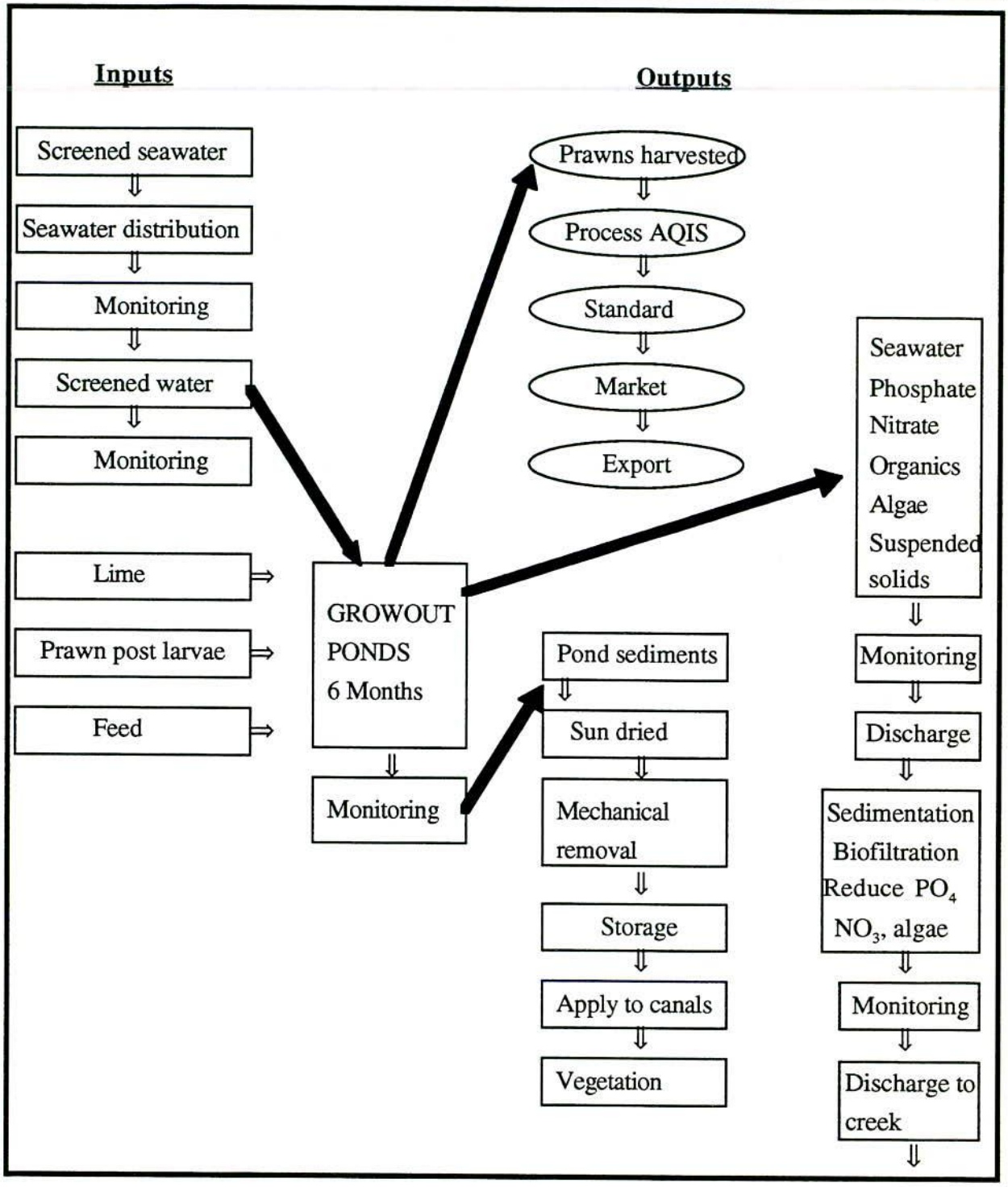
7.4.7. If the disease were reportable or highly infectious then the pond including prawns would be treated with chlorine. This would include viral diseases.

7.4.8. Water containing chlorine would affect the animals in the secondary species ponds so the water would be held in the ponds until the chlorine had dissipated. After the pond is drained the dead prawns would be removed and placed in a pit away from the ponds and burned and then buried. The solid sediments will be used as land fill in a area where the sediments cannot re-enter the mudflat drainage system.

7.4.9. Detailed records of monitoring methods will be kept for ongoing assessment of disease risk to improve the health and sanitation of the prawn farm.

Commitment 14:
The Kimberley Prawn Company will comply with all the requirements of the draft Environmental Code of Practice for Prawn Farmers.

Process Flow Diagram



7.5 Summary of Environmental Impacts & Associated Management Controls & Commitments.

This CER has assessed the environmental impacts of the Kimberley Prawn Company proposal. From the assessment it can be seen that the project is not expected to have any significant adverse effects on the land, mangroves, water table or waters of the Doctor's Creek system. All of the potential impacts have been identified as either minor or easily controlled.

The proponents have made a number of significant commitments designed to ensure that the proposal complies with the relevant guidelines and regulations. These commitments are summarised below ;

Commitment 1 : *Refer to page 11*

Public access to the area between the two arms of Doctor's Creek will be maintained by a permanent raised crossing over the inlet canal.

Commitment 2 : *Refer to page 24*

In accord with the Code of Practice and Best Practices for Prawn Farms the Kimberley Prawn Company is dedicated to ensure that protection against erosion, storm surge, cyclonic flooding and dust and noise protection are incorporated into all stages of the project. Management measures to be taken include -

- All earthen constructions will be designed to minimise erosion and run off and stabilisation will be incorporated into design plans.
- All internal drainage will be directed into the settling ponds to protect the health of the mangrove zone.
- Drainage from the workshop will be routed through oil interceptors.
- Oils and fuels will be stored in such a manner as to preclude accidental spillage effecting the groundwater table.
- Drainage from the processing shed will be placed into a settling pond.
- All buildings will be constructed to region C, terrain category 2,

wind speed 57 m/s cyclone certification
(Derby/West Kimberley Shire regulations).

- The processing works will need to comply with AQIS export standards.

Commitment 3 : ***Refer to page 25***

All imported prawn feed will be held under strict import and quarantine arrangements under AQIS quarantine regulations

Commitment 4 : ***Refer to page 25***

Kimberley Prawn Company are committed to ensure that quality of both the stock and the environment are sustained. The prawns will be acquired from hatcheries with quality assured product.

Commitment 5 : ***Refer to page 26***

Kimberley Prawn Company will ensure that clearance is obtained under the *future act* clause in the *Aboriginal Heritage Act.*.

Commitment 6 : ***Refer to page 40***

No mangrove or samphire will be cleared during the construction phase. Photographic monitoring will be used before and after construction to satisfy the DEP.

Commitment 7 : ***Refer to page 40***

Rehabilitation will be carried out to the satisfaction of the DEP and monitored annually to ensure that the vegetation approaches pre-construction amounts.

Commitment 8 : ***Refer to page 41***

If in the future it is found that it is necessary to rehabilitate part of the operation, the decommissioned area will be rehabilitated to pre-construction conditions, in accordance with Best Practices for the Prawn industry and the West Kimberley region and the DEP.

Commitment 9 : ***Refer to page 46***

Kimberley Prawn Company will commission a heritage survey over the lease area and in compliance with the *Aboriginal Heritage Act of Western Australia,* will cease construction work in the immediate area until

cleared by the Department of Aboriginal Affairs if any aboriginal artefacts or burial sites are discovered or inadvertently disturbed.

Commitment 10 : *Refer to page 53*

Kimberley Prawn Company will monitor the water quality and physical appearance of East Doctor's Creek and the health of the mangroves to ensure that the discharge water from the prawn farm is having no adverse effects on the mangroves of Doctor's Creek. The monitoring programme will be implemented to satisfy the Fisheries Department and the DEP.

Commitment 11 : *Refer to page 54*

Kimberley Prawn Farm will prepare a monitoring programme to the satisfaction of the DEP before commencing operation. The purpose of the monitoring programme will be to ensure that the impact on the quality of the East Doctor's Creek water is not compromised and that any adverse effects are detected and rectified quickly. The monitoring programme will set out the water quality criteria, details of monitoring sites, frequency of monitoring and further reviews of monitoring as required in consultation with the DEP and Fisheries Department.

Commitment 12 : *Refer to page 57*

The proponents undertake to maintain the level of phosphate and nitrate in the return water at levels acceptable to the DEP and Fisheries Dept. This will be done on the basis of the monitoring program in 8.1 and 8.2.

Commitment 13 : *Refer to page 58*

Kimberley Prawn Company will implement a disease contingency plan to control the possible escape of disease into wild stock should an outbreak of disease occur. The plan will be submitted to the Fisheries Department for assessment.

Commitment 14: *Refer to page 59*

The Kimberley Prawn Company will comply with all the requirements of the draft Environmental Code of Practice for Prawn Farmers.

8.0 APPENDICES

8.1 References.

Battaglene, T. and Kingston, A. 1990. Poor outlook for prawns as Japanese market downturn persists. *Australian Fisheries* , **49**(4).

Charoen Pokphand Feedmill Co. Shrimp culture Training Manual

Hardman, J. R. P., Treadwell, R. and Maguire, G. 1990. Economics of Prawn Farming in Australia. Int. Crustacean Conf. Brisbane, 2-6 July 1990.64

Johnstone R. E. 1990. Mangroves and mangrove birds of Western Australia. *Rec. West. Aust. Mus.* Supplement **32**: 1-120.

Jones A. B. and Preston N. 1996. Biofiltration of shrimp pond effluent by oysters. Proc. World Aquaculture Society meeting Bangkok, 1996.

Semenuik, V. 1980a. Mangrove zonation along an eroding coastline in King Sound, North-Western Australia. *J. Ecol.* **68**, 789-812.

Semenuik, V. 1980b. Quaternary stratigraphy of the tidal flats, King Sound, Western Australia. *J. Roy. Soc. WA.* **63**, 65-78.

Water Authority of Western Australia. 1992 Derby groundwater management plan.

Water Authority of Western Australia. 1993 Derby groundwater management.

Ziemann, D. A., Walsh, W. A., Saphore, E. G. and Fulton-Bennett, K. 1992. A Survey of water quality characteristics of effluent from Hawaiian aquaculture facilities. *J. World Aqua. Soc.* **23** (3), 180-191.

8.2 Glossary of Technical Terms.

amplitude	size of tide, difference between low and high tides, distance from mean tides
aquifer	confined stratum of rock or gravel which contains water in quantity
detrital	eroded and decomposing matter usually vegetation
mangal	mangrove dominated forest
phytoplankton	floating microscopic plants
Pindan	red sand peculiar to the Kimberley
samphire	assemblage of heath-like plants above the high tide
secchi disk	a 20 cm diameter disk either white or black and white used to measure light penetration in water and hence estimate turbidity

AQIS	Australian Quarantine Inspection Service
DEP	Department of Environment
DOLA	Department of Land Administration
CALM	Conservation and Land Management
ACWA	Aquaculture Council of Western Australia
IDCA	Interdepartmental Committee on Aquaculture
WRC	Water and Rivers Commission
KDC	Kimberley Development Commission
MRWA	Main Roads of Western Australia

8.3 Public Involvement and Consultation.

October 5-8, 1994	Discussions with Queensland prawn growers and site inspections.
October 8, 1994	Meeting with Shire Clerk Phillip Andrew and Shire President Peter McCumstie regarding possible use of a site near the Derby airport for the prawn farm.
December 16, 1994	Discussions with Wolf Martinick, Caroline de Mori and Ross Calnan from Western Metals regarding use of Derby wharf and synergy of transport.
January 12, 1995	Prawn farm Aquaculture Application to interdepartmental Committee on Aquaculture (IDCA).
January 12, 1995	Copy of Aquaculture Application given to Shire President Derby-West Kimberley Shire for comment.
January 15, 1995	Meeting with Harry Lennard, Alphonse Buck, Frank Benning at Winun Ngari Aboriginal Resources, detailing area of land being applied for.
February 24, 1995	Aquaculture presented to the IDCA.
February 25, 1995	Public meeting with Hamlet Grove residents; they requested access be retained for fishing in Doctor's Creek and that fences not be erected. Those present : Malcolm Albright, Kimberley Land Council; Tony Plant, builder; Leila Plant, domestic worker; Brian Martin, builder; Carol Martin, Kimberley Land Council; Les Plietner, Shire clerical assistant; Cindy Plietner, egg farmer; Mick O'Keefe, plant operator; Sue O'Keefe, domestic worker; Ian Heseltine, plant operator.
March 20, 1995	Discussion with Fisheries Department regarding area requested in Aquaculture Application.
April 7, 1995	Received fax copy of IDCA responses to Application
May 5, 1995	Mr Carl Drysdale presents arguments against the Project in the Boab Babbler (local newspaper in Derby)
May 12, 1995	Details requested by IDCA sent , Water Authority gives qualified support to Project
May 23, 1995	"Phone contact with Alex Cechner of Fisheries re Project.
May 29, 1995	Meeting with Charles Thorn of Fisheries Dept. in Perth to explain proposal in detail. 'Phone conversation with Gabby Corbett from Department of the Environment (DEP); she had not looked at the proposal at that stage.
May 30, 1995	Letter from Shire regarding reduction in area of land requested and giving support to the Project.

August 9, 1995	'Phone conversations with Alex Cechner of Fisheries, Simon Hancocks of Conservation and Land Management (CALM) regarding the reduced area being requested. 'Phone conversation with Cliff Uren of Department of Land Administration (DOLA) re application and new legislation.
August 18, 1995	DOLA advise they cannot advertise application until new legislation is passed.
September 4, 1995	Visit to Derby by Cliff Uren of DOLA, historical research being undertaken but this was not enough to form an agreement with traditional owners, advised that GPS sitings sufficient if there are no fences.
September 11, 1995	DEP advertise a consultative review in the West Australian newspaper, incorrect site advertised.
September 18, 1995	Corrected area of application advertised in the West Australian.
September 21, 1995	Resident Bob Griffiths visited to request explanation for reason for siting the prawn farm on the mud flats.
September 25, 1995	Because of conflict with fishermen, a modified requested lease area map was sent to IDCA, DEP and Shire; Shire tabled the new area at their next meeting and resolved to support the modified proposal.
October 28, 1995	Met with Eve Bunbury of DEP at an aquaculture seminar in Broome, draft of CER requirements supplied by her.
October 30, 1995	Derby site visit by Colin Ostle Fisheries Dept., Simon Bennison of Aquaculture Council of Western Australia (ACWA), and Eve Bunbury (DEP).
November 9, 1995	DEP's CER requirements received.
January 1996	Proposal flagged in the Aquaculture Council of WA News magazine, no.12, p7.
March 7, 1996	Meeting with Environmental Assessment Committee in Perth to discuss the Proposal.

8.4 Correspondence.

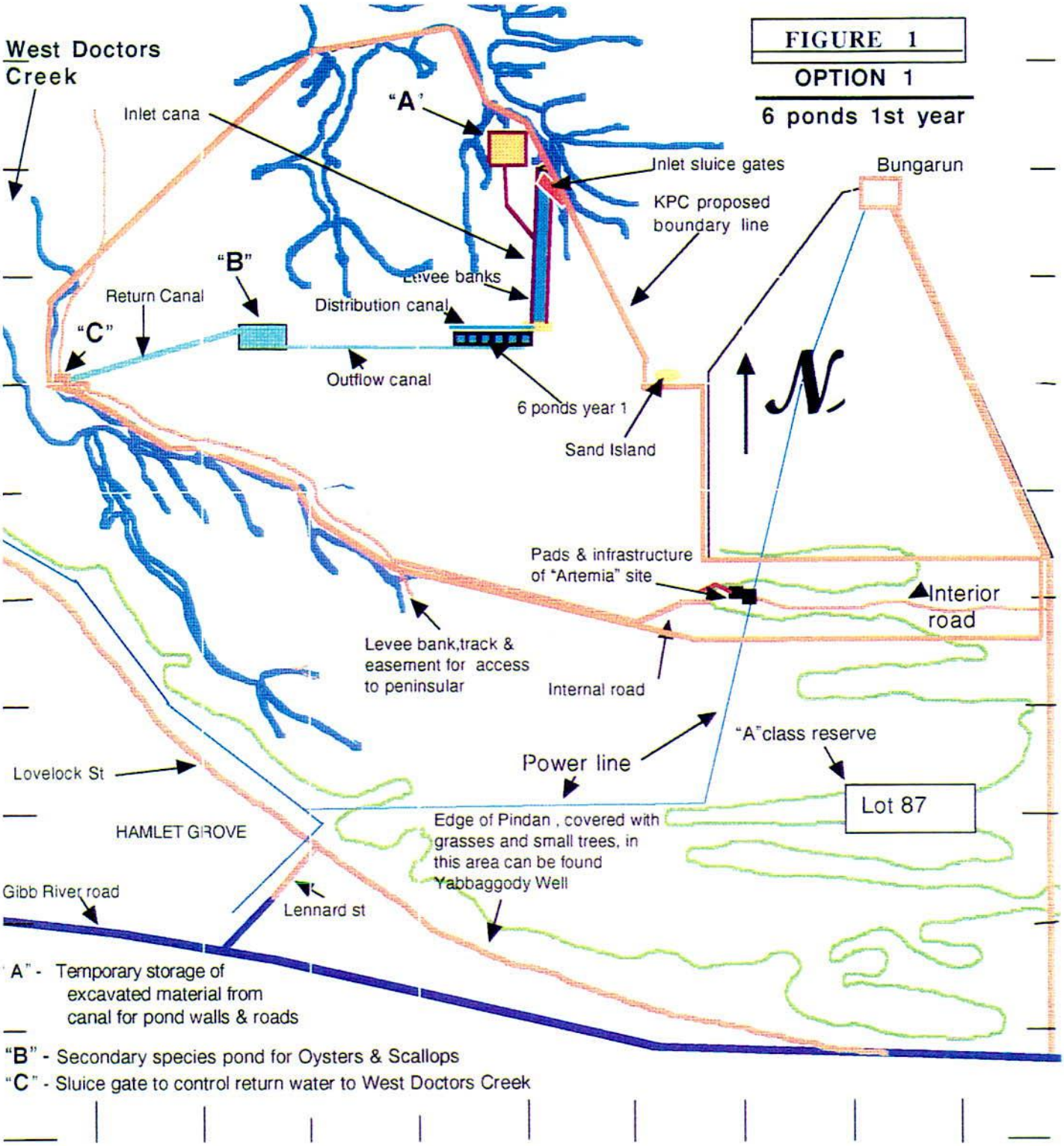
August 23, 1994	L. Jones Kimberley Development Commission, documentation for IDCA and support for Project.
January 20, 1995	John Panizza, Senator, support and advice to deal with the relevant government authorities in WA.
January 24, 1995	Phil Lockyer Member for Mining and Pastoral Region, support wishes to visit.

January 27, 1995	Norman Moore Member for Mining and Pastoral Region, support and wishes to be informed of progress.
March 6, 1995	Kevin Prince Minister for Aboriginal Affairs, support and advises observation of the requirements of the Aboriginal Heritage Act 1972-1980 to ensure that the development does not affect any sites of cultural and heritage significance.
May 5, 1995	Hendy Cowan Deputy Premier, support and request to work through Kimberley Development Commission.
June 21, 1995	Shire of Derby-West Kimberley considered the reduced area and resolved to continue support.
June 27, 1995	H. G. MacLachlan, no objections to the use of the mud flat and support for the Project.
June 27, 1995	Derby Chamber of Commerce, support
July 17, 1995	Western Australian Water Authority (WAWA, but now Water and Rivers Commission-WRC) no objection to proposal and deemed to have no polluting effects on water resources, need for bore licences.
August 4, 1995	Kimberley Land Council advising Ben Wurm handling Project, currently assessing Native Title implications.

8.5 List Of Figures.

Figure 16 Aerial photograph looking north-east showing proposed ponds in the foreground, and the inlet canal reaching to the east Doctor's Creek.

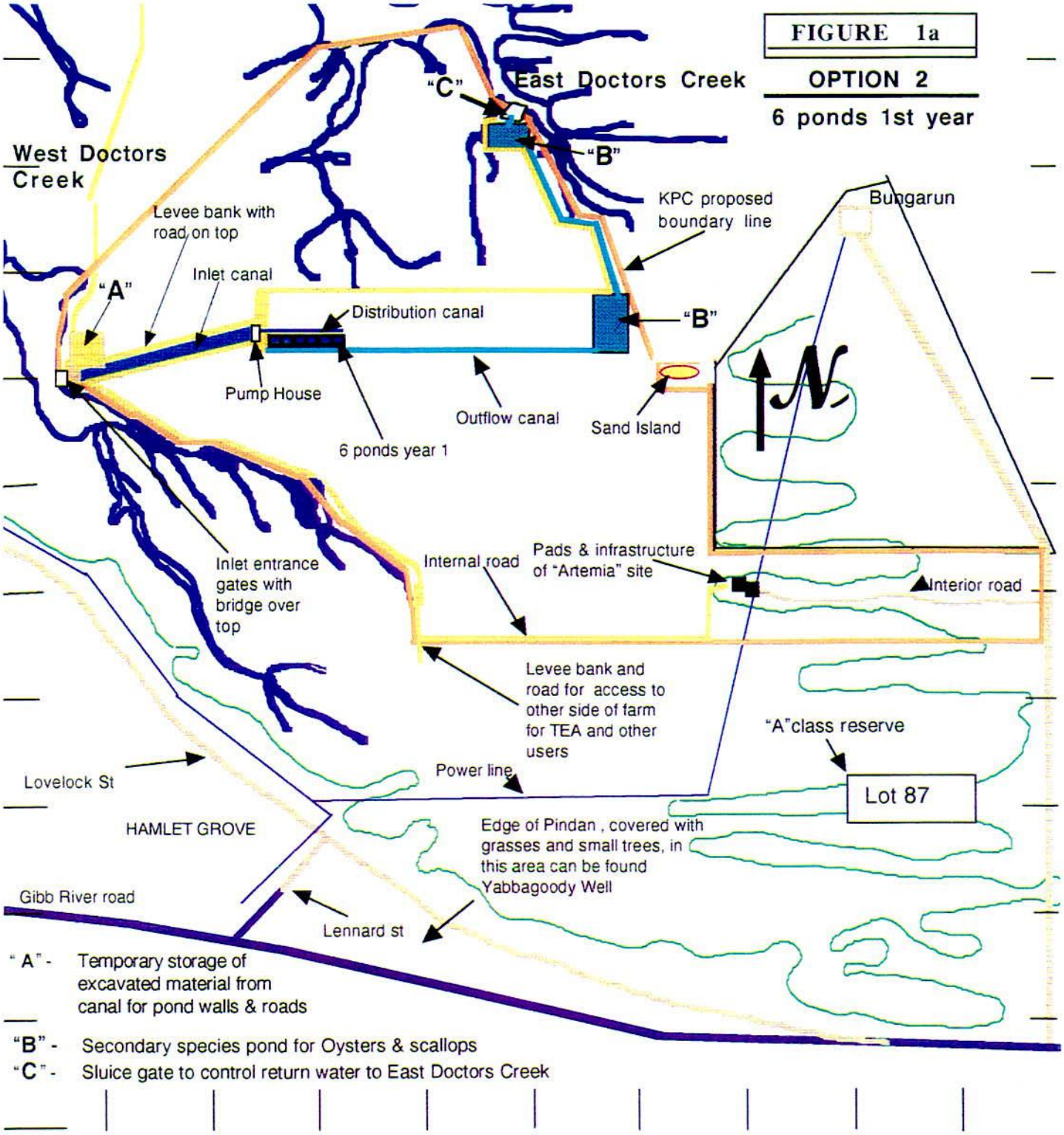
Figure 17 Photo showing Mangal and samphire species and limit of inland spread. Inlet canal would be outside this line (approx where vehicle stands).



Kimberley Prawn Company proposal

FIGURE 1 has been copied from the Australian Topographic Survey map - Derby: Scale 1:100 000 : Series R611 : Sheet 3663
The copying of the map and the details enclosed are fairly accurate. The total area of land now involved is approx 2300 ha. The only entrance would be from theBungarun road.

Diagram showing West and East Doctor's Creek, inlet canal, distribution canal, ponds, roads, secondary species pond and outflow canal. The water is taken from the East Doctor's Creek and is returned via West Doctor's Creek.



Kimberley Prawn Company project proposal

FIGURE 1a has been copied from the Australian Topographic Survey map - Derby: Scale 1:100 000 : Series R611: Sheet 3663
The copying of the map and the details enclosed are fairly accurate. The total area of land involved is approx 2300 ha. The only entrance would be from the Bungarun road.

Diagram showing West and East Doctor's Creek, inlet canal,distribution canal, ponds, roads, secondary species pond and outflow canal. The water is taken from the West Doctor's Creek and is returned via East Doctor's Creek.

Figure 2 Aerial photograph of inlet canal, road and pump station looking south-east.

Figure 3 Aerial photograph with secondary species pond and return canal to West Doctors Creek looking north–east.

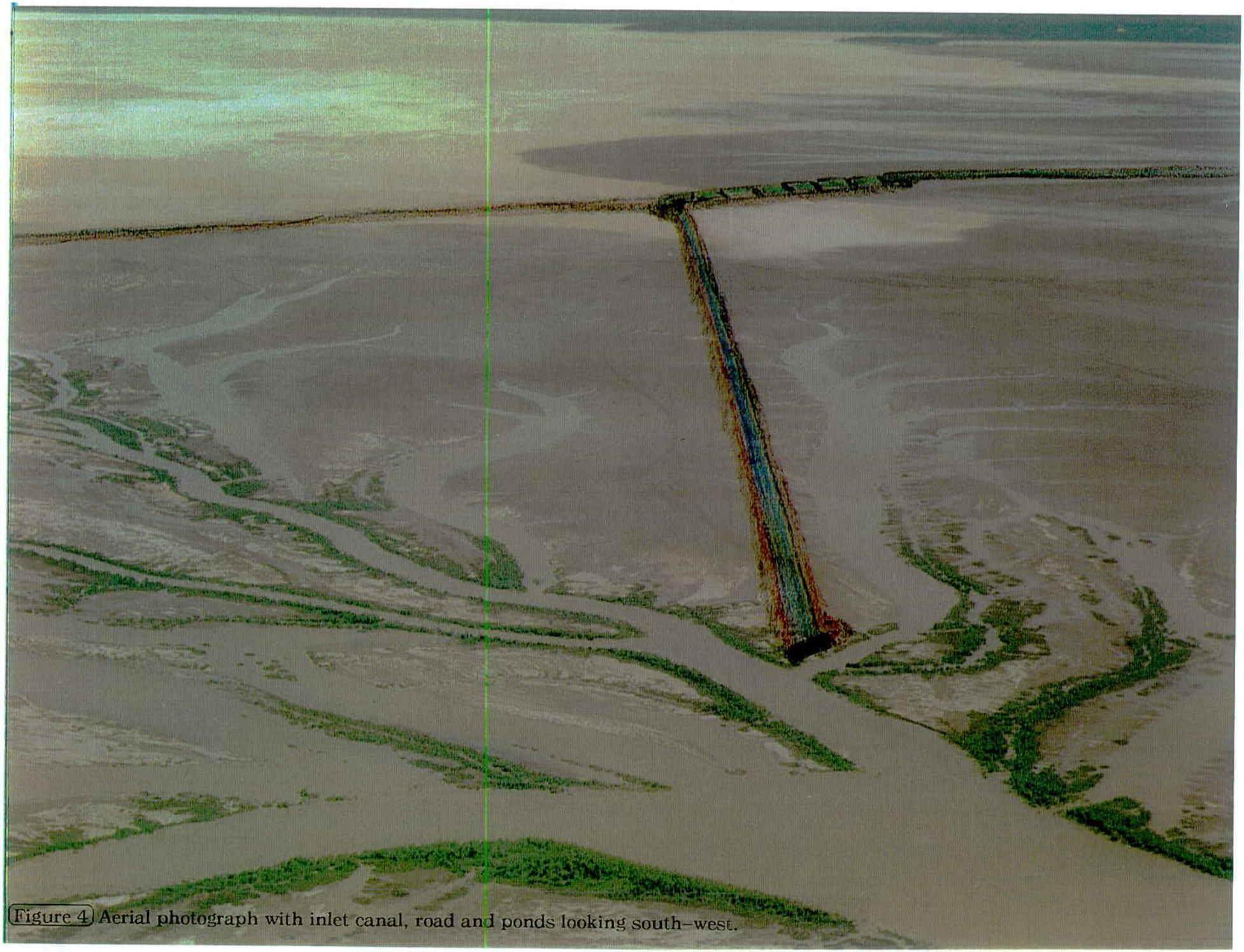


Figure 4 Aerial photograph with inlet canal, road and ponds looking south–west.

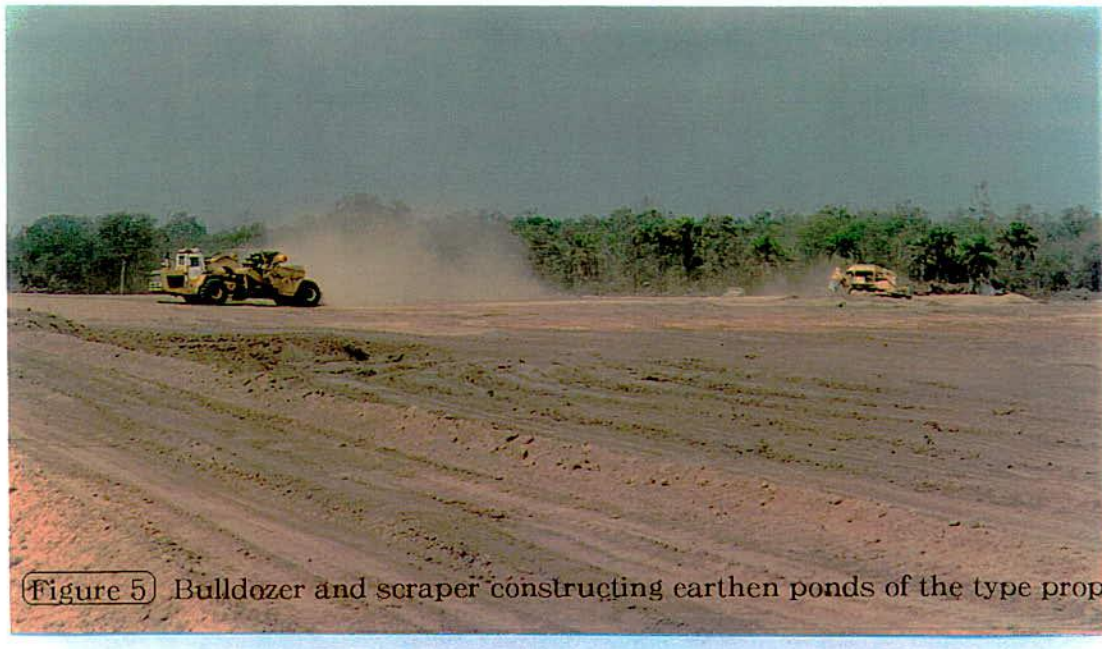


Figure 5 Bulldozer and scraper constructing earthen ponds of the type proposed.

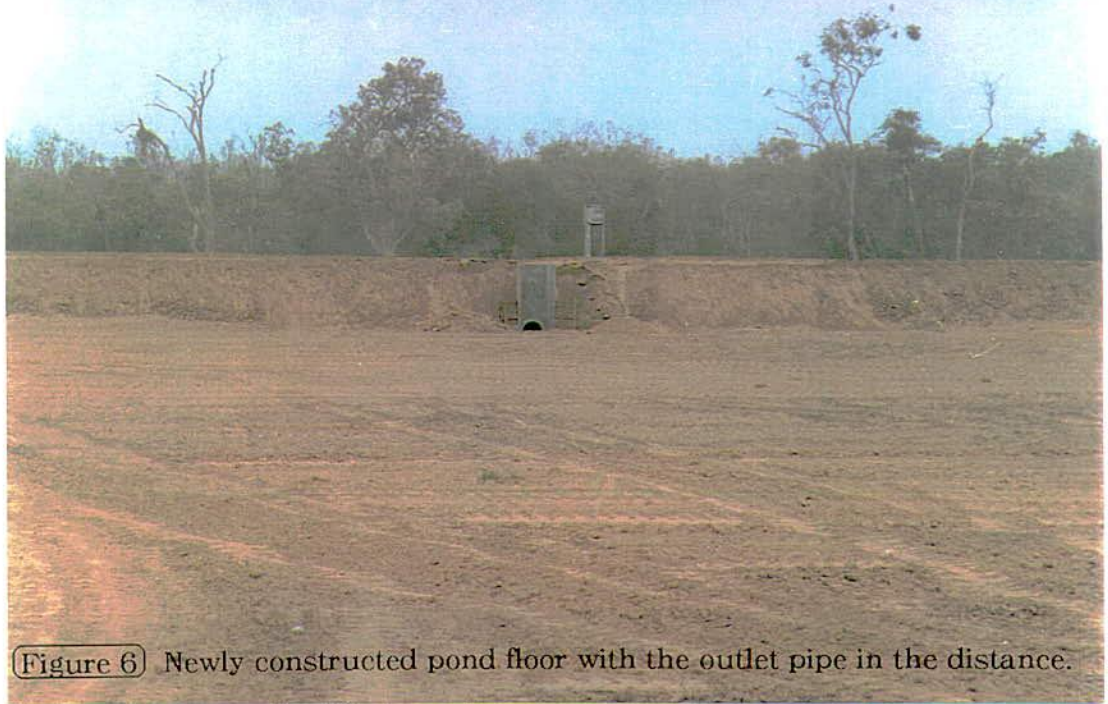


Figure 6 Newly constructed pond floor with the outlet pipe in the distance.

Figure 7 Inlet canal in centre, road to left and pond to right similar to proposed construction.

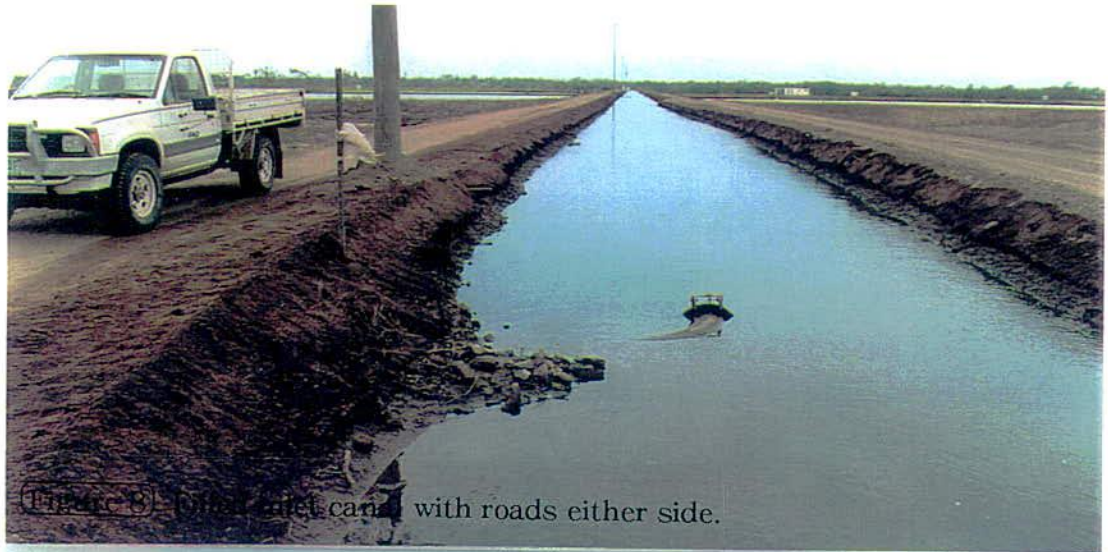


Figure 8) Main inlet canal with roads either side.

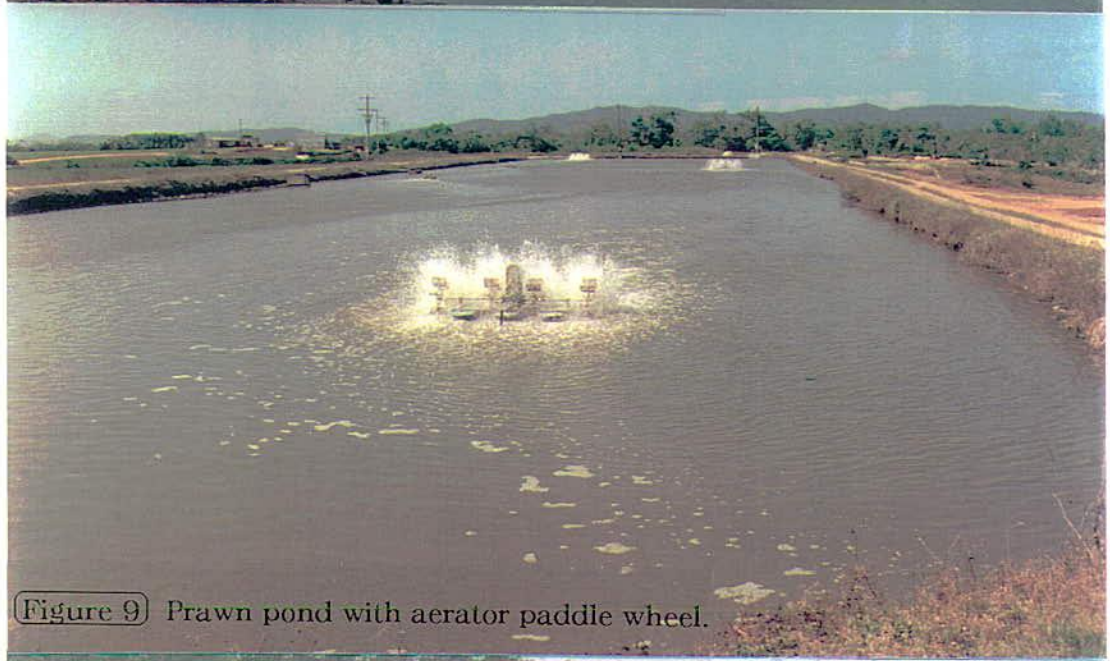


Figure 9) Prawn pond with aerator paddle wheel.

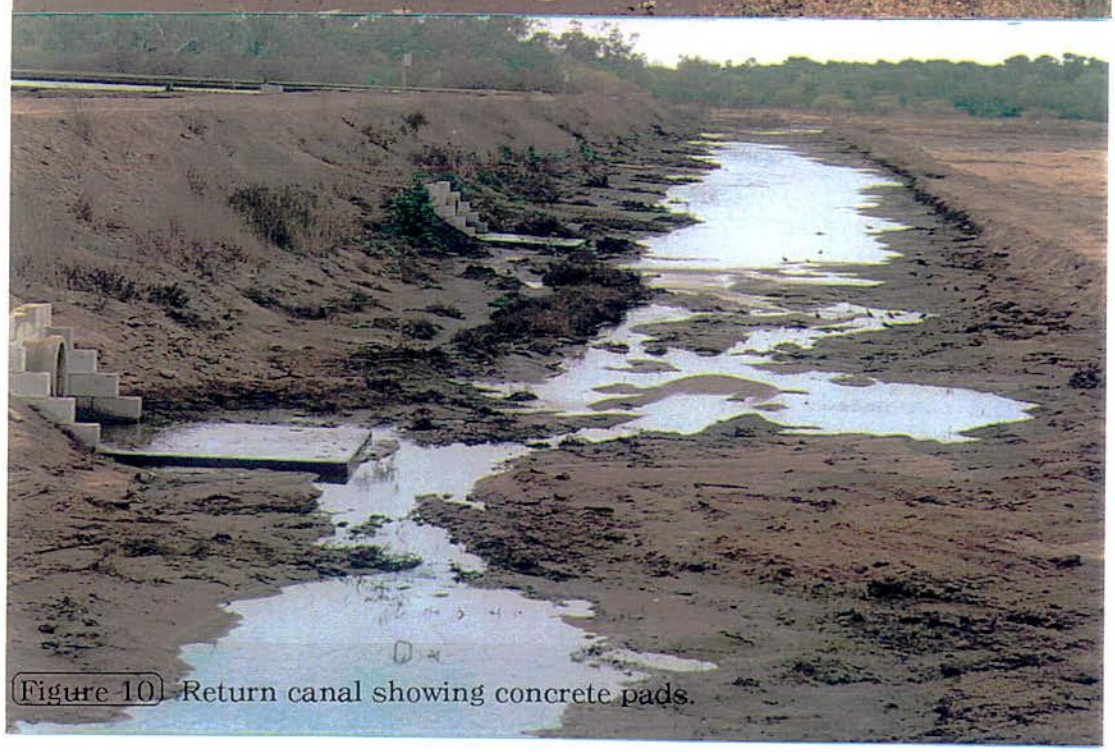


Figure 10) Return canal showing concrete pads.

Figure 11 An inlet canal on a longer established farm with vegetation growing on the earth walls

Figure 12 A typical prawn farm pump house.

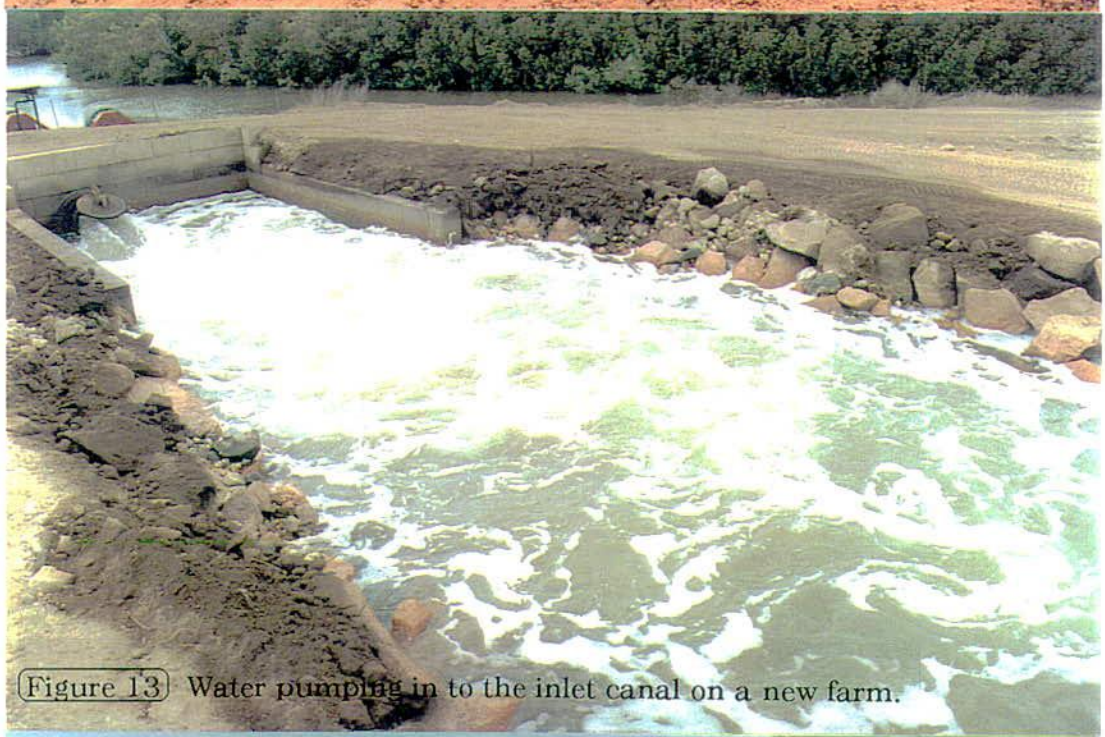


Figure 13 Water pumping in to the inlet canal on a new farm.

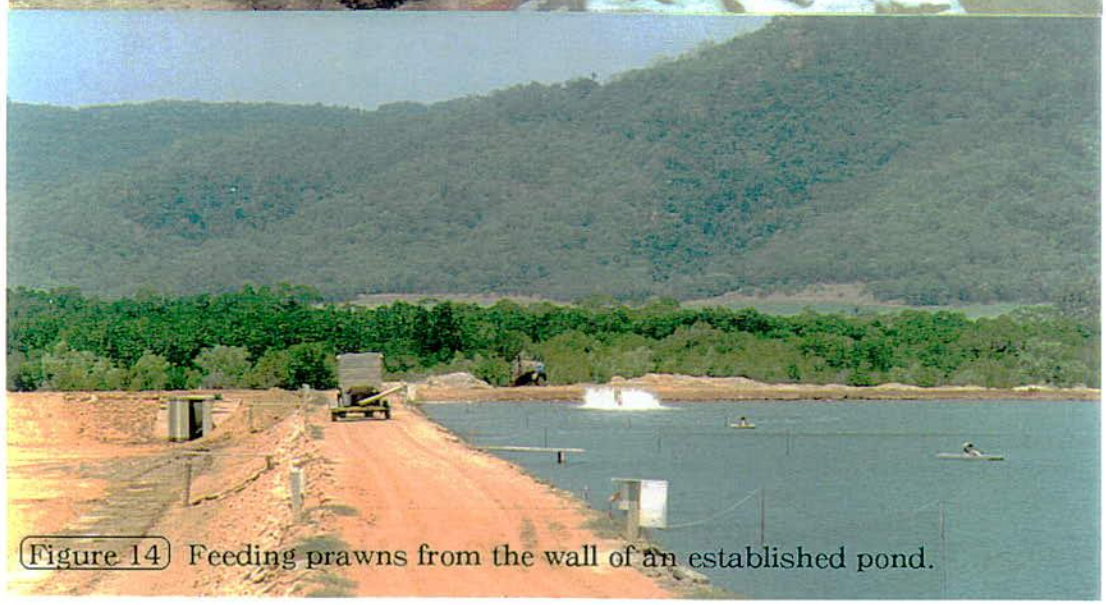


Figure 14 Feeding prawns from the wall of an established pond.

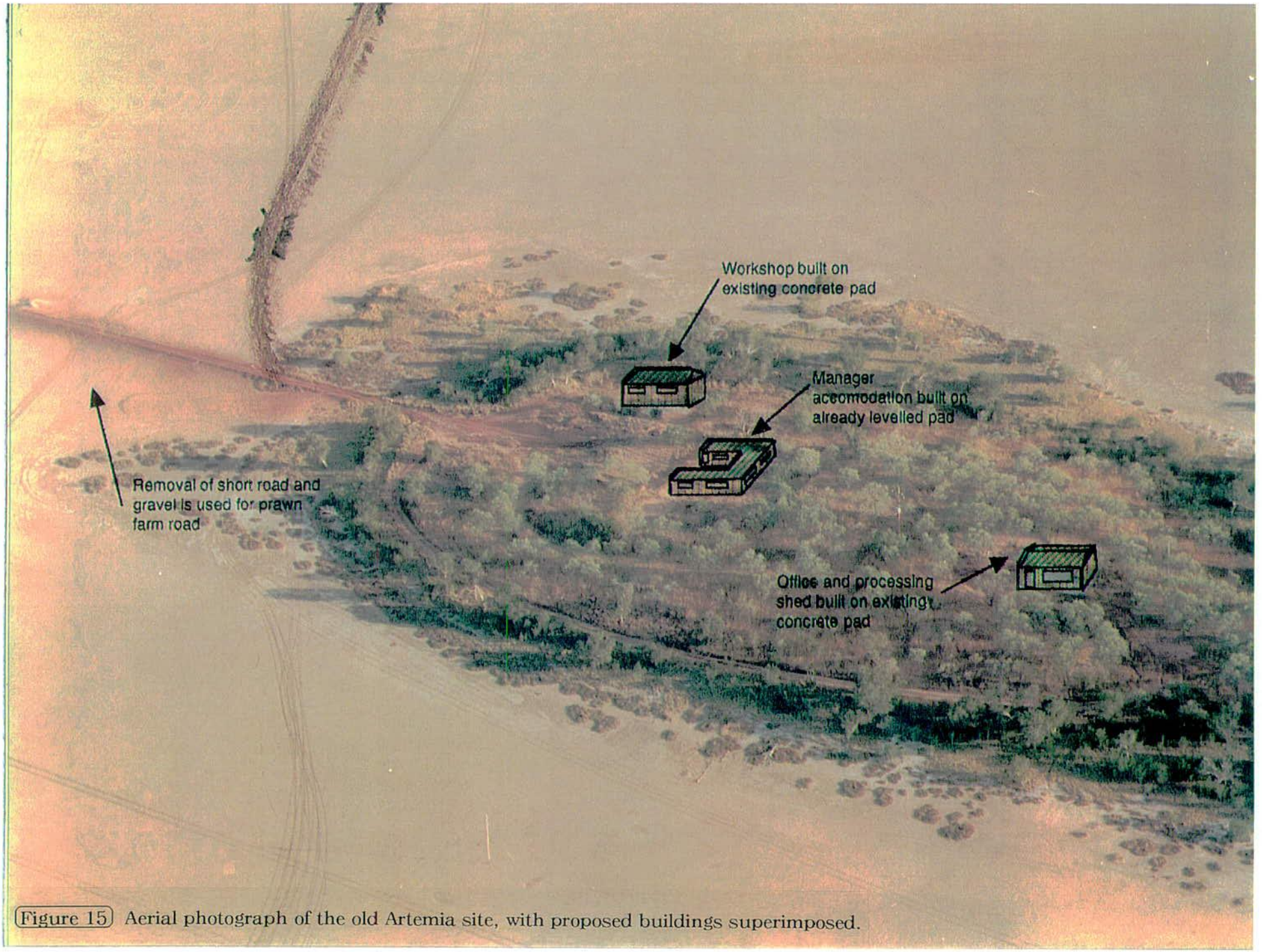


Figure 15 Aerial photograph of the old Artemia site, with proposed buildings superimposed.

Figure16 Aerial photograph looking north-east showing proposed ponds

Figure 17 Photo showing Mangal and samphire species and limit of inland spread.

Inlet canal would be outside this line [approx where vehicle stands].

Draft Environmental Code of Practice for Australian Prawn Farmers

October 1996

If you would like to comment on this Environmental code of Practice for Australian Prawn Farmers or provide relevant environmental information to the Australian Prawn Farming industry please contact:

Mr Dallas J Donovan
Managing Director
Kuruma Australia Pty Ltd
67 Ashfield Street
East Brisbane QLD 4169

phone (07) 3393 1162
fax (07) 3393 1583
mobile 019 610 277

Table of Contents

Introduction

The potential for environmental impacts to result from prawn farming has received increased attention internationally over recent years. The Australian prawn farming industry through their national body, the Australian Prawn Farmers Association, has formulated this Code of Practice in recognition of the industry's need to become recognised as an environmentally sustainable industry.

Specifically the document aims to:

- Provide realistic objectives;
- Be flexible;
- Be relevant to Australian prawn farmers;
- Provide a mechanism for environmental self regulation;
- Be practical;
- Focus on outcomes;
- Provide options for management;
- Fall within the legal requirements of Queensland's Environmental Protection Act 1994.

It is the objective of the Australian Prawn Farmers Association to pursue Ministerial approval for this Code of Practice in Queensland and similar recognition in the Northern Territory and New South Wales. Resulting in a reduction in the level of external regulation on the industry.

Need for a Code of Practice

Compliance with this *Environmental Code of Practice for Australian Prawn Farmers* will ensure that all Australian prawn farms minimise the potential environmental impacts of Australian prawn farming both now and in the future.

The Code of Practice has been prepared to address the potential environmental impacts associated with prawn farming in Australia and to provide suitable Best Practice Environmental Management for members of the Australian prawn farming industry.

It is outside of the scope of this Draft Code of Practice, to address in detail all the techniques used by the Australian prawn farming industry in producing prawns. This document has focused on issues of environmental significance.

The only sound approach to the development of the Australian prawn farming industry is through maintaining the integrity of the environment so as to enable the industry to be sustainable. In general, Australian prawn farms are sparsely located, with few regions containing a proliferation of prawn farming activities. This low concentration of development and current disease free status, places the Australian prawn farming industry in a position to implement an environmentally responsible approach to both future developments and existing operations.

It is believed that through this Code of Practice the Australian prawn farming industry will be able to make substantial progress toward both the economic and environmental sustainability of the industry, while ensuring that prawn farmers meet their General Environmental Duty of Care.

The Environmental Protection Act 1994 allows the Minister for the Environment to approve this Code of Practice, which states ways for prawn farmers to achieve compliance with the General

Environmental Duty of Care and so be within the law for activities that may cause or are likely to cause environmental harm. An approved Code of Practice is not a regulation under the Environmental Protection Act 1994 however it does have legal standing.

By following this *Environmental Code of Practice for Australian Prawn Farmers*, prawn farmers will be able to show "due diligence" and meet the legal requirements of the General Environmental Duty of Care. No penalties can be directly imposed on a prawn farmer for failing to follow advice in a Code of Practice approved by the Minister.

At present prawn farm wastes are managed through "end of pipe" regulations. This Code of Practice attempts to move members of the Australian prawn farming industry toward ecologically sustainable production by recommending management practices that minimise contaminant levels in discharge waters and subsequently improve profitability. The final result of improvements in management techniques is to replace "end of pipe" regulation with sustainable management practices.

This *Environmental Code of Practice for Australian Prawn Farmers* does not remove the legal requirements that prawn farmers have under their current Environmental Authority and associated conditions.

Ecologically Sustainable Development

The concept of Ecologically Sustainable Development has evolved from the World Commission on Environment and Development's report, *Our Common Future* (1987). It can be generally defined as conserving and enhancing the community's resources such that, our total quality of life, both now and in the future, is secured.

The *Environmental Code of Practice for Australian Prawn Farmers* has adopted the principles of Ecologically Sustainable Development and the Precautionary Principle.

Consistent with the three operational interpretations of the Precautionary Principle, it is suggested (Young 1993), that as confidence with an activity increases, a transition should be made to require only the use of best available technology when this does not entail excessive cost.

The management practices set out in this Code of Practice provide a responsible approach to environmental management while ensuring that prawn farms will continue to be economically sustainable.

Specifically the *Environmental Code of Practice for Australian Prawn Farmers* endorses the following objective:

To protect Australia's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.

Expected Environmental Outcomes

Outcomes

Prawn farmers should achieve the following in order to comply with their legal responsibilities to protect the environment. Compliance may be demonstrated if these Expected Environmental Outcomes can be shown to have been met.

1. All reasonable and practical measures must be adopted to minimise the clearing of native vegetation and associated fauna habitats;
2. All reasonable and practical measures must be adopted to ensure that a prawn farm operation does not lead to unacceptable direct or indirect impacts to mangrove and other aquatic ecosystems.
3. All reasonable and practical measures must be adopted to ensure that a prawn farm operation minimises the discharge of nutrients into the receiving environment, the discharge of prawn farm effluent must not result in an unacceptable increase in nutrients outside the initial mixing zone;
4. All reasonable and practical measures must be adopted to ensure that a prawn farm operation minimises the discharge of phytoplankton into the receiving environment, the discharge of prawn farm effluent must not result in an unacceptable increase in phytoplankton levels outside the initial mixing zone;
5. All reasonable and practical measures must be adopted to ensure that a prawn farm operation minimises the discharge of suspended solids into the receiving environment, the discharge of prawn farm effluent must not result in an unacceptable increase in suspended solids outside the initial mixing zone;
6. All reasonable and practical measures must be adopted to ensure that a prawn farm operation does not lead to significant deterioration in groundwater quality, through unacceptable increases in groundwater salinity;
7. All reasonable and practical measures must be adopted to minimise impacts on noise levels at noise sensitive locations at sensitive times;

The Expected Environmental Outcomes will be achieved if producers adopt the appropriate management practices outlined in this Code of Practice.

Performance Indicators

Performance indicators are necessary to measure the level of change in a variable and relate the measurement to a level of change that may be considered a significant environmental impact.

It is not possible to recommend a uniform set of performance indicators for the entire industry due to the high variability in receiving environments. ANZECC (1992) advises that individual acceptable water quality parameters for receiving waters must be determined on a site specific basis. The measurable parameters for all environmental values should be determined in a holistic manner and must take into account the varying natural community structures within different receiving environments.

The final site specific performance indicators should be determined by Administering Authorities in consultation with prawn farm operators using:

- Natural background levels;
- Environmental values of the receiving environment;
- Assimilative capacity of the receiving environment.

Industry Commitment and Environmental Policy

Management of the Australian prawn farming industry recognises that protection of the environment is a requirement of all businesses to ensure long term benefit to all stakeholders. The Australian prawn farming industry is committed to the development and operation of an environmentally sustainable prawn farming industry.

This Code of Practice supports a commitment to environmental management, which recognises that only the financial success of the operation can ensure the provision of adequate resources to manage environmental issues. It recognises that to maintain such a commitment will require Australian prawn farmers to carry the burden of some cost.

Participants in the Australian prawn farming industry are encouraged to:

- support industry research into environmental issues;
- achieve and where practical, go beyond compliance with all legislation and license conditions;
- ensure that its products are produced, packaged, delivered, disposed of and recycled in an environmentally responsible manner;
- minimise its use of raw materials and energy;
- design their production systems to minimise adverse environmental impacts;
- take into consideration environmental impacts of new projects at the planning stage;
- provide management and employees with appropriate levels of environmental training and education;
- require employees to accept environmental responsibilities as a part of their job description;
- conduct environmental reviews at appropriate intervals.

Compliance with this Code of Practice is not only likely to reduce the potential environmental impacts of prawn farming, it is likely to improve the profitability of existing and new farms through reduced operating costs.

Industry Description

Prawn farming in Australia involves the saltwater culture of Penaeid prawns in artificial environments. In general this involves the intensive culture of prawns in earthen ponds. Farmers manage the pond environment for maximum survival and growth rates, through a balance of aeration, feed and water quality management. As a result of water quality management there is a need for farmers to discharge prawn pond effluent into the surrounding environment.

Queensland farmed prawn production has increased from 233 tonnes in 1988/89 to 1450 tonnes in 1994/95, with a farm gate value of approximately $30 million. This increase is based on an increase in farm numbers and increased productivity from existing farms.

Currently the majority of this product is *Penaeus monodon* and is targeted at the domestic market. Approximately 160 tonnes of *Penaeus japonicus* was exported to Japanese markets in 1995 (Kitada, 1996).

Australian producers are beginning to target their product at the world farmed prawn market as the traditional producers (such as South-East Asia) decrease production due to poor resource management strategies and the associated environmental degradation.

Australia has the ideal opportunity through this Code of Practice, coupled with quality operational and resource management strategies, to maintain the high quality of the existing environment.

Potential Environmental Impacts

Recent observations by Boyd (1996) have indicated that Australian prawn farmers are amongst the most environmentally sustainable in the world. Accurate levels of environmental impacts related to prawn farming in Australia have not yet been adequately defined, although anecdotal reports and preliminary research, suggest that adverse impacts to water quality and indirect impacts to aquatic flora and fauna are arguable at best.

Water Quality

The discharge of prawn farm effluent has the potential to create significant changes to the quality of the receiving waters. The major concerns in regard to the discharge of prawn farm effluent, relate to the discharge of:

- dissolved metabolic wastes from prawn activity and the biological breakdown of waste feed particles and prawn faecal matter;
- particulate nitrogen and phosphorous, originating primarily from organic matter as prawn faecal matter, algal cells, waste feed particles and soil particles, in some cases significant levels originate from farm intake water sources;
- suspended solids from particulate organic matter and erosion of pond floor, walls and discharge channels, in some cases significant levels originate from farm intake water sources;
- excess phytoplankton.

The possible impacts of prawn farm effluent on water quality include:

- creation of eutrophic zones within the receiving waters;
- creation of visible plumes;
- accumulation of nutrients within the receiving waters.

Aquatic Flora & Fauna

The direct impacts to aquatic flora and fauna generally relate to the clearing of mangroves and disturbance of wetland areas during the construction phase of development.

Further potential impacts are related to changes to the tidal prism and creek flow rates caused by the pumping or discharge of water and the subsequent alienation of *wetland areas or changes to stream* morphology.

The indirect impacts to aquatic flora and fauna by prawn farms, relate to the potential changes to water quality within

the receiving environment. Potential impacts include; changes in the level of epiphytic growth, changes to the speciation within mangrove communities, shading of seagrasses from phytoplankton and increased populations of macroalgae.

Aquatic flora and fauna are potentially affected by the disturbance of potential acid sulphate soils during construction of prawn farms and the subsequent entrance to the ecosystem of jarosite, pyrite and acid leachate. Possibly resulting in low pH levels within waterways which may be detrimental to the structure of marine communities.

Terrestrial Flora & Fauna

Terrestrial fauna and flora may be directly affected by clearing of vegetation and native habitats associated with the construction and subsequent operation of prawn farms.

The clearing of native terrestrial flora has the potential to significantly impact on the biodiversity of a region, specifically in relation to the removal of habitats occupied by threatened or endangered species. The removal of coastal wetlands has the potential to impact on migratory birds which may be specifically protected under international conventions.

Prawn farming requires the storage of artificial feeds which has the potential to attract pest species.

The construction of open expanses of water and the culture of prawns has the potential to provide a food source for predatory bird species.

Tidal Hydrology

The intake and discharge of seawater for a prawn farm has the potential to impact on estuaries and creeks through an increase in the tidal flow and subsequently the tidal prisms of the estuaries and creeks. Significant changes have the ability to impact on stream bank stability, which in turn may indirectly impact on the aquatic flora and fauna of the affected estuaries.

Groundwater

Prawn farm developments have the potential to provide a conduit for salt water to enter groundwater supplies, leading to salinisation of groundwater supplies and the possible degradation of groundwater suitable for irrigation and other established uses.

Noise

Where prawn farms are constructed near other rural users or have had residential development encroach on previously rural areas, there is the potential for operational noise to create a nuisance. Impacts are likely to result principally from aeration devices, pump operation and feeding operations. The level of impacts will vary depending on background noise levels, distances to sensitive places and buffer zones.

Best Practice Environmental Management

The Best Practice Environmental Management of an activity is the management of the activity to achieve an ongoing minimisation of the activity's environmental harm through cost-effective measures assessed against the measures

currently used nationally and internationally for the activity (EPA 1994).

In deciding the Best Practice Environmental Management of an activity, regard must be had to the following measures:

- Strategic planning by the person carrying out, or proposing to carry out, the activity;
- Administrative systems put into effect by the person;
- Public consultation carried out by the person;
- Product and process design;
- Waste prevention, treatment and disposal.

Site Selection

Site selection and evaluation must ensure that the proposed site will be capable of operating in an economically viable and environmentally responsible manner and in accordance with this Code of Practice.

In evaluating potential prawn farm sites, developers must identify features of the site and its environment which represent important aspects of its ecological value. Evaluations should take into account the objectives and the likely environmental risks of the proposed project.

The following list although not exhaustive, identifies the major issues that should be considered when evaluating a potential prawn farm site.

- Water quality and tidal hydrology;
- Existing flora and fauna, both on and surrounding the site;
- Soil types, including clay content, erosion potential, and Acid Sulphate Soil Potential;
- Topography and flood levels;
- Freshwater influences;
- Neighbouring land uses;
- Existing water users;
- The proximity of Marine Parks, Fish Habitat Zones and World Heritage Property;
- Capacity of the receiving environment to dilute and assimilate the discharge waters;
- Environmental value of the site and the region;
- The potential impacts of the development on environmental values and biodiversity;
- Regulatory requirements of the development, site and region;
- Historical land uses.

Farm Design and Planning

The planning stage of any prawn farm development (new or expanding), is crucial not only for financial success, but also as an opportunity to design the development in a way which will not cause undue influences on the environment.

New prawn farms and any expansion of existing farms, must be designed and planned to minimise the risk of harm to important environmental areas.

Where reasonable and practical, the planning and design of proposed prawn farms should incorporate the following:

- Identification of features of the farm and its environment which are important aspects of ecological value;
- Vegetated buffer zones and where necessary habitat corridors;

- Intake points should be located to create access to high quality water, while recognising the need to minimise disturbance and potential impacts to marine vegetation;
- Pond wall batters must be constructed from suitable material and designed with optimal batter angles to prevent slump and erosion;
- Ponds should be aligned across prevailing winds to reduce wave setup and associated bank erosion;
- Farm layouts should minimise disturbance to potential acid sulphate soils;
- Ponds should be completely drainable;
- Pond drainage may be through a monk gate, stand pipe or centre drain system;
- In the event of a prawn farm utilising a centre drain system, pond discharge water must be retained for an appropriate, time to reduce the suspended solid loading, prior to release into the receiving waters.
- Farm design must incorporate a settlement pond of appropriate size or other design features that will assist in reducing the level of suspended solids in discharge waters;
- Discharge points should be located to create access to tidal waterways that will maximise the advection and dispersion of discharge waters and minimise impacts to tidal hydraulics, while recognising the need to minimise disturbance and potential impacts to marine vegetation;
- Farm size should be limited according to the advection, dispersion and assimilative capacities of the receiving environment, to ensure that unacceptable pressure is not placed on these systems;
- Areas of significant vegetation should be preserved, wherever and whenever possible, provided that the economic and productive efficiencies of the operation are not compromised.

The final design should ensure that the proposed farm will operate in an environmentally sustainable manner and in accordance with other sections of this Code of Practice.

Construction

Correct construction of the farm is likely to lead to increased profitability through savings in maintenance and unexpected construction failures.

> Prawn farms must be constructed in such a way as to minimise the risk of harm to surrounding areas.

Where reasonable and practical, the following practices should be complied with when constructing a new prawn farm.

Earthworks and Erosion Control

- The area disturbed should be limited to the immediate construction area;
- Appropriate methods (such as perimeter bunds), should be used to prevent overland flow from entering the construction site;
- Appropriate methods should be used to reduce erosion of topsoil from within the development site and subsequent siltation of waterways (such as using hay bales or sediment traps);
- Stripped top soil should be stored within a bunded area;
- Downstream conditions should be checked for possible erosion and/or flooding due to concentrated flows;

- Top soil should be placed over pond walls and suitable vegetation should be encouraged to grow on the pond walls and batters, or other erosion protection methods should be used

Acid Sulphate Soils

- The excavation and disturbance of known potential acid sulphate soils should be minimised;
- If disturbed, potential acid sulphate soils should be managed by burial, neutralisation or other forms of treatment;
- Leakage of potential acid sulphate leachate should be prevented, minimised or treated;
- Areas where potential acid sulphate soils have been disturbed and exposed should be rehabilitated.

Groundwater

- Ponds should be constructed from material capable of retaining water;
- Pond walls and floors should be constructed to minimise hydraulic conductivity.

Vegetation Clearing

- Boundaries of the construction area should be clearly marked prior to the commencement of vegetation clearance;
- Roads for construction access should be constructed to minimise vegetation clearance;
- Clearing and disposal of cleared vegetation shall be in accordance with the Administering Authority requirements.

Pond Management

Feed Management

Feeding methods and products vary considerably according to the species cultured, prawn weight, operating environment and operator preference. Food types and feeding methods are significant contributors to production efficiency, profitability and nutrients within discharge water. An improved level of feed management has the potential to significantly contribute to waste minimisation and farm profitability.

Feeding strategies must be managed to optimise Food Conversion Rates, productivity and minimise the associated nutrient levels in discharge water.

In accordance with this Code of Practice and the objective of minimising the level of waste products in discharge waters, prawn farmers must:

- Use artificial feed derived from a certified source;
- Monitor the amount of feed eaten by prawns on a regular basis;
- Calculate feed requirements according to a recognised formula and the results of feed monitoring;
- Conduct regular biomass calculations;
- Use a feed with the least amount of dust/fines possible;
- Maintain the quality of feeds by storing in cool dry areas;
- Store feed in a manner that will not attract pest species;
- Ensure feeds are not stored for extended periods;
- Use a quality feed with a suitable water stability;

- Use a feed with an appropriately low level of phosphorous;
- Use a feed which provides an optimal protein/energy balance;
- Use a feed which has a high percentage of digestible ingredients;

Stocking Densities

Stocking densities of prawn farms will vary between and within farms. The stocking density of ponds will contribute significantly to production efficiency, profitability and nutrients within discharge water.

Stocking densities must be managed to optimise production, minimise the pressure placed on water quality within the ponds and minimise associated wastes.

Prawn farmers must consider the following when calculating stocking densities:

- Aeration capacity;
- Water exchange capacity;
- Feed quality;
- Impacts of increased metabolic wastes;
- Disease implications;

Aeration

Appropriate use of aeration has the potential to increase productivity and reduce waste products within the discharge waters.

Farmers must seek to optimise their aeration rates in accordance with pond biomass levels and phytoplankton levels.

Aeration devices should:

- Maintain pond floors in an oxidised state;
- Not promote pond wall and floor erosion;
- Promote pond water circulation and reduce stratification.

Water Exchanges

The level of water exchange on prawn farms varies depending on climate, phytoplankton levels, pond biomass, management techniques and species cultured. The appropriate use of water exchanges has the potential to increase productivity and reduce waste products within the discharge waters.

Farmers must seek to optimise their water exchange rates in accordance with other appropriate complimentary management techniques.

Water exchange strategies should be determined in accordance with:

- Stocking densities;
- Feed management strategies;
- Pond aeration techniques.

Escape Prevention

There are various methods employed within the Australian prawn farming industry to ensure that cultured animals are not released into the environment.

Prawn farmers must take all reasonable and practical measures to ensure that no animals (endemic or non-endemic) are released into the environment from a prawn farm.

Stock containment practices could include any or all of the following:

- Screening of pond discharge structures with an appropriately sized mesh;

- Exchanging pond water at times when animals are known to be inactive;
- Screening farm discharge structures with an appropriate sized mesh.

Harvesting

The various harvesting methods employed throughout the Australian prawn farming industry have the potential to impact on the environment indirectly in varying degrees.

Prawn farmers must utilise a harvesting method which minimises the potential environmental impacts from increases in the suspended solid loading of discharge waters.

Harvesting practices may include:

- Net and trap harvesting;
- Trawl harvesting;
- Drain harvesting.

In the event of a prawn farm utilising trawl or drain harvesting methods, pond discharge water must be retained for an appropriate time to reduce the suspended solid loading, prior to release into the receiving waters.

Operational Erosion Control

In accordance with this Code of Practice prawn farmers should manage operational erosion in such a way as to minimise the risk of harm to surrounding areas. Increased operational erosion control is likely to result in marked decreases in the levels of suspended solids and particulate phosphorus within discharge waters. Additionally, suitable advanced erosion control practices are likely to lead to increases in profitability through a reduction in the maintenance costs associated with pond wall erosion.

Prawn farmers must initiate appropriate operational erosion control methods which minimise the potential environmental impacts from increased suspended solid loading in discharge waters.

Where reasonable and practical the following practices should be complied with:

Pond Wall and Floor Erosion Control

- Aerators should be located so as not to promote pond bank erosion;
- Pond walls should be of a suitable batter angle to reduce scouring and erosion;
- Vegetation should be encouraged to grow on pond batters, above the water line;
- Progress should be made toward protecting pond walls from erosion below the water line;
- Walls exposed to prevailing winds and the corresponding waves should be adequately protected from erosion;
- Final pond draining (last 30 cm) should take place slowly, to reduce erosion of pond floors and the subsequent removal of sediment with pond discharge water;
- Farmers should monitor the volume of sediment in each pond at the end of each crop, (this will provide a performance indicator for management changes).

Discharge Channel Erosion Control

- Pond discharge structures should be designed in such a manner as to minimise the level of erosion resulting

from the discharge of pond waters, with special emphasis on protecting drain walls from direct water impact and associated erosion;

- Channel walls should be constructed from a suitable material and be of a suitable batter angle to reduce scouring and erosion;
- Vegetation should be encouraged to grow on channel batters, above the water line;
- Progress should be made toward protecting channel walls from erosion below the water line;
- Discharge channels should be constructed in such a way as to minimise discharge water velocity.

Farm Discharge Point Erosion Control

- Farm discharge structures should be designed in such a manner as to minimise the level of erosion resulting from the discharge of waters;
- Discharge to waterways should be minimised or avoided at times when unacceptable erosion of creek or stream banks is likely to occur;
- Farm discharge points should be suitably protected against scouring.

Pond Effluent Management

Prior to the release of pond discharge waters, waste minimisation must be practiced. Farmers must make progress toward suitable management of pond effluent prior to its release. The effect of appropriate management will be to reduce the level of suspended solids, particulate nitrogen and particulate phosphorus within discharge waters. In addition, some advanced techniques are likely to lead to decreases in the levels of dissolved nitrogen, dissolved phosphorous and chlorophyll 'a' within the discharge waters.

Prawn farmers must, where reasonable and practical, implement pond effluent management procedures which minimise the potential environmental impacts from increases in the suspended solid and nutrient levels of discharge waters.

Where appropriate prawn farmers should utilise one or more of the following practices:

- Installation and use of an appropriately designed settlement pond;
- Reduction of discharge water velocity in discharge drains;
- Protection of pond discharge points from erosion;
- Installation of pond recirculation systems;
- Retain pond discharge water for a suitable period after final pond draining;
- Use biological filtration mechanisms, such as bacteria, macroalgae and bivalves.

Sediment Management

The biological activity, aeration and feeding practices involved in prawn farming results in the accumulation of sediments within the production ponds. In some cases these sediments are removed at the end of each production cycle. The storage of these sediments has the potential to impact on the environment through erosion of sediment into surrounding waterways and the associated leaching of nutrients and salts into waterways and groundwater supplies.

The minimsation of these wastes will substantially promote environmental sustainability. Additionally, suitable

sediment management practices are likely to lead to increases in profitability through a reduction in the maintenance costs associated with the removal and storage of these sediments. Prawn farmers should manage the production of sediment and should also manage the sediment once it has been removed from the ponds. Sediment production should be minimised using appropriate operational erosion control, feed management and stocking density techniques.

On removal of sediment from ponds, prawn farmers must store or dispose of the sediment in a manner that will minimise any potential environmental impacts from erosion or leachate.

On removal from ponds, sediment must be stored in a designated disposal area or spread as top soil in appropriate crop or pasture areas. These areas should have the following properties:

- If sediment is stockpiled for extended periods, the floor of the designated storage area should be compacted sufficiently to minimise hydraulic conductivity;
- Appropriate methods (such as perimeter bunds), should be used to prevent overland flow from entering the designated storage area and resulting in unacceptable levels of sediment/top soil erosion;
- Appropriate methods should be used to reduce erosion of the sediment from within the storage area and subsequent siltation of waterways (such as using cropping, hay bales or sediment traps).

Noise

Prawn farm noise sources are principally aeration, feeding and pumping. The majority of prawn farms are constructed in areas where there are no noise sensitive locations. In some instances, where prawn farms are constructed near other rural users or have had residential development encroach on previously rural areas, noise emissions need to be managed.

It is unavoidable that, at times, noise associated with Best Practice Environmental Management will be created at sensitive times.

Prawn farmers must take all reasonable and practical measures, to minimise the impact of noise on sensitive places at sensitive times.

Chemical Use

A variety of chemicals may be used in the Australian prawn farming industry to treat and/or control various diseases, fungi and parasites or to facilitate production. Use of chemicals necessarily involves user responsibility for any or all methods of safe handling.

Members of the Australian prawn farming industry must ensure that chemicals are not discharged, in concentrations which are likely to cause unacceptable changes, in the receiving environment

Prawn farmers should ensure that all chemicals stored and used within the prawn farm are stored and used in accordance with:

- The manufacturers instructions as contained within labels and other supplementary documents;

- Their Material Safety Data Sheet;
- Work Place Health and Safety regulations.

Farmers should seek advice from the DPI before using any chemicals if the farmer is unsure of their suitability. The use of unlabelled or inappropriately labelled chemicals, lacking adequate advice on correct use, dosage, withholding periods and maximum residue levels may result in:

- Reduced efficiency and safety of the treatment for target species;
- Chemical residues within prawns;
- Reduced safety to consumers of food from treated species;
- Reduced safety to operators;
- Market refusal to accept products;
- Production of chemical resistant disease strains;
- Adverse environmental impacts to flora and fauna.

Environmental Contingency Plans

Due to the difference in management techniques and site variability in the Australian prawn farming industry, the development of an industry contingency plan is not possible.

Each prawn farm location must develop in consultation with Administering Authorities, a satisfactory, site specific environmental contingency plan.

An environmental contingency plan should take into account the following:

- There may be contamination of pond water in excess of normal management expectations (eg. spillage of a contaminating substance or failure of erosion control mechanisms);
- The contingency plan should be initiated to ensure that there is no or limited effect on the quality of discharge waters;
- Remedial measures may be required to minimise the discharge of pond waters;
- Management techniques should be reviewed in the area specific to the contamination;
- Specific procedures should be implemented until the breach is resolved and normal operating procedures are restored;
- Monitoring of discharge effluent should be more frequent than normal should a contingency plan be initiated;
- On the implementation of a contingency plan, the Administering Authority must be notified as soon as practical by the management of the operation, where the contamination is likely to be released into the receiving waters.

Predator Management

A range of predators have the potential to impact on prawn farming operations. The management of predators will vary considerably depending on the species, region and operator preference. The appropriate management of predators is likely to increase profitability and minimise the potential environmental impacts to predator species.

Predators must be managed, where reasonable and practical, to minimise impacts to native fauna species while protecting the economic viability of the prawn farm.

In order to appropriately manage predators, prawn farmers should utilise one or more of the following practices:

Eels, Finfish and Crustaceans

- Screening of pond intake and discharge structures with appropriately sized mesh;
- Appropriate chemical treatment of pond water.

Avifauna

- Overhead netting of ponds;
- Installation of waterline nets;
- Installation of overhead wires;
- Use of repellent sound emissions;
- Use of repellent light emissions;
- Culling of target species, under an appropriate permit as issued by the Administering Authority;
- Increased personnel around ponds at peak feeding times for birds;
- Installation of predatory images or models.

Disease Management

Disease and health management requires a holistic management approach inclusive of, water quality management, hygiene, feed management, aeration, bird control and post larval health.

Members of the Australian prawn farming industry must ensure that, in the event of a disease outbreak, the threat of disease spread within a farm and spread from a farm is minimised and that disease pathogens are not discharged, in concentrations which are likely to cause unacceptable changes, to the receiving environment.

Prawn farm managers should implement an appropriate disease management strategy in accordance with the Prawn Health Management Guidelines.[1] Compliance with this strategy will benefit farmers through providing a set of standard procedures in the event of a disease outbreak and subsequently minimising losses from disease and by contributing to the long term sustainability of the industry in the face of increasing pressure from exotic diseases.

[1] To be developed by the APFA in consultation with Administering Authorities.

Prawn Feed Packaging

Currently the feed used in prawn farming is transported in paper or plastic bags. A reduction in the level of feed packaging will reduce the costs associated with the storage and disposal of this waste.

Reduction of this waste is a direct consequence of a reduction in the food conversion rate of the production cycle. As prawn farmers reduce their FCR, they will proportionally reduce this type of waste.

It is an unrealistic objective to strive for a disproportionate reduction in this waste. Other forms of reduction such as larger bags and changes to packaging materials create other problems such as with workplace health and safety (heavy bags and related worker injuries), feed contamination and moisture absorption.

Negotiations should be undertaken at an industry level, with feed manufacturers to ensure that packaging is of a recyclable nature.

Members of the Australian prawn farming industry must, where reasonable and practical, progress toward reducing the amount of non-recyclable packaging materials resulting from prawn feed storage and transportation.

Prawn farm managers should, where reasonable and practical:

- Reduce the FCR for production;
- Monitor and liaise with feed suppliers to ensure packaging is minimised and is of a recyclable nature;
- Recycle packaging material;
- Determine sources of excess packaging and implement remedial management actions as necessary.

General Domestic and Office Wastes

This waste stream is generally minor in its nature and is limited to office waste paper, domestic garbage and lunchroom wastes. The Australian prawn farming industry should reduce as practical the amount of wastes generated from office and lunchroom activities.

Energy Use

The Australian prawn farming industry recognises that large amounts of energy are regularly required to ensure that production levels are maintained and to assist in maintaining environmental management practices.

As commercial operations, the use of excessive energy during the production cycle is not in line with the financial objectives of prawn farmers. Improved energy management will benefit farmers directly through reduced operating costs. This Code of Practice promotes responsible energy management and prawn farmers should:

- Promote daily awareness of energy use patterns;
- Monitor annual and quarterly energy expenditure;
- Isolate and remedy energy waste actions;
- Minimise unnecessary vehicle usage;
- Maintain electrical equipment for optimal performance.

Training

Training employees is a vital part of ensuring that an organisation maintains a suitable level of compliance with this Code of Practice. Staff should be aware of the requirements of the Code of Practice , in varying levels of detail, depending on their duties.

Training programs should contain common elements such as familiarisation with the company environmental policy, the Code of Practice, commitment to waste prevention and raw materials conservation. Employees should be encouraged to suggest new ideas which are in line with compliance with the Code of Practice.

Environmental Monitoring

An environmental monitoring program will be required by Administering Authorities to quantify the extent and nature of any environmental changes attributable to a prawn farming operation. The environmental monitoring program should aim to differentiate such environmental changes from naturally occurring environmental fluctuations. A suitable programme will provide benefits to the operators in terms of addressing potential false claims of environmental damage.

Prawn farmers should implement an appropriate environmental monitoring program to quantify changes in the receiving environment attributable to the prawn farming operation.

The design of appropriate monitoring programs should consider the following:

Cost Effectiveness

A monitoring program should aim to be cost effective. The level of change to be detected needs to be balanced against the costs associated with monitoring and the environmental values of the receiving environment.

Performance Indicators

It is not possible to recommend a uniform set of performance indicators for the entire industry due to the high variability in receiving environments. ANZECC (1992) advises that individual acceptable water quality parameters for receiving waters should be determined on a site specific basis.

Natural Variability

It is important to have a clear understanding of both acceptable levels of environmental change and levels of natural variability, to ensure that the monitoring program can determine potential environmental impacts as required by the Administering Authority. Unless these two issues are adequately addressed, it is possible that a monitoring program may result in the collection and processing of unnecessary and excessive data or collection of unreliable data in terms of determining potential environmental impacts.

Monitoring Frequency

The frequency of data collection needs to take into account the magnitude and time scale of potential impacts. Environmental impacts resulting from a prawn farming operation are most likely to be from discharge of large volumes of waters which contain concentrations of suspended solids, phytoplankton and nutrients. Potentially influenced communities are likely to respond slowly and changes will occur gradually.

In this regard, monitoring frequency can be less frequent than if potential impacts and associated responses were both quick and extreme.

Control Sites

The inclusion of control sites is required to detect any wide-spread natural influences that are unrelated to the aquaculture operation but nevertheless may result in significant changes to communities and/or variables being measured.

Baseline Data

It will be important for the monitoring program to incorporate a baseline data collection phase to provide a set of background data to assess natural variability and the spatial and temporal scale at which monitoring would be most appropriate. Administering Authorities could use this information to determine a threshold for the cost effective, detectable level of change in a monitoring program.

Sampling Techniques

Sampling techniques and monitoring of environmental parameters must be in accordance with appropriate and recognised scientific methodology. Specifically the techniques utilised when taking environmental water samples must be in accordance with the *Water quality sampling manual* (1995).

Environmental Complaints

Complaints in regard to environmental issues of prawn farms may take three forms:

1. Receipt of a written complaint from Administering Authorities on behalf of a third party;
2. Receipt of a written complaint from Administering Authorities on behalf of the Administering Authority;
3. Receipt of a written complaint from a third party.

Complaints will be recognised by prawn farmers under this Code of Practice on the basis that the complaint:

- is in writing;
- notes the specific incident;
- notes the specific concern or potential impact of the alleged incident;
- notes the place of the alleged incident;
- notes the date and time of the alleged incident.

On receipt of a complaint made in the appropriate form, the prawn farmer will notify the Administering Authority in writing of the complaint and will implement an internal investigation to either substantiate or refute the alleged incident. Such an investigation will include, a review of the relevant environmental records, communications with the responsible employee(s) and any other actions the prawn farm management deems as necessary.

The Administering Authority will be informed in writing of the outcome of the investigation within thirty days of completion of the investigation.

In the event that a single incident is substantiated by the investigation, the prawn farmer must undertake a review of operating procedures to ensure that the incident is not repeated. If the incident identified is a continuing breach, the farm contingency plans must be implemented.

Environmental Records and Auditing

Under this Code of Practice, prawn farmers should undertake to keep all records required to provide a substantial base of information for the collation of environmental data relevant to the aquaculture operation. Such records should include:

- Time and date of monitoring activities;
- Laboratory water quality results in line with monitoring requirements;
  - original analysis report;
  - collated data;
- In situ water quality measurement results in line with monitoring requirements;
- Discharge volumes for each day as calculated by the exchange requirements of each pond;
- Pond sediment volumes, as removed from ponds after draining;
- Rainfall records;
- Records of major rain events and visual observations of surrounding waterways;
- Correspondence with Administering Authorities;
- Relevant correspondence with interest groups and community organisations;
- Written complaints received by the company;
- A copy of relevant licenses and approvals;
- Environmental Audit and Review reports;
- Names and addresses of consultants and contractors engaged in environmental matters.

Under this Code of Practice, prawn farmers should conduct an annual audit of their environmental records and management systems. The review shall comprise an internal review to confirm that the proposed actions are appropriate. The results of the review are to be forwarded to the Administering Authority if required and as appropriate.

Site Rehabilitation

This Code of Practice provides for the rehabilitation of prawn farm sites on termination of prawn farming activities.

> Where a prawn farmer chooses to terminate the operation of a prawn farm and not continue with a similar use, the prawn farm site must be rehabilitated to the extent that no further impacts to the environment result from the development site.

Site rehabilitation may include one or more of the following actions:

- Restoration of topography;
- Burying of pond sediments;
- Revegetation of site;
- Closure of farm intake and discharge channels;
- Restoration of Crown Land.

Code of Practice Review

This Code of Practice should be reviewed by the Australian prawn farming industry on an annual basis. New technology should be incorporated where appropriate, based on its efficiency and effectiveness to minimise the environmental impacts of prawn farming.

In conjunction with this Code of Practice, a series of procedural guidelines should be developed to deal with specific issues which require substantial detail, such as health and disease management. Similar procedural guidelines should be developed for each step of the prawn farming process.

Review is the responsibility of the Australian Prawn Farmers Association which should conduct the review in consultation with Administering Authorities.

Consultation

The following Administering Authorities and interest groups have been offered an opportunity to contribute to the development of this Code of Practice:

- Australian Prawn Farmers Association
- Australian Seafood Industry Council
- Great Barrier Reef Marine Park Authority
- Mackay Conservation Group
- North Queensland Conservation Council
- Northern Territory Department of Primary Industries & Fisheries
- NSW Environment Protection Agency
- NSW Fisheries
- Queensland Commercial Fisherman's Organisation
- Queensland Conservation Council
- Queensland Department of Environment
- Queensland Department of Primary Industries
- Sunfish

To date the following Administering Authorities and interest groups have participated and contributed to the development of this Code of Practice:

- Australian Prawn Farmers Association

- Great Barrier Reef Marine Park Authority
- North Queensland Conservation Council
- Northern Territory Department of Primary Industries & Fisheries
- NSW Environment Protection Agency
- NSW Fisheries
- Queensland Department of Environment
- Queensland Department of Primary Industries

Relevant Environmental Legislation

Prior to developing or operating a prawn farm it is the responsibility of the prawn farmer to ensure that all necessary regulations have been satisfied. It is not within the scope of this Code of Practice to provide a detailed list of all regulatory mechanisms which have the potential to impact on prawn farm developments. Individual prawn farmers should ensure that they seek appropriate legal advice in regard to their responsibilities.

Relevant Environmental Legislation (Commonwealth)

Great Barrier Reef Marine Park Act (1975)

The Great Barrier Reef Marine Park Act (1975), provides for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the care and development of the Great Barrier Reef Marine Park. When assessing the impacts of proposed prawn farms, the likely impacts to the Great Barrier Reef need to be assessed.

World Heritage Properties Conservation Act (1983)

The Commonwealth World Heritage Properties Conservation Act (1983), protects registered property and areas against any activity that is "*likely to damage or destroy*" an area of World Heritage Property. When assessing the impacts of proposed prawn farms, the likely impacts to World Heritage Areas need to be assessed.

International Treaties and Conventions

The Federal and Queensland Governments have agreed to and become involved in, a number of environment based treaties and conventions, including Ramsar, CAMBA and JAMBA. These treaties and conventions have the objective of protecting various world environmental values such as bird migration and wetlands preservation.

Relevant Environmental Legislation (Qld.)

Environmental Protection Act 1994

The Environmental Protection Act 1994 requires that a person must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practical measures to prevent or minimise the harm.

Further, the Environmental Protection Act 1994 provides that aquaculture is an Environmentally Relevant Activity, persons undertaking this activity are required to be licensed.

Fisheries Act 1994

Aquaculture licenses are required by all persons conducting aquaculture activities

where the product is for sale. The Fisheries Act 1994 restricts the clearing or removal of marine plants and works within declared Fish Habitat areas. It also provides the DPI with options in regards to disease management.

Local Government (Planning & Environment) Act 1990

The Local Government (Planning & Environment) Act 1990, requires that when an application is made to a local government authority for town planning approval, consent, permission or authority in relation to a planning scheme for a designated development, an Environmental Impact Statement must be prepared and submitted in accordance with the Act.

Local Authority By-laws and Regulations

Some Local Authorities require that developments within their jurisdiction seek approval for specified earthworks, clearing areas under Vegetation Protection Orders and building construction.

Water Resources Act 1989

The Water Resources Act 1989, requires that permits be obtained prior to altering riverine environments or drawing from groundwater supplies.

Nature Conservation Act 1992

The Nature Conservation Act 1992, requires that permits may be required for activities within in areas prescribed in Nature Conservation Plans, defined as critical habitats or covered by a Conservation Order.

Harbours Act 1955

Under Section 86 of the Harbours Act 1955, approval is required prior to construction, for other than private use, of any structure on tidal lands or waters.

Marine Parks Act 1982

The Marine Parks Act 1982, provides for the protection of declared marine areas as Marine Parks. Under the various Marine Park Orders, declared marine areas are protected from certain activities in order to provide conservation of the area.

Coastal Protection & Management Act 1995

This Act provides for the protection, conservation, rehabilitation and management of the coast and requires that any use of the coastal resources is undertaken in an ecologically sustainable manner.

Relevant Environmental Legislation (N.S.W.)

NSW Fisheries Management Act 1994

Provides for the issue of aquaculture permits and licenses and the development of new types of aquaculture. It provides for contributions to aquaculture research and promotes environmental responsibility in the industry.

National Parks and Wildlife Act 1974

This Act provides for the protection of sites of archaeological and cultural importance and for the protection of terrestrial fauna and flora.

Threatened Species Conservation Act 1995

The Threatened Species Conservation Act 1995, provides for the protection and conservation of threatened species and ensures that potential impacts to

threatened species are considered as a part of any development.

Environmental Planning and Assessment Act 1979

This Act determines whether an aquaculture development requires Consent of a local council or if another government department is to be the determining authority. This Act also determines whether an Environmental Impact Statement is required for a designated development and considers the Threatened Species Conservation Act 1995.

Local Government Act 1993

The Local Government Act 1993, requires that development applications consider Local Environment Plans and State Environmental Planning Policies for wetlands and other protected habitats.

Clean Waters Act 1970

The Clean Waters Act 1970, provides for the licensing of prawn farms where the farm discharges effluent to external waterways.

Pollution Control Act 1970

This Act provides for the regulation and licensing of facilities which house or create pollution.

Crown Lands Act 1989

Under the Crown Lands Act 1989, approval is required prior to construction, , of any structure on Crown Land.

Rivers and Foreshores Act 1948

This Act provides for the protection of river banks and the prevention of erosion.

Water Act 1912

The Water Act 1912 provides for protection of groundwater from saltwater intrusion and the regulation of developments on flood plains.

Relevant Environmental Legislation (N.T.)

Northern Territory of Australia Fisheries Act

Aquaculture licenses are required by all persons conducting aquaculture activities in the Northern territory. The Fisheries Act also restricts the clearing or removal of marine plants.

Planning Act 1993

The Planning Act 1993 requires that public notification of a proposal relating to a prawn farm. Section 51 of the Act specifies the matters to be considered by the Administering Authority when considering development proposals.

Darwin Regional Structure Plan 1990

The Darwin Regional Structure Plan 1990, outlines aquaculture development opportunities for the Darwin Region and location requirements.

Environmental Assessment Act

This Act requires that the environmental impacts associated with prawn farming in the Northern Territory are fully considered.

Water Act

The Water Act provides regulations in relation to all aspects of water works, including; damming of water courses, installation of bores and discharge of waste waters.

Port Authority Act

The Port Authority Act, provides for regulation of construction within tidal waters in the Darwin region.

Territory Parks and Wildlife Conservation Act 1993

This Act provides for the protection and conservation of native fauna and flora within the Northern Territory and for the establishment and protection of marine parks.

Definitions

Acid Sulphate Soils	- Soils which contain pyrite and have the potential to produce acid leachate when oxidised.
Administering Authority	- Government agency responsible for the administration and approval of aquaculture developments.
Aeration	- the process of adding oxygen to the pond water.
CAMBA	- China - Australia Migratory Bird Agreement
Certified Source	- A supplier or manufacturer of product which has been certified as environmentally appropriate by the Australian Prawn Farmers Association.
Chemical	- A chemical, drug, antibiotic or disinfectant.
Chlorophyll 'a'	- A standard measure of filterable photosynthetic material, used as an indicator for phytoplankton levels in a water sample.
Dissolved Nitrogen	- Typically nitrate, nitrite and ammonia.
Dissolved Phosphorous	- Typically Ortho-phosphates.
DPI	- Queensland Department of Primary Industries or equivalent agency in other states.
Effluent	- Prawn farm discharge water; primarily seawater with an additional load of nutrients, suspended solids and phytoplankton.
Environmental Authority	- A license, permit or other authority that is issued under law, allowing the conduct of an Environmentally Relevant Activity.
Environmentally Relevant Activity	- Any activity which has the potential to release a contaminant into the receiving environment when the activity is carried out. This is a specific term in the Environmental Protection Act 1994 (Qld) but the concept applies equally to all other States and Territories.
Exotic diseases	- Diseases that are not known to be endemic to Australian waters.
Farm Discharge Point	- Point at which water is released from a prawn farm into the external environment.
Feed	- Artificial pellets or crumbles manufactured for prawn diets.
Fish Habitat Zones	- An area of water protected by legislation for its value as a fishery habitat.
Food conversion Rate	- Mass of feed used related to mass of prawns produced.
General Environmental Duty of Care	- A persons duty not to carry out any activity that causes or is likely to cause, environmental harm, unless the person takes all reasonable and practical measures to prevent or minimise the harm.
Groundwater	- Water occurring beneath the natural ground level.

Initial Mixing Zone	- The part of the receiving water where the waste water is diluted before it reaches the same density as the receiving water.
JAMBA	- Japan - Australia Migratory Bird Agreement
Marine Parks	- An area of water protected by legislation for its environmental values. Includes State and Federal Marine Parks.
Noise Sensitive Location	- A place defined as a "noise sensitive place" by the Environmental Protection (Interim) Regulation 1995.
Nutrients	- The mix of phosphorous and nitrogen contained within discharge waters.
Particulate Nitrogen	- Typically nitrogen found in organic matter.
Particulate Phosphorous	- Typically phosphorous bound to inorganic suspended solids and some organic matter.
Pathogens	- Causative organisms of disease.
Performance Indicator	- A predetermined environmental value which is used as an indicator of the impacts or potential impacts of a prawn farm.
Pond discharge structures	- Point and structure at which water is released from a prawn production pond into a discharge channel.
Pond recirculation systems	- A system which will allow for partial or total reuse of pond discharge water within a single prawn farm.
Ramsar	- Convention on Wetlands of International Importance (Ramsar Convention).
Reasonable and Practical	- Where consideration has been given to the following: • the current state of technology in the industry • the financial considerations of the action • the likelihood of successful outcomes from the action • the nature of the harm or potential harm • the sensitivity of the receiving environment
Settlement Pond	- A pond of sufficient size to retain all pond discharge water for sufficient time to allow for some or all settleable particles to settle.
Stocking densities	- Number of prawns stocked on a square metre basis.
Suspended Solids	- A measure of the filterable particulate matter in a water sample.
Unacceptable (Increase/Change)	- Changes in the parameter under consideration, which would be regarded as incompatible with the concept of ecologically sustainable development.
Work Place Health and Safety regulations	- Any state or federal regulations which seek to protect the health and safety of workers.
World Heritage Property	- Areas as defined by the World Heritage Register.

References and Further Reading

ANZECC (1992) *Australian Water Quality Guidelines for Fresh and Marine Waters*. National Water Quality Management Strategy.

Bell A.B. & Lightner D.V. (1992) *Shrimp Facility Clean-Up & Restocking Procedures*. College of Agriculture, The University of Arizona.

Beveridge, M.C.M., Phillips, M.J. & Clarke, R.M. (1991) A quantitative and qualitative assessment of wastes from aquatic animal production. pp 506 - 553. In D.E. Bruce & J.R. Tomasso (Ed). *Advances in Aquaculture. Volume 3*. World Aquaculture Society, Baton Rouge, Louisiana USA.

Boyd C.E. (1996) Comments made at the APFA Conference Cairns Qld July 1996.

Boyd C.E. (1995) Chemistry and efficacy of amendments used to treat water and soil quality imbalances in shrimp ponds, pp 183-199. In Browdy, C.L. & Hopkins, J.S (eds) *Swimming Through Troubled Waters* - proceedings of the Special Session on Shrimp Farming at Aquaculture '95. Published by World Aquaculture Society.

Boyd C.E. (1995) *Effluent and Solid Waste Management in Pond Aquaculture*. Presented at 3rd Equadorian Aquaculture Conference, November 1995.

Boyd, C.E, Tanner, M.E, Madkour, M & Kasuda, K (1994) Chemical Characteristics of Bottom Soils from Freshwater and Brackish Water Aquaculture Ponds. Journal of World Aquaculture Society 25 (4) pp 517-534.

Boyd, C.E. & Pippopimyo, S. (1994) Factors affecting respiration in dry pond bottom soils. Aquaculture Journal 120, pp 283-293.

Boyd, C.E. (1995) Effluent and Solid Waste Management in Pond Aquaculture. Personal manuscript which evaluates the results of large study on *Aquaculture Sustainability and the Environment* conducted by Network of Asian Centres for Aquaculture (NACA) and Asian Development Bank (ADB).

Boyd, C.E. (1995) Regional Review of Environmental Issues and Aquaculture Sustainablity. Draft manuscript prepared for NACA which reviews the country reports, S.E. Asia, on *Aquaculture Sustainability and the Environment*.

Briggs, M.R.P. & Funge-Smith, S.J. (in prep) A nutrient budget of some intensive marine shrimp ponds in Thailand. Institute of Aquaculture, University of Stirling, Scotland. UK

Chien Y.H. & Liao I.C. (1995) Integrated approach to prawn growout system design pp 167-182. In Browdy, C.L. & Hopkins, J.S (eds) *Swimming Through Troubled Waters* - proceedings of the Special Session on Shrimp Farming at Aquaculture '95. Published by World Aquaculture Society.

Endander, M & Hasselstrom, M (1994) An Experimental Wastewater Treatment System for a Shrimp Farm in Malaysia. INFOFISH International 4/94 pp 56-61

EPA (1994) Environmental Protection Act 1994.

Flaherty, M & Karnjanakesorn, C. (1995) Marine Shrimp Aquaculture and Natural Resource Degradation in Thailand. Environmental Management Vol. 19 No.1 pp 27-37.

Funge-Smith, S.J. & Briggs, M.R.P. (1994) Institute of Aquaculture, University of Stirling, Scotland. UK Appendices of Final Report to the Overseas Development

Administration - *Development of Strategies for Sustainable Shrimp Farming in Thailand.*

Funge-Smith, S.J. & Briggs, M.R.P. (in prep) The organic composition of soil and accumulated sediments in intensive marine shrimp ponds in Thailand. Institute of Aquaculture, University of Stirling, Scotland. UK

Funge-Smith, S.J. & Briggs, M.R.P. (in prep) The origin and fate of solids and suspended solids in intensive marine shrimp ponds in Thailand. Institute of Aquaculture, University of Stirling, Scotland. UK

Funge-Smith, S.J. & Briggs, M.R.P. (in prep) Water quality and nutrient discharge of intensive marine shrimp ponds in Thailand and their relationship to pond productivity. Institute of Aquaculture, University of Stirling, Scotland. UK

Gavine, F.M, Phillips, M.J. & Kenway, M. (1995) The integration of treatment systems to reduce environmental impacts of effluent from coastal shrimp ponds in Thailand - biological and physical constraints. (In press)

Hajek, B.F. & Boyd, C.E. (1994) Rating Soil and Water Information for Aquaculture. Journal Aquaculture Engineering 13 pp 115-128.

Hopkins, J.S, Hamilton, R.D, Browdy, C.L & Stokes, A.D. (1993) Effect of Water Exchange Rate on Production, Water Quality, Effluent Characteristics and Nitrogen Budgets of Intensive Shrimp Ponds. Journal World Aquaculture Society. 24 (3) pp 304-320

Hopkins, J.S., Sandifer, J.S. & Browdy, C.L. (1995) A review of water management regimes which abate the environmental impacts of shrimp farming, pp 157-166. In Browdy, C.L. & Hopkins, J.S (eds) *Swimming Through Troubled Waters* - proceedings of the Special Session on Shrimp Farming at Aquaculture '95. Published by World Aquaculture Society.

Jory D.E. (1995) Feed management practises for a healthy pond environment, pp 118-143. In Browdy, C.L. & Hopkins, J.S (eds) *Swimming Through Troubled Waters* - proceedings of the Special Session on Shrimp Farming at Aquaculture '95. Published by World Aquaculture Society.

Kitada (1996) Report and presentation to Kuruma prawn farmers, March 1996.

Kiyoshi, M & Boyd, C.E. (1994) Effects of Aeration, Alum Treatment, Liming, and Organic Matter Application on Phosphorus Exchange between Soil and Water in Aquaculture Ponds at Auburn, Alabama. Journal of the World Aquaculture Society 25 (3) pp 405-416

Kwei Lin C. & Beveridge M.C.M. (1993) Shrimp Culture and the Environment: Lessons from the World's most rapidly expanding warmwater aquaculture sector. *In* Pullin R.S.V. Rosenthal H. & MacLean J.L. (eds) *Environment and Aquaculture in Developing Countries.* ICLARM Conference Proceedings.

Lobegeiger R (1995) *Aquaculture Production Survey, Queensland 1994/95. Report to Farmers.* Aquaculture Information Series. QDPI.

Macintosh D.J. & Phillips, M.J. Environmental Issues in Shrimp Farming. (source of reference and year unknown) pp 118-144

New, M.B. (1995) Feed management and Nutrition for Sustainable Aquaculture. Paper presented at PACON 1995 meeting Hawaii.

Our Common Future (1987) Report by the World Commission on Environment and Development.

Phillips, M.J, Beveridge, M.C.M. & Clarke, R.M. (1991) Impact of Aquaculture on Water Resources. pp 568-591 In D.E. Bruce & J.R. Tomasso (Ed). *Advances in Aquaculture. Volume 3.* World Aquaculture Society, Baton Rouge, Louisiana USA.

Phillips, M.J, Kwei-lin, G. & Beveridge, M.C.M. (1993) Shrimp Culture and the Environment. Lessons from the worlds management rapidly expanding warmwater aquaculture sector. Environment and aquaculture in developing countries ICLARM. ICLARM conference proceedings 3 pp 171-197

Pillay, T.V.R. (1992) Aquaculture and the Environment. Oxford Fishing News Books.

Pruder, G.D. (1990) Effluent Treatment Processes Literature Study. Project II *Aquaculture Effluent Discharge Program Year 1 Final Report* prepared for Centre for Tropical and Subtropical Aquaculture Hawaii. pp 55-66

Robertson, A.I. & M.J. Phillips. (1995) Mangroves as Filter of Shrimp Pond Effluent: predictions and biogeochemical research needs. Hydrobiologia 295 pp 311-321

Wang, J.K. (1990) Alternative Effluent Treatment Processes. Project II *Aquaculture Effluent Discharge Program Year 1 Final Report* prepared for Centre for Tropical and Subtropical Aquaculture Hawaii. pp 97-105

Water quality sampling manual 2nd Ed (1995) Department of Environment. and Heritage

Ziemayan, D (1990) Characterisation of Aquaculture Effluent and Environmental Assessment for Effluent from Hawaiian Aquaculture Facilities. Project I *Aquaculture Effluent Discharge Program Year 1 Final Report* prepared for Centre for Tropical and Subtropical Aquaculture Hawaii. pp 2-53