

# SEAWATER IRRIGATION SYSTEM FOR INTENSIVE MARINE SHRIMP FARMING IN THAILAND

By

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The aim of seawater irrigation system (SIS) is to clean up shrimp pond effluent and provide high quality seawater for shrimp farming. The system has three components: water intake, treatment reservoir and discharge system. There are criteria for site selection because shrimp farmers are required to form associations so they can work closely together. The construction site must be on the coastal area outside a mangrove forest. The site must be located away from a productive agricultural area. All construction sites must have undergone an environmental impact assessment (EIA), and should be located on the area listed in Thailand's Coastal Zone Management Plan (CZMP).

Five SIS projects were completed and operated. These covered a culture area of 6,500 ha and 1,300 farmers (families). Department of Fisheries (DOF) has planned for another 28 projects. It will cover almost 44,000 ha of culture area.

When Thailand started producing shrimp, most of the farms depended on natural resources which turned out to be an inefficient way of production. Expensive shrimp farming occupied large areas along the coastal zone in the Upper Gulf. Large ponds of at least 1.6 ha were built in mangrove forests because shrimp larvae in the mangrove were automatically recruited into the ponds as water was pumped in. The shrimp were left in the pond, feeding on natural food, for about 6 months. After the rearing period, grown-up shrimp were harvested and sold to the local market. This primitive way of shrimp culture reduced mangrove forests. Harvests were low. Not until the last decade was intensive shrimp culture introduced in the country. Small ponds averaging 0.5 ha in size were built, and these replaced the large ponds in the mangroves. Culture areas also expanded to new locations outside the forests. Shrimp larvae from hatchery were stocked at high density and given artificial food. Antibiotic was administered for bacterial disease control.

These practices led to higher pond yield, with shrimp production increasing at an average of 8-18 mt/ha/yr. The result was the proliferation of intensive shrimp farms. Shrimp farms in Thailand comprised 40,769 ha in 1984; expanded to 75,332 ha in 1991; and decreased slightly to 70,400 ha in 1998 which produced 310,000 mt in 2000. Thailand has been the leading shrimp exporter since 1991 (Table 1 and Figure 1). Its major markets are USA, Japan, and the European Union countries.

## Keys to success

The key reasons for Thailand's success in marine shrimp farming have been well discussed and reported. Key factors include favorable agroclimatic conditions, availability of wild

broodstock, farmers' long experience in aquaculture, strong infrastructure and support services, the fact that the industry is made up of small, efficient and nimble operations, and lately, strong control of environmental problems. An example of the latter is the Seawater Irrigation System or SIS, a solution introduced by the Department of Fisheries to the inadequate design of water supply that causes water pollution and shrimp diseases. The situation has occurred in many places, like Taiwan, where shrimp culture collapsed after a long period of growth.

## Major constraints to Thai shrimp farming

Increasing attention has been given in recent years to some major constraints to marine shrimp farming industry in Thailand. One of these is water pollution from effluents. Pollution loading and toxic materials have been cited as the main reasons for the deterioration of coastal natural resources and the environment. Another concern is the loss of mangrove, which occurred during the expansion of shrimp farms.

Some studies show the quality of effluent and pollution loading from marine shrimp farms. A 1993 study revealed that the pollution loading from an intensive tiger shrimp farm in Ranot, Songkhla province was as follows: total nitrogen 202 kg/ha/day, total suspended solid 532.2 kg/ha/day and chlorophyll 0.11 kg/ha/day.

Other studies revealed that the total loading from marine shrimp farm in Kung Krabaen Bay, Chantaburi province discharged 67,400 t/ha/crop of used water. This contained total nitrogen 1.77 t/ha/crop, total organic carbon 160 t/ha/crop BOD<sub>5</sub> 35.10 t/ha/crop and sludge (wet weight) 134 t/ha/crop.

## ABOUT THE AUTHORS

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TABLE 1. World production of marine shrimp (tons)<sup>1</sup>

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Thailand	110,000	153,000	163,000	209,000	250,000	225,000	205,000	170,000	230,000	230,000
Indonesia	120,000	140,000	130,000	100,000	100,000	100,000	132,000	110,000	50,000	100,000
China	150,000	145,000	140,000	30,000	35,000	70,000	80,000	80,000	na	85,000
Ecuador	na	na	95,000	76,000	100,000	100,000	120,000	130,000	130,000	110,000
India	32,000	35,000	45,000	55,000	70,000	60,000	80,000	60,000	70,000	70,000
Bangladesh	25,000	25,000	25,000	30,000	35,000	30,000	35,000	34,000	na	na
Others	68,500	101,500	131,000	139,000	168,000	147,000	153,000	126,200	257,200	219,250
Total	505,500	599,500	729,000	639,000	758,000	732,000	805,000	710,200	737,200	814,250

<sup>1</sup>World shrimp Farming (2000); na = production less than 25,000 tons.

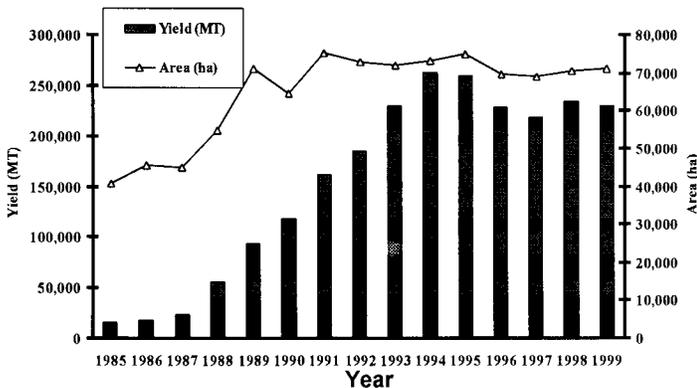


FIGURE 1. Shrimp production, culture area, annual yield from 1985 to 1999 in Thailand

Meanwhile, a 1995 survey showed that the utilization of mangrove in Thailand, synthesized from the satellite image in 1993 (Landsat TM: 50,000), was of three main types:

- 6,500 ha (17.5%) used for shrimp farm
- 138,785 ha (37.31%) used for land settlement and other purposes
- 168,028 ha representing the unused mangrove

Only a small portion of mangrove has been utilized for shrimp farming. However, through zoning or licensing, DOF has tried to move all shrimp farms from the productive mangrove to the unproductive mangrove areas, or to private land outside mangroves.

Macintosh and Phillips in a 1992 study compared the quality of shrimp farm effluent with that of effluent from other potential sources of pollution. They found that polluted water from shrimp farm has pollution loading considerably less than that of domestic or industrial wastewater.

However, polluted water from intensive shrimp farm still plays

a major role in the coastal water contamination. This is because the considerable amount of effluent contains a variety of suspended solid including excess feeds, fertilizers, chemicals and antibiotics.

Marine shrimp effluent is highly diluted but it is a large volume, requiring high investment for treatment. A 1994 study suggested that the suitable treatment process would be a combination between chemical and physical treatments. DOF has long studied the problems of inadequate design of water supply, water treatment process, as well as mangrove destruction to find the optimum solution for sustainable shrimp culture development. The conclusion: seawater irrigation system.

**What seawater irrigation system (SIS) does**

The aim of SIS is to clean up shrimp pond effluent and provide high quality seawater for shrimp culture. Its general purpose is to provide small-scale shrimp farms with a reliable supply of clean water. The SIS has three components:

- *Water intake.* Shrimp farms in the project are supplied with sufficient high quality seawater. The uncontaminated seawater is carefully taken from offshore via a pumping facility and through underground pipeline
- *Treatment reservoir.* The partially treated effluents from private shrimp farms are pumped into a common treatment reservoir and then treated by appropriate treatment procedures
- *Discharge.* After the water is treated, the effluent is drained offshore. The quality of discharged water will be controlled by the government or by shrimp culture groups and should not exceed the assimilative capacity of the adjacent sea

Because of non-uniform small-scale shrimp farms, the design engineers frequently find it difficult to design a simple seawater system existing in the shrimp culture area. Thus, a variety of seawater systems has been designed depending upon location, water resource availability and pond topography.

- Healthy and safe living and working conditions should be provided
- Shrimp farm management should have clearly defined and posted security policies
- Employees should have a clear understanding of their duties and of company expectations regarding their performance

#### Farmer associations and education

Shrimp farmers should form cooperatives or associations by region in order to exchange technology and to achieve cooperation in water use and waste management. Shrimp culture techniques are also constantly improving, and it is important that shrimp operators continue to increase their knowledge of sustainable farming techniques.

GMPs for farmer association and education include:

- Farmer associations should be encouraged. Meeting among members should be routinely held for exchanging information on shrimp culture
- The farmers would participate in training in the aspects of shrimp farm management, in the manner of friendly environment practices, and for law and regulation for shrimp culture industry
- The association should promote “environmentally-friendly” practices

#### Data collection

Data collection on the above topics and farm accounts should be done. Shrimp farming associations should cooperate with the department of Fisheries to collect, organize, and evaluate data to demonstrate the adoption of GMPs and document the benefits of their use.

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#### What is SIS

Several Seawater Irrigation Systems have been built and it is likely that more will be constructed in the near future. The systems differ because of the variety of pond layout, different ecological systems and limitation of land utilization in different areas. They are normally designed using three types of water management.

- *Open Sea System (SIS type I)*. In private shrimp farms most of which have their own water intake facilities, the DOF will provide a drainage pumping system to collect shrimp farm effluent which is then given appropriate treatment in a common reservoir. The water is pumped out to a safe distance offshore
- *Bay System (SIS type II)*. High quality water supply will be provided by pumping through an underground pipeline. The length

of the pipe depends on the distance of the best all-season water quality found offshore. The effluent will be treated in shrimp farms before release into a common treatment facility and then discharged into the water resource nearshore

- *Shrimp Farm Consolidated System (SIS type III)*. The system is the combination of the first two management systems. The water will be provided via a pumping system and stored in a common treatment facility. The drainage pumping system is also provided. This type of water management is ideal for the shrimp industry; it must be operated in a large area by the same management team and shrimp pond layout must be completely redesigned. Therefore, a land reclamation program is required

#### Criteria for site selection

Thailand has large areas for shrimp culture. It has developed site selection criteria for future construction plans as follows:

- *A Shrimp Farming Association* is required in order to keep farmers working closely together. The association committee selected from the members provides linkage between farmers and the government. They will transfer the new technologies and government regulations to the farmers while informing the government about the problems during the rearing period (e.g. shrimp disease) and the difficulties of doing shrimp culture under the new environmental protection law
- *The construction site must be on the coastal area outside a mangrove forest*, preserving land for environmental protection or other purposes, and protecting the area for tourism
- The site must be located away from a productive agricultural area. If necessary, the construction sites near agricultural areas must have additional studies on environmental impact
- *All construction sites must have undergone an EIA* which is included in the feasibility study prior to the engineering design work
- *The construction sites should be located on the area listed in the Country's Coastal Zone Management Plan (CZMP)*

#### Implementation

Several SIS projects have been completed – in Ranot, Songkhla province; Ban Nakot, Nakorn Sri Thammarat province; and Kung Krabaen Bay, Chanthaburi province. Others are in varying stages of completion, and 28 more locations are on the list for feasibility study and engineering design. The ongoing project will cover a shrimp culture area of 44,000 ha. The government has invested US\$ 77.28 million. Farmers are expected to pay for the operation and maintenance cost through the farmers cooperatives management system.

#### Project details

There are a few sites that have been completed on the southern coast of Thailand, in Ranot, Songkhla province and Nakot, Nakorn

TABLE 2. Water quality at Ranot project before the project construction (1994)

Offshore Distance (m)		Depth (m)	Vis (m)	Sal (ppt)	pH	TAN (ppm)	TP (ppm)	TN gen (ppm)	TOC (ppm)
100	x	3.01	1.50	28.0	7.88	0.022	0.0095	0.59	0.31
	SD	0.30	0.00	0.0	0.09	0.012	0.030	0.11	0.14
500	x	4.95	2.36	27.7	8.02	0.009	0.133	0.897	0.15
	SD	0.30	0.312	0.6	0.03	0.001	0.086	0.411	0.06
1.000	x	6.28	1.88	27.7	8.04	0.009	0.009	0.417	0.17
	SD	0.24	0.537	0.6	0.01	0.004	0.004	0.098	0.05
1.500	x	6.90	2.21	28.0	8.08	0.004	0.138	0.597	0.10
	SD	0.173	0.26	0.0	0.03	0.003	0.028	0.064	0.07
2.000	x	7.07	2.17	27.7	8.11	0.005	0.085	0.313	0.16
	SD	0.40	0.29	0.6	0.03	0.005	0.025	0.164	0.1

TABLE 3. Water quality at Ranot project (near shore station) after operation, October 1999 to September 2000

Date	W.T (°C)	Sal (ppt)	pH	D.O. (mg/l)	TAN (mg/l)	No <sub>2</sub> -N (mg/l)	No <sub>3</sub> -N (mg/l)	PO4 (mg/l)	BOD (mg/l)
Oct '99	29	11	7.50	5.3	0.371	0.055	0.056	0.016	2.60
Nov '99	28	9	7.43	5.5	0.604	0.086	0.051	0.034	2.71
Dec '99	26	4	0.00	5.3	0.429	0.077	0.039	0.029	2.72
Jan '00	28	9	0.00	5.6	0.276	0.68	0.071	0.015	2.45
Feb '00	28	10	7.72	6.5	0.339	0.061	0.052	0.022	2.36
Mar '00	29	3	6.96	5.1	0.242	0.032	0.36	0.020	2.48
April '00	30	4	7.11	4.9	0.273	0.048	0.044	0.017	2.11
May '00	30	21	7.74	6.2	0.620	0.187	0.187	0.007	2.62
June '00	29	17	7.98	6.7	0.832	0.926	0.124	0.003	3.57
July '00	29	21	8.10	6.5	0.803	0.110	0.077	0.007	3.14
Aug '00	29	24	8.06	6.6	1.037	0.124	0.059	0.013	2.91
Sept '00	29	13	7.50	5.4	0.811	0.159	0.063	0.016	2.60

Sri Thamrat province. Details of the Ranot project are as follows:

Design	SIS – I design (Open Sea System)
Drainage area	4,800 ha
Farms covered	2,000 small and medium scale farm
Year started	Mid 1996
Treatment process	Physical aerated sedimentation
Period	10 hours
Pumping system	6 vertical mixed flow pumps; 2 underground HDPE pipelines 1 m in diameter placed 2 km offshore

The Ranot project was designed for pumping treated water offshore. The effluent collected from shrimp farms in the project area are treated by aeration and sedimentation along the drainage canal. The physical aeration and sedimentation process are the main treatment processes. Residence time is 10 hours. The water is rechecked at the pumping station for final treatment. If the water quality is acceptable, coagulant such as calcium oxide, alum and zeolite are added. The National Institute of Coastal Aquaculture

and Songkhla Coastal Aquaculture Station conducted the environmental impact assessment (EIA) before construction work and after the project started. The results showed that water quality meets the coastal quality standard as shown in Tables 2 and 3.

### Conclusion

The Seawater Irrigation System is one of the first attempts to prevent environmental degradation resulting from shrimp culture. The aquaculture industry produces excessive metabolic waste products. Uneaten food may be flushed into adjacent environment during pond preparation for the coming crop.

As the world's leading marine shrimp producer, the Thai government has realized its responsibility towards minimizing negative impacts of intensive shrimp culture operation. It has tried to devise several solutions to sustain its marine shrimp culture industry and protect the environment.

One solution that has shown promise is the Seawater Irrigation System. The system would incorporate pre- and post-water treatment through mechanical and biological measures. The pollution load in pond effluent is significantly reduced.

Although SIS can help reduce pollution loading from shrimp pond effluent

and provide high quality water supply resulting from increasing shrimp production, it is only contributory to a sustainable shrimp farm management. There are other crucial parts.

Farmers should be well educated on sustainability shrimp farm practice e.g. a limit of 10 mg/l biological oxygen demand (BOD) in all shrimp farm effluents, a ban of flushing of mud or silt from shrimp farm area into natural water source or public area, a ban on releasing of saltwater into public freshwater resources and a limit on stocking and amount of feeding.

Regulations have been established, but enforcement is another issue partly because of budget and manpower constraints. Therefore, farmers should be given incentives such as tax reduction or export privileges. These could provide strong incentives to follow environmentally sound shrimp culture practices.

The experience of SIS in shrimp farming in Thailand could be adopted by other countries in the region. The system has shown results that warrant serious consideration. It is environmentally friendly and can promote sustainable shrimp farming. ###