42. RESULT OF STUDY

ON

POLLUTION LOADING SURVEY

ผลการสำรวจมลภาวะสิ่งแวดล้อมทะเลสาบสงขลา

43. SUB-PROJECT TEAM

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44. Purpose of Study

This is the report for the pollution loading survey Phatthalung, Haadyai and Songkla municipality prepared by the authers for the first three-month peroid of study after joining with the Lake Songkla Project (LSP).

The purpose of the work deals with the study of the impact of pollution and pollution sources, to the lake's environment. The purpose may be written as follows :

44.1 Study the water quality in the main streams through out the large community e.g. Haadyai, Songkla and Phatthalung.

44.2 Study the characteristics of the wastewater and the wastes from various point sources such as urbanized and/or industrial areas.

44.3 Establish the per capita load per day for the sanitary wastes and industrial wastes.

44.4 Predict the tendency in water quality change for various selected main streams as the case study.

15. Introduction

Pollution assessment of point and non-point or diffused sources in the Lake Songkla basin is one of the main activities of the project. The results of studies are presented under four general categories : community wastes, industrial wastes, agricultural wastes and wastes derives from transportation activities both on land and water. The waste products from people and from manufacturing processes from various sources around the lake, especially from Amphur Haadyai and Changwat Songkla together represent the major waste effluents that drain or dump directly or indirectly to Lake Songkla without any treatment. Land reclamation of both Haadyai and Songkla in future have previsionally been selected as a growth pole for industrial and associated development in particular in relation to the pollution of the lake from the drainage of effluent from populated and industrial area.

Other sources of pollution includes the construction of port and associated investment, including the effect of dredging, There will also be effects on hydrology, including those due to a possible bridge/causeway which may be constucted. Also, the use of fertilizers, pesticides, and other agricultural chemicals can be expected to affect lake water quality. Particulary, the Penot Irregation Project, which will soon be implemented, may be important in this aspect.

Pollution of the lake and its environment could come from a number of sources in relation to population growth and resources development in the neighbouring area. It is timely now to estimate the capacity of the lake to absorb polluting agents and to control or to protect the pollution at source from each case.

Most primary data are based on field surveys and laboratory analyses by the staff undertaken under the project. Published data and results of previous studies are sometimes used when necessary, especially in projecting future conditions.

Pollution assesment for a lake basin of this size and complexity involves a variety of factors and aspects. Although best efforts have been made under the existing constrains of technical manpower and meterial availability and the time element, it is the project staff's belief that the extensive pollution monitoring plan during the implementation phase of the proposed water quality management program prepared under the project should be set up for verification of trends and future programming of pollution control measures.

46. Background

46.1 General Description of Lake Songkla

Lake Songkla, a lagoona lake of Southern Thailand (100°4' E and 7°5' N), measures roughly 6.5 km. from wast to east and 150 kr. from north to south, and has an area of about 616,750 rai or about 1,040 square kilometers (1,2) produces one of the largest lakes in Southeast Asia. The lake is quite typical of a combination of low land, receiving water flow (from more than a hundred short streams) and sand dune. The component of the lake sustem is, generally, very shallow (about 1 to 2 meter) and of a flat bottom.

According to NEDECO "Report on the Preliminary Survey of the Thale Sap Basin Project"[1] the general deseription of the lake may be condensed as follows :

46.2 Boundaries and Size of the Basin

The boundaries are as follows (Figure 1 and 2). On the west side the mountain range along the length of the penisula, with the mountains rise as high as 1,200 meters above sea level in some places. The boundary between Phatthalung and Trang closely follows the watershed. On the north side the catchment of Pak Phanang river. The watershed on this side is not clearly defined becaues of the intermediate swamps and interconnecting creeks and canals. The watershed has been drawn arbitarily midway through the swamp. The Gulf of Thailand locates on the east side. On the south side the mountains on the border with Malaysia and the catchment of Klong Na Thap.

The total area enclosed by these boundaries is found to be about 8,000 km^2. East of the Phet Kasem highway from Amphur Pattapum via Phatthalung and Amphur Khuan Khanun to Amphur Cha-Uat the land is, in general, gently sloping to very flat ; west of the highway the land becomes gradually more hilly and mountainous.

All rivers usually small in their size an called "Klong", and creeks in the basin drain towards the lake. The only outlet to the sea with the exception of a few very small klongs, which are blocked or dammed at the sea - shore is the fairly wide and deep chanuel at Songkla (cross section at mean standard sea level (MSL) about 3,000 - 4,000 m^3).

The lake system comprises four different parts, forming three basins of a lake chain. The areas of the basins can be found in Table PL/1

Table PL/1 Lake areas*

Lake	Area in Km^2	Sub-total in Km^2
Thale Noi	30	30
Thale Luang	470	500
Thale Sap	360	860
Thale Sap Songkla	180	1,040

*All of the areas are involved the island areas

The catchment areas draining towards the lake, sub-devided into areas east and west of the Lake are shown in Table PL/2

Table PL/2 Catchments

Draining towards	Area in Km^2					
	west of P.K. highway	west of P.K. highway sub-total	east of P.K. highway	east of P.K. highway sub-total	east+west of P.K. highway	east+west of P.K. highway. sub-total
Thale Noi + Thale Luang	1,600	1,600	1,300	1,300	2,900	2,900
Thale Sap	300	3,660	820	3,840	1,100	7,500
Thale Sap Songkla	Not available (NA)	NA	NA	NA	3,000	7,020

46.3 Climate

The frequencies of average annual rainfall, October through December rainfall and January through September rainfall, recorded at the 10 stations in Songkla and Phatthalung, based on monthly data for the peroid 1971 - 1977 are shown graphically in Figure 55. The 7-year annual average rainfall for 10 stations is 1,915 mm, while the mean is 1,950 mm. The average distribution of the rainfall per month at five stations (Phatthalung, Khuan Khanoon, Haadyai, Rattapum and Ranot) during the peroid 1952 - 1971 is shown in Table PL/3

Table PL/3 Average rainfall[1]

	A	M	J	J	A	S	O	N	D	J	F	M	Total
Average rainfall (mm)	88	125	68	82	85	99	288	472	368	121	33	45	1,884
Average number of rainy days	5.1	8.1	5.5	6.0	6.8	7.2	14.2	16.2	13.3	6.4	2.5	3.1	94.4

Clinatological data for the peroid 1951 - 1975 recorded by Songkla meteological station can be found in Table 3. It is observed that the wind is south-west from May through September (south-west monsoon + transition) and east from October through April (north-east monsoon + transition). There is no information about rainfall on the mountain ridge in the western part of the basin but orographic effects can be concluded clearly from the runoff of the different klongs. The annual rainfall is assumed to be highest in the central part of the mountain ridge where altitudes higher than 1,000 meters above MSL occur.

The annual rainfall in the southern part of the basin the catchment of the Klong U - Tapao is lower according to the 25 year average annual rainfall of 1,613 mm. at Sadao, which is situated at the headwaters of this klong

Table 31 shows monthly runoff of Klong U - Tapao, Klong Ratthapum, Klong Tha Khae and Klong Phru Pho, which are considered to be the main stream through highly urbanized areas on the catchments.

Based on the available data in Talbe PL/3 the mean monthly lake evaporation has been has been calculated using the Penman-Rijkoort formula. For comparison, some class A pan evaporation data multiplied by a pan factor of 0.7 are also given in Table PL/4.

Table PL/4 Mean lake evaporation (millimeter)

	A	M	J	J	A	S	O	N	D	J	F	M	Total
Mean monthly evaporation of Songkla	125	105	100	105	110	100	95	95	110	125	130	140	1,340
Pan at Khao Chaison x 0.7	117	113	97	94	100	86	86	63	70	104	119	120	1,169
Pan at Wat Ban Ai To x 0.7(1969)	136	116	105	112	116	110	94	62	82	109	118	118	1,278
Pan at Wat Ban Ai To x 0.7(1970)	116	113	97	94	102	86	85	63	68	110	102	109	1,145

46.4 Long-Peroid variations in Sea Level and Tides

Due to long-peroid tidal movements and to seasonal changes in meteorologic comditions, i.e. the effects of the monsoon winds on the shallow waters of the Gulf of Thailand, the yearly variations in sea level along the gulf are relatively great. In Songkla, roughly 60 cm, can be observed as these annual variations with the highest levels in November and December and the lowest in July and August. The strength and duration of the monsoons are not thesame every year, so the variations also differ slightly from year to year : for example, the sea level was exceptionally low in 1968

The tide in Songkla is semi-diurnal with inequalities. At spring tide the tidal range is approximatily 60 cm. and at neap tide approximatily 25 cm. The daily tidal volume (ebb+flow) is in the order of 70 - 140 million m^3. Inland, the tidal range is some 10 - 18 cm. at Ban Laem Chak, 6 - 10 cm at Pak Phayun and

3-4 cm. at Ban Thin. The daily tidal volume (ebb+flow) at Ban Laem Chak is in the order of 10 - 20 million m^3 The annual variations in sea level, even if, the variations of only a few days'duration are closely followed by the lake with more or less evaporation depending on the distance from Songkla.

It is notified that only in the rainny season (November - January) is the water level of Lake Songkla higher than the sea level due to runoff.

46.5 Lake Songkla and their surroundings

Generally, the lake are all very shallow and flat bottomed, except a natural channel running from Songkla North along Ko Yo to Ban Laem Chak there are no channels in the lake. The depth of this channel is 7 to 8 m at Songkla and $3\frac{1}{2}$ m at Ko Yo, but further north the depth decreases quickly to $1\frac{1}{2}$ m. In the northern shore of Thale Sap Songkla, the depth in the channel decreases further to approximately 1 m. and then suddenly increases to 12.m just before Ban Laem Chak. The maximum depth is approximatily 7 m can be observed at Ban Laem Chak. Klong Luang is deep from Ban Laem Chak to Pak Phayun with the maximum depths from 7 to 10m, but Ao Tong Ben is shallow (1 to 3 m in the deepest parts).

In a short survey the following depths were observed for Lake Songkla

Thale Sap (outside the channel)	1.0 - 1.3 m. MSL
Thale Sap	1.3 - 1.7 m. MSL
between Laem Khu La and Laem Chong Thanon	1.7 - 2.0 m. MSL
Thale Luang	2.0 - 2.4 m. MSL
Thale Noi	1.0 - 1.3 m. MSL

The land immediately surrounding the lakes is very flat and large parts of it are inundate every year during November and December. The lowest parts are situated in the north between Ban Thale Noi and the Banot irregation scheme and in the south near Ban Laem. Most of the villages around the lake are situated above 0.25 m. from MSL. An important number is situated between 0.50 m. and 0.75 m. above MSL, and a small number is situated between 0.25 m. and 0.50 m. above MSL.

It can be found that the yearly flood levels are highest in the northern part of the lakes, of about 0.8 m. to 1.4 m. above MSL., and some 30 to 50 cm. lower at Ban Laem Chak.

The bottom, everywhere, of Lake Songkla consists of fairly thick soft unconslidated layers of clayey or silty material. It is found by boring at the pumping station of the Banot ivvegation scheme on the northern shore of Thale Luang that soft silts and clays to roughly 8 m. below MSL and stiff clays to at least 19 m. below MSL (at which depth the borings were terminated) can be observed.

46.6 Runoff

Due to short peroid prelionary study, an available limited number of data about monthly and annual runoff from various klongs on the catchment of the lake are shown in Table 2 . Table PL/4 summarized average annual runoff, size of catchments and runoff coefficients of the main streams.

It is clearly that the highest amounts of rainfall most likely occur in the catchment of Klong Hua Kon, the eastern slopes of Khao Nok Ra and Khao Luang, the highest peaks in the mountain range. To a lesser extent this also applied to Klong Rattapum.

NEDECO consultants tried to correlate, graphically, average annual rainfall to average annual runoff based on the results of discharge measurements carried out by the Royal Irrigation Department (RID) at Ban Laem Chak using the fall between Pak Phayun and $V/R^{1/2}$ as parameters (where V is the average velocity in the cross section and R is the hydralic radius). The fairly straight kines cna be drawn through the points representing the years 1965, 1966 and 1968. The year 1967, however, shows a relatively much higher runoff. This is partly due to the abnormal high rainfall.

Average total amoun of annual runoff to Lake Songkla may be roughly estimated bt Rational formula. With the overall catchment of about 8,691.20 km^2 measured graphically from the highest contour, the boundaries of the catchment of Lake Songkla to the lake shore as shown in Figure 2., and the annual average approximately million m^3 per year, upon sitting the runoff coefficient to be.

According to the Habour Department, it was reported that the total annual water discharge in 1973 was 12,045 million m^3 with the current range from 0 - 2,545 m^3 per second. Together with this speed and volume, the water carries as high as 1,334,925 tons of silt per annum with an average of 3,657 tons per day into the sea. Non understanding the process could enormously help in delaying the filling up of the lake so, any type of development that locks the flow would result in shallowness in the basin. The available data show that the reverse flow from the open sea into the lake can be observed in March, June, September and October wiht the figures of 2, 164 ; 154 ; 1,328 and 958 million m^3 respectively. This indicates that an inflow regulation from the watershed area during these months should be performed to counter balance the reverse flow in order to prevent the amount silt transport of 93,644 tons into the lake, since the amount has been carried into the lake with the said reverse flow[2]

46.7 Litureture Survey

46.7.1 Community Wastes

46.7.1.1 Present Corditions

The Lake Songkla basin located in close proximity to Songkla, and Haadyai municipal area. It functions as a major drainage outlet, agricutural resources, support base for agricutural and industrial development and as the medium for extensive aquaculture and fishing industry.

The basin is bounded on the north and east by Songkla ; on the south by Haadyai ; and on the north and west by Phatthalung respectively. Its only outlet is the short narrow chanel at Songkla which joins the Gulf of Siam

46.7.1.2 Population

Limpadanai (1977) reported that there are 4,500 families (approximately) that reside on Lake Songkla's shore and about 150,000 aboriginal people around the lake.

These shoreline residents greatest dependence on the lake is for its animal protein mainly in the subsistence category with 6,000 tons of catch per annum used to be observed.

In fact, there are small revers or "klongs" numerously in the catchment area of Lake Songkla, say, more than a hundred klong. Most of these Klong usually are joined together to become the larger one which discharge runoff water and all pollution wastewater into the lake (Figure 2). Hence, the people distribution in Songkla, Haadyai, Phatthalung and the remained catchment area of the lake would be recognized especially community and local government area which have their locality near by the Klongs. These communities are considered as the sources of domestic and industrial water pollution which impact the lake's environment influently, and they would be neccessary to do their case studies about the pollution loading survey, population equivalent to BOD value and other predominant parameters help in assessment of pollution loads from various sources.

Table 52 show the population in and out municipal area of Songkla, Haadyai and Sadao. The census of the area was conducted during 1964 to 1975. The total population of Haadyai and Songkla municipal area amounted to 62,805 and 57,998 respectivily, which respresented 41 and 60 percent increase over the 1964 record popuation of 44,513 for Haadyai and 36,277 for Songkla municipal area with an average annual growth rate of about 2.8 and 3 percent respectively. The total population of Songkla and Haadyai at the year 1975 amounted to 748,233 and 200,980 with population concentration of 112.14 and 176.09 persons per square dilometer respectively. It is understood that an average annual growth rate of population increase during 1976 to 1981 is about 3.12 percent and during 1981 to 1991 is about 2.27 percent as shown in details in Table 53 prediction of population growth in Songkla. The latest census of Songkla has not conducted during 1979, at the present. However, it could be expected from Table 53 that the total population at that time amount to 0.8 million.

The lastest census of Phatthalung was conducted during 1978. It was found that the total population amounted to 392,096, with an average annual growth rate of 2.8 percent over the five-year peroid. This rate is then applied to the 1978 census to derive the 1979 population of about 403,075. In brief, it is estimated that there are more than 1.2 million people, the total population of both Songkla and Phatthalung abide in the encloced area of the lake.

the population distribution at various localities which licated nearby the small rivers or canals as shown in detials in Figure 50 for the resident distribution nearby Klong U - Tapao, Klong Lampum and Klong Ranot. These data are very useful for the case study as the aspect of water pollution loading assessment to the lake.

46.7.2 Water Supply

According to comprehensive water quality management plan for Lake Songkla, consideration must be given to water resources development, water supply and water utilization, Any development of the area should closely tied to the availability of high quality water to the economics involves. Surface and ground water sources are diminished and preferable in municipal areas of Haadyai, Sonokla Phatthalung and Ranot, the supplies from current scurces tend to be limited loss by evaporation amounted to 700 million m^3 per year with the lake capacity of about 1,600 million m^3. The mass balance of water in and out of Lake Songkla shows that the sore amount of seawater flow into the lake with the quantity, probably, slightly less than the irrigation demand because of some amount of underground water flows in to the lake. It is also, found that, the runoff water carries the huge in quantity of suspended solids at the rate of 1,334,925 tons per year or nearly 0.3 million m^3 per year which sediment partially on the lake bottom[4]. As two of the results, the salinity of the lake water tends to increase while overall capacity of the lake tends to decrease in future, in the future because of their population and industrial growth. Irrigation water, although seemingly in abundance, may be severely restricted if the lake is to be utilized as a major source domestic and industrial purposes. Nachiangmai (1978)[3] concluded that there were 9 irrigation projects in the catchment area of the lake, eight-ninth were the irrigation by dams and the remaining one, the Ranot irrigation project purposed to irrigate by pumping lake water directly with an amount of 56.2 million m^3 per year for servicing area of about 65,000 rai (10.4 square kilometer). Overall projects demanded both runoff and lake water with average of 358.8 million m^3 per year to serve 368,500 rai (58.96 square kilometer) as the cultural area while averall runoff water discharged to the lake was estimated to be 1,800 million m^3 per year, the lake surface

The temperature of the water in Songkla Lake, like in any other tropical low land water, has been measured throughout the year and the range was between 25.0 to 32.5 ^{o}C. No considerable fluctuation of temperature has beend found. Therefore, the temperature is not a limiting factor in the ecological distribution of the lake's organisms. The salinity regrime in Songkla Lake is one of the most important limiting factors for aquatic life. Normally the salinity fluctuates all the year round. Annual average of salinity in the northern basin range 0-8 ppt. while in the southern basin 16-28 ppt. The change is very well known as for years it has been observed continerously from 1965 to 1971 by The Songkla Fishery Station. Nutrients, in so far as the survey has been reviewed, the assessment of the nutrient cycles in this lake has been carried out. Therefore the nutrient budget is unknown. It is recommended that the nutrient that the nutrient cycles and budget of Songkla Lake should be carried out as soon as posible since the nutrients are very important limiting factors for its autochthonous production .

Oimocha[5] (1975) concluded about the irrigation projects which have the service areas in Songkla and Haadyai as shown in Table PL/4 also shown the location of these irrigation projects which four of them should be briefly described as follows :

46.7.2.1 Klong Wad irrigation project According to Figure 58 Klong Wad's source is in the mountain area named Nakornsithamarat, the westhern area of Haadyai. Its catchment area begin at Tambol Khaun Lang to Klong U - Tapao through the distance of about 10 kilometers. The project consists of two sections, first, Klong Wad dam. The concrete dam has 2.5 meter height and 32 meter width, with the three-3 meter wide gate at the middle of the dam.

The second part of the project is the irrigation system comprises two main canals which serve for the agricultural area of about 46 sq.km. The average yearly water runoff and average rainfall are found to be 9,770,000 m^3 during 1953 - 1971 and 2,283.54 millimeters per year during 1967 - 1975, respectively. However, information about the figure of the catchment area is not available.

46.7.2.2 Chamuong irrigation and Chamuong irrigation extension project. Both of the projects are completed and they purpose to serve the agricultural area of 120.48 sq. km. for the people that reside on both Klong Patthaphum banks by the concrete dam of 3 meter height and 30 meter width on the Klong Ratthaphum at 18^{th} kilometer from Khuenniang - Ratthaphum - Satul high way Bnd Khogchang, Amphur Ratthaphum. Based on the data in Table PL/4 and Figure 55 the average yearly runoff water and average rainfall are found to be 158.76363×10^6 m^3 during 1967 - 1977 and 1867.33 millimeters during 1971 - 1977 respectively with the catchment area of 272 square kilometers. Calculation on the available data shows the figures of about 0.3126 as runoff coefficient, C which is merit for estimating average rrnoff by Rational formula.

46.7.2.3 Ranot irrigation project The project comprehens on both Ranot pumping station and irregation system. The first one is purposed for pumping the lake water and discharge to the irrigation system. The station is located nearby the lake's

shore at Ban Huakha, 1 kilimeter westhern from junction of Klong Takria to the lake. The intake station includes with 10 units of 36 inches in diameter for suction pipes with the total discharge capacity of about 56.2 million m^3 per year[1]. The pumping water then discharge to the irrigation system comprise main and subsidary canals serve for 184 square kilometer as cutural area.

46.7.3 Sources of Community Wastes

No data are available on volume of sewage and sewage characteristecs in all communities in catchment area of Lake Songkla. Since there are no communities in the basin that have centralized collection systems, except the large municipal areas. Assessment of the point source wasteloads within all communities preferably, be done by studies conduct throughout the selected communities. For the pruposes of these studies, the per capita pollution load contribution from the more developed and highly-urbanized areas would be established. According to pulousness of Haadyai, Songkla and Phatthalung municipitality are silected for the case studies. Similarly to the highly-urbanized areas, the population equivalent to pollution load for the low-urbanized areas could be found by the case studies. It is unfortunate that most of the residents reside nearby various "Klongs" or small rivers have their households with sanitary facilities include units with septic tanks and sealed tanks without centralized collection, and some of these facilities discharge directly to the klong. Overmore, some of households with unsanitary facilities include only privy without anythings, and discharge immediately without anytreatment to the klong. So the wasteloads assessment may be only done by examining water quality upstream and downstream of the delected locatities along the banks of the klong. Depending on limited data source, at the present, only Klong U - Tapao is selected for the case study finding the per capita pollution load contribution from the low-urbanized areas. The results of community pollution loading survey are based on liturature surveys and field surveys which may be incompleted because of constrains of manpower, material availability and the time element, however, they preferably present as follows :

46.7.3.1 Sanitary Wastes in Haadyai

Haadyai Municipality is the commercial junction of the south. Amphur Haadyai itself is the largest of the ten Amphur of Songkla Province. It is a centre of tourism, commerce and industry. Haadyai also play the important role

in pollution Klong U - Tapao, and Lake Songkla. Particularly, Klong U - Tapao, the main stream of Haadyai, is now anxiously contaminated and preferably say to be heavily polluted in dry seasons. Klong U - Tapao flows from the mountain of Malaysia at Amphur Sadao and passes through many villages before traversy Haadyai Municipality and then proceeding to Lake Songkla. It is a dumping place for Haadyai Municipality for all types of wastes including solid waste and wastewater from community and industrial sources without any treatment.

The community sanitary wastes include commercial and domestic waste. Haadyai Mucicipality itself has a population at about 87,200 in 1977 and is expected to reach 114,900 by 1982. The municipal area include about 8 squar kilimeters. Community sanitary wastes not only come from Haadyai Municipality, but also from the many villages of the eight Tambols of Amphur Haadyai, which are situated along both sides of Klong U - Tapao.

Nachiangmai[3] (1977) reported that there 2 markets, 43 hotels, 208 restaurants, 8 saloons, 8 barbershops, 5 night-clubs, 6 turkist bath houses, 6 theatres, 5 hospitals, etc, together with 87,200 people which drain or dump directly and indirectly at under the bridge of Klong U - Tapao and at Klong Toey, the subsidiary of Klong U - Tapao which join together at Tambol Klong Hae, about 3 kilometers to the north of Haadyai Municipality. (Figure 58 shows in the map of Haadyai.

Phanratanaphaitoon[6] et.al (1976) studied about water pollution assessment of Haadyai Municipality. Their study disclosed that the B.O.D index of 60 kgs per year by the per capita sanitary waste loading standard of the Ministry of Health for every 1,200 persons per year of the growth of waste-producing inhabitants, could be expected. However, the per capita sanitary waste load contribution from Haadyai Municipality directly was not established. The principal purpose of the study was the apprehension of water qualities in Klong U - Tapao, up and down stream at the urbanized area. The work was made by five collections of water sample from three different stations along the stream within five months

from September 1976 to February 1977. the rainy season of that year. Various parameters were concerned and the results were shown in Table 66.-7.

Sewerage and Drainage

Sewweage system : Haadyai has no central public sewerage system at present but depends on using of oesspools or septic tanks serving individual buildings. In the future a publec sewerage system will likely be necessary in this area where the extend of growth results in a total volume of waste which exceeds the leaching capacity of the ground.

Table 36 shows number of water seal privies at selected Tambols along Klong U - Tapao. The data is notified that the people to privy ratios of all Tambols, excent Haadyai Municipality, are very low and vary from 70 to 2589, so the community waste eatimation, likely be difficult. It is understand that the waste assessment may be done easily by assessment of pollution load in the stream throuch that community because of limitation of alternatur methods,

Solid Waste.

Garbage collecting service is providing by the municipal for the entire municipal area. The refuse is haulded to an open dump about 8 kilimeters west from the city. It is burned in the open air. Also, additional solid waste from commercial and domestic sources are dumped into the klong and some is dumped on the land . During flooding, plastic bags, rubbish, etc, are readily risible in Klong U - Tapao.

46.7.3.2 Sanitary Wastes in Songkla

only six-seventeenth tambols of Amphur Muang the highly urbanized area in Songkla play the importance role as pollution sources for Lake Songkla. These six Tambols are include Songkla Municipality. The people who live around the lake consist of about 13,300 families comprise about 400,5900 and 7000 families in Thale Noi, the upper zone and the lower zone of Lake Songkla respectively. Fisheries is the most important occupation, totaling about 7,700 families, with 3,500 families in the upper zone, 4,000 families in the lower zone, and 200 families at Thale Noi[3]

Songkla Municipality itself has a population of about 57,473 people with an area of 6.7 square kilometer Ko Yo, an island famous for Thai silk has a population of about 3,699. Ko Yo in the future, after the bridge construction is finished, is expected to develop into an important tourist attraction. Fishing village around Lake Songkla include Ko Yo, Hua Kua, Bating Mo, Pawong, and Kao Poopchang

Small and large ships, about 400 to 500/day are frequent at the harbor. Oil pollution can be observed at places of docking and berthing ships which release oil in the vacinity include both fishing boats and tanker and other commercial ships. However, oil pollution is not yet serious in this region, but could be in the future as shipping or port construction or industrialization grow unless proper contrils are implemented.

46.7.3.2.1 Sewerage and Drainage System

Like practically Haadyai Municipality, Songkla Municipality has no public sewerage system at present but depends on use of cesspools or septic tanks serving individual bukidings. Because the soils are reasonably permeable and the ground water levels are not close to the surface, this system has performed reasonably satesfactorily in the part It can be expected to be used indefinatily except for the built-up area of the city including the business section where, sooner or later, a public sewerage system will be need to maintain minimum environmental chanliness. As mentioned above, many building along the lake shore (Nakorn Nork Road) do not have any cesspools or septic tanks.[3] They have discharged wastes to the lake for many years.

Songkla municipal area is drained by KLong Kwang, a natural stream running through the town, and then discharge to the lake.

46.7.3.2.2 Solid Waste Collection and Disposal System

The range of domestec solid waste weight generated per person per day usually lies between 250 and 1000 grams, generally, and density varies from 100 - 600 kg/m^3 with the volume of $\frac{1}{2}$ to 10 liters/person-day of the solid wastes could be espected.

The main constituents of domestic solid wastes vary as follows[10].

egetable-putrescible matter	20-75 %
Inert matter	5-40 %
Paper	2-60 %
Glass	0-10 %
Metals	0-15 %

It is unfortunately that there are no data available about the solid waste characteristics in both Songkla and Haadyai areas, then they are likely, assumed to fall with in the above mentioned ranges. The method of collection and disposal of solid wastes may be described as follow :

Songkla municipality has about 85 struts with a total length of about 48 kilimeters from which the solid waste have to be collected. There are about 5 side-loaded trucks working in 5 zones in the municipal area ; one truck work between 3-11 am, while the other three work between 6 am. to 3 pm. dialy with one spare truck for additional collection of solid wastes deposited in the storm sewers. The collection efficiency seems to be as low as in Haadyai municipality so the litters of wasetes are still present in most places.

After collection, the wastes are then disposed of by open dumping and daily burning at a site on the Songkla Lake shore west ot the city. It is different from the disposal of solid wastes in

Haadyai, which are disposed of by open durning and daily burning on an area of over 400 rai. 8 km. southwest of the town. Due to the topography and distance of this open durr, the chance of its contamination or causing adverse effects to Klong U - Tapee and the town is expected to be minimum.

Contrast with above mention, the solid wastes disposal in Songkla is not considered hygienic because bachates from the open durre generated during the wet season can easily find their way into the lake, It was reported that the leachates in some location such as in the nited State were found to contain high concentrations of toxic materials and enteric organisms. The contents of BOD of as high as about 3,300 mg/l have been reported along wiht heavy metals such as zinc (0 to 370 mg/l), copper (0-9.9 mg/l) and lead (as high as about 23 mg/l) [10]. Thus, the discharge of solid wastes leachate into Lake Songkla present a possible threat to the aquatic lives and human-being. Moorover, the open dump is not desirable from the aesthetic view point because it can cause unsightliness and offensive odour to the residents near that area. It is recommended that another area far away from the lake shore, and far away from community be considered as a disposal site for the solid wastes, or the present open dump area should be converted to sanitary landfill with provision of a proper drainage system for divergence of the leachate generated away from the lake.

46.7.4 Industrial Wastewater

Limited available informations for industrial survey and classification in Phatthalung, Songkla and and Haadyai are shown in Table 57 to 64. Figure 60 shows distribution of industries in the catchrent area of Lake Songkla.

According to the available data, it is mention that only industrial sources in Haadyai and Songkla are the main sources of industrial wastewater dump to Lake Songkla and impact televantly to the lake environment.

The necessary discroption about these industrial sources in Phatthalung Haadyai and Songkla may be written as follows :

46.7.4.1 Phatthalung : Refers to table 57 to 58, there are the total of 923 light industrial plants in Phatthalung, with 822 plants are the rice mills, the major industry. Most of them are small scale industrial plants, and are widely distributed in community areas. Some of them located near the lake shore and discharge the wastes directly to the lake but the environmental impact due to their wastes seems to be no significant.

46.7.4.2 Haadyai : the major industries together with other pollution sources in Haadyai which discharge their wastewaters into Klong U - Tapao and Klong Toey can be found in Table.

Munag Koa Roopchang, a tin mine in Amphur Sadao discharges large quantity of its wastes into Klong U - Tapao upstream from the Haadyai waterworks. The wastes contrain high concentrations of solids and silty particles which could impair the water quality and ecology balance in Klong U - Tapao.

The wastewater from Nakornthip Co. Ltd., a soft drink bottling factory, is produced in large volume daily and is high in organic content. The discharge point of this wastewater, which is partially treated by activated sludge process, is about 200 meters upstream of the Haadyai waterworks posing a potential treat to efficiency of the water treatment processes.

Two ice plants in Haadyai damp hot, oily and turbic water into Klong U - Tapao at the rate of abut 50 m^3/day per plant. Two rubber processing plants also discharge their wastewaters into the klong, while another larger rubber processing plant, discharge its wastewater into Klong Toey

nearby with the rate of 3,270 m^3 per day, and the water is recycled three times prior disposal without treatment. The wastewateractually, contain dirt mud, sand, tree bark and rubber bite which cause serious pollution to Klong Toey.

There is one alcohol distillery, the Alcohol Distillation Co. Ltd., located at Haadyai, discharges its partially treated wastewater of about 20 m^3 per day containing mostly molasses and alcohol into Klong U - Tapao.

At the present, there are about 349 factories of various types and sizes in Songkla province, of which approximatilly 30 percent are rice mills, 3.4 percent are fesh processing factories, 0.06 percent are mines, 1.8 percent are rubber processing factories and 35.26 percent are miscellaneous. Details are shown in Table 59. Among various pollution sources, the fish mills at Klong Phawong are considered to be the source yield highly strength pollution in the huge quantity to that klong. The water quality analysis found that Klong Phawong is completily contaminated by wastewaters from the factories and is sererely polluted in dry season. Some information about water quality in the klong will be found and discussed later. The treatment provided is a series of 3 ponds which did not seem to operate properly.

46.7.4.3 Songkla Fish processing and cold storage factories are the major industries in Songkla which create pollution to Lake Songkla, as shown in Table 63. There are presently about 400 - 500 small and large fishing boats catching fishes, shrimps, squids, crabs and clams in the deep sea, Lake Songkla and its nearshore area. The most polluted part of Lake Songkla is on the shoreline of Songkla municipality where various pollution sources such as the fish markets, Fishery dwarfs, cold storage factories, gasoline stations, piers for commercial and fishing boats and houses are located. Oil pollution problem is rather sever at the piers and anchorages due to discharges and spill of oil from the boats.

Table PL/5 Wastewaters in Haadyai Area*

Progress Report on Preliminary Tourism Development Study of Songkla Haadyai, TOT : Bangkok (1979)

Sources of wastewater	Quantity and characteristics of wastewater
1. Tin Mining at Amphur Sadao	Turbid water and some minerals dissolved
2. Nakornthip Co., Ltd. Ban Phru	Washing water and organic wastewater
3. B.U. Commercial, Pholphichi Road,**	962 m^3/day washing water (pH 6.95, BOD_5 117 mg/l, COD 375 mg/l, ss 368 mg/l)
4. Sinn Thai Tin B. Rubber Co., Ltd., Sakorn Mongkol Road***	1360 m^3/day washing water (pH 7, BOD 153 mg/l, ss 144 mg/l)
5. Teck Bee Hang, Petchakasem Road (Discharge to klong Toey)****	2450 m^3/day Washing water (pH 7.01, BOD_5 134.5 mg/l, COD 479 mg/l, ss 584.4 mg/l
6. Solid wastes from Haadyai municipality and domestic	Sewage from markets, hotels housing, industries.
7. Wastewater from Haadyai minicipality, with 2 main public sewers	Sewage from markets, hotels housing, industries.
8. Two ice plants : Prathan Cold Storage Co., Ltd. and Watanasin Co., Ltd.	750 m^3/day (cooling water, oil turbid water
9. Haadyai Alcohol Distillation Co., Ltd,	720 m^3/day (Klong U - Tapao become seriously turbid and odourous.) Foam can be observed at least 2 kilometers downstream. Offensive odour can be detected at least 10 kilometers away ; etc.)
10. Sawing factory, Pholphichi Road	Dumping solid waste from processing
11. Haadyai waterworkd*****	drain highly turbid water from sedimentatoon tanks and water sand filters which comprise alum and calcium oxide, directly to Klong U - Tapao

Sources of Wastewater	Wastewater Quantity m^3/day
1) Thai Marine Food Co.Ltd	3,000 cu.m/day
2) Thai Seri Cold Storage Co.Ltd.	3.000 cu.m/day
3) Pand N.S. associate Co. Ltd. (Gas Station)	Oil
4) Fishery dwarf, Fishery Department	5,000 cu.m/day
5) Commercial ships and boat	at least 400-500 ships/day
6) Solids wastes from Songkla municipality	No Record
7) Waste water from Songkla municipality (includes mardet, domestic and business zone)	No Record
8) Koyo ; 3,699 people	No Record
9) Tambol HuaKoa ; 9,894 people	No Record

* Narong Na Chiangmai (1977)[3]

** Udsanangkornchai, J., and Khaw neam D. (1979)[11]

*** Pudthiphairoj, Pisit (1977)[12]

**** Pinijchai, S., and Chatchawan. V. (1979)[13]

***** Eield survey by the research group.

47. Results and Discussion

47.1 Water Qualities of Selected Main Streams

Non-living water resources of Lake Songkla watershed include small rivers or "klongs" and ground water in addition to the lake water itself. Data on the exact number of streams and their flows are not available although the RID has gauging records of a few important ones.

From the best available map, eleven major streams may be seem as show in Figure 265, to drain into Lake Songkla as follows

a) To Thale Noi
   1. Klong Pa Phayom (to the mangrove area north)
   2. Klong Tha Nae (through Amphur Khuan Khanun)
   3. Klong Mae Toey

b) To Thale Luang
   4. Klong Yai (through Phatthalung)
   5. Klong Hua Mon (through Ban Lam Pam)
   6. Klong Tha Madua (through Amphur Kao Chaison)

c) To Thale Sap
   7. Klong Pa Bon and Klong Loet
   8. Klong Long
   9. Klong Phru Pho

d) To Thale Sap Songkla
   10. Klong Kao Yai (through Amphur Rattapum)
   11. Klong U - Tapao (through Amphur Haadyai)

According to the significant figures of runoff and population distribution , Klong U - Tapao through Haadyai municipality and klongs through Phatthalung municipality are selected for the case study of pollution loading assessment. Partial study on water qualities of water at Lake Songkla shore near Songkla municipality and water of Klong Phawong, the fish mill zone of Songkla are also carried out. Methods of the study are described briefly here and the details can be found in the methodological section of this report. The results of study may be devided

into three parts according to Songkla , Haadyai and Phatthalung municipality respectively and, they are presented and are discussed breifly as follows :

47.2 Water Quality at Klongs through Phatthalung Municipality.

There are two upstreams on the west of the municipal area, the main stream is Klong Tha Khae, the remaining is a short stream with the name is not available. These klongs are joined together at the central area of the municipality, receive all most domestic, commercial and some amount industrial wastewaters. The combined down stream called Klong Khuan Rae flow to the east of the town there meet Klong Lam Pam and Klong Tha Pho at Tambol Lam Pam before discharge the wastewaters to Thale Luang.

The partial municipal wastewater, also, discharge to the rice field, the easthern of the town and then are drained to the lower part of Klong San at Tambol Khuan Thop before joining with Klong Khuan Rae.

Klong Lam Pam is likely considered as the largest source of diluted water for the wastewater. It is noticeable as the lower part of Klong Hua Mon, one of the most important klong on Lake Songkla catchment*.

BOD : It is obvious that the BOD values of the downstream is signifucabtkt high at the station P.4, the weir at Khuan Thop with the figures of 19.2 mg/l in April and 8.3 mg/l in March, This is possible because partial wastes from the markets and commercial areas in Phatthalung municipality are discharges directly to Klong San with the dilution by small amount of water in that klong because of dry season peroid. BOD, also sums to be too low with the average figures of 6.2 mg/l for the two months, it may be, due to a large amount of diluted water by Klong Tha Khae. The water qualities of Klong Tha Khae itself, show as much as 2.65 mg/l BOD at station P.6, the bridge at Tambol Tha Khae. (Table 65 - 66))

The BOD values in all stations for the peroid are recorded to be not more than 6 mg/l, the lowest level of the heavily polluted water according WHO standard, except for station 4, the range from 19.2 to 8.3 mg/l

BOD indicated severely the bad quality of water which have no suitable for small aquatic lifes, It is also found that there are the gas bubbles appear along Klong Khuan Rae and the lower part of Klong San between station P.4 to P.2 and P.3 to P.2 respectively, espectially at station P.2. It is understanded that large amount of organic matters are deposited at the bottom of these streams, and the organic decomposition by anaerobic bacteria, should, therefore, be expected to be quite high.

According to Figure 62 BOD values along up and downstreams through Phatthalung municipality, it is clearly that the water qualities are contaminaled by the municipal wastes. Increasing BOD between station P.5 and P.4 is roughly 90 % in April. The BOD values are reduced by the self purification of the klong along the downstream distance, and is found to be reduced to about 33 % and 6 % in the summer, March and April respectively. Then all polluted downstreams are effectively diluted by large quantity of water in Klong Lam Pam which BOD values are reduced to be about 17 % and 39 % of the values at station P.4 for March and April respectively. The dotted lines represent the munical wastewater discharge partially into the lower part of Klong San. The volumetric flowrate of the total downstreams measures at station P.4 is found to be approximately 14,144 m^3 per day. With the amount of the flowrate, the total BOD load of 25.884 kg/day can be expected from the municipality with the population of about 18,939 yields the per capita pollution load per hour of 13.86 or 14 g/capita-day. The fiqures are quite low than 20 g/capita-day, the standard of Department of Environmental Health, Ministry of Health.

There are ofc ause, serious errors in the BOD measurements, So the results of analysis should be used only in somecases of interpretations where significant figures are not significant. It is reccommended that the BOD analysis should be done at the same temperature of the sampling stream, which is about $30^{o}C$ instead of $25^{o}C$ because $30^{o}C$ is more suitable for the mitabotism of tropical bacteria than another one, yielding the higher in BOD values which are more closed up to the true values than the analysis at $25^{o}C$

Briefly, the water qualities in all downstreams, is obviously polluted by the municipal wastewater and are not suitble for water supply according to the WHO standard for raw water. Any constructions that reduce the water flowrate of the upper part of Klong Lam Pam will make the more deterioration of the water qualities, then impact directly to the lake environnent,

Total alkalintiy and acidity : Total alkalinity in the rang of 49 to 60 mg/l as $CaCO_3$ which is above of 20 mg/l, the lowest limit for freshwater aquatic life and water supply according to .S.E.P.A. quality criteria for water[15]. The acidity, generally, is found to be high throughout at station P.1, P.2 and P.4.

Nitrate and Phosphate : It is stressed that the figures of NO_3-N and PO_4-P are rather low and have less significant in interpretation. In the point of veiw of NO_3-N along distance to downstreams of Phatthalung municipality as shows in Fogire 63, it is clearly that the NO_3-N in Klong Tha Khae is increased while it passes throughout the town. The evidance of partial conversion of NO_2-N in fresh wastewater at station P.4, to NO_3-N along the downstreams is shown by reaching to the maximum value of NO_3-N at station P.2 and P.3, about 8 km along the downstreams from station P.4. Then, NO_3-N is apparently decreased at Station P.1, the junction of the downstreams and Klong Lam Pam because of dilution by the large amount of water in that klong.

Figure 64, shows PO_4-P along distance to downstreams. It is doubted about two abnormal highly points at station P.5 and P.3, however, the results in April sums to be convincing data. Increasing of PO_4-P between station P.5 and P.4 ofcause, due to the contamination of yeilding phosphorus from the community wastes. Increasing of PO_4-P between station P.4 and P.3 may be, due to the leaching phosphorous in theerice feild by wastewater and then drains into Klong San at station P.3. This understand is based on the assumption that some of chemical fertilizers are used by the farmers in their in their rice cultivation.

The NO_3-N and PO_4-P at station P.1 are obviously, droped to some degree while the chlorophyl content is quite high. This is may be due to conversion of NO_3-N and PO_4-P to energy and the growth with photosysthesis by phytoplankton and algae. It is understand that the null contents of the chlorophyl at various stations P.4, P.3 and P.2 shownonavailability of photosynthesis because of the stream turbulence which retards the potosynthesis greatly.

The PO_4-P and NO_3-N contents in upstream at station P.5 and P.6 are small and have less significant in interoretation. However, they indicate very the conclusion that the land of watershed is generally, clean and unurbanized area.

Refers to Table 65 to 66 phosphorus to nitrogen ratio (P : N) can be found approximately to be 1 : 10 at station P.5. This ratio is more closed up to 1 : 5 than the P : N ratio of another stations.

With the 1 : 5 as actual P : N ratio of natural fresh water according to the standard of fresh Water quality Standard. and the lowest BOD value at station P.5, it is reasonable to believe that the stream at that station is mostly not contaminated by pollutants.

Up on the agreement, the water qualities at station P.5 are considered to be the best and will be used as reference of the remaining stations in the next studing peroid.

47.3 Water Quality at Klong U - Tapao through Haadyai Municipality

Little information is available on such subjects, it cannot as yet be established definitively to which the pollution loads will be estimated. The pollution loading assessment, therefore, be considered as very tentative. It has only been made to allow a preliminary study of Klong U - Tapao's water qualities.

According to Nachiangmai[3] (1977), the water qualities of the klong are studied and reported as shown in Table 69. The water qualities analysis are made by collection of water sample from six different positions along the stream within two months from May, 1977 to June, 1977. The samples are collected and examined in laboratory to test the various parameters, however, BOD, phosphate, cholride and nitrate content are not involved.

DO : Based on the available data in Table 67 to 69, plotting of DO versus up and downstream distance of Klong U - Tapao through Haadyai municipality. The DO in the stream is generally acceptable at station U.1, the upstream station of the municipal area, then decreases along the stream distance. DO values of station O, IP and B are found to be 5.7, 4.9 and 4.5 mg/l respectively. It is obvious that Do is droped repidly at station DP., the downstream of the town, due to the discharge of Haadyai municipal wastewater and the wastewater from Haadyai Alcohol Distillation Co. Ltd., then, the DO sums to be gradually increased at station RB, the station at railway bridge across Klong U - Tapao, about 3 kilometers south of the town.

According to the quality criteria for water of the U.S. Environmental Protection Agency and the standard of receiving water which is suitable for aquatic life as shown in Table 70 and 71, It is reasonable to report that the downstream is heavily polluted with the DO below than 2 mg/l, the minimum value allows for gquatic life, while the upstream at the station IP and B are considered to be contaminated because of their DO values are lower than 5 mg/l, the minimum value allows to maintain good fish populations. The serious consideration of the capability of the self purification of the klong should be established.

Nutrients : Only NO_3 -N values at various stations are plotted versus the up and downstream distance along the klong as show in Figure 66. It is cleared that the NO_3-N at various stations are obviously higher than the NO_3-N values of the streams through out Phatthalung municipality as deseribed in the section 8.2. With the NO_3-N values are more than 10 mg/l, the maximum allowance for water supply according to the criteria for water of .S.E.P.A., it is recommended that the raw water in the klong is not suitable for water suply purpose without any necessary pretreatment to reduce degree of the pollution. Morever, comparision with the industrial wastewater standard of Ministry of Industry as shown in Table 916, with NO_3-N values are more than 1.0 mg/l, the maximum allowance for polluted water, the water of Klong U - Tapao is likely to be completely polluted.

Figure67 shows relationship between DO and NO_3-N at the various stations along the stream leading to the conclusion that the nitrate nitrogen (NO_3-N) is inverse proportion to dissolved oxygen (D)). This is likely contrast with the theory of generalized effects of organic pollution on a stream which is stated that the nitrate nitrogen should be decreased with decreasing of dissolved oxygen except the zone of clear water, the nitrate nitrogen is gradually declined while dissolved oxygen approaches to its initial saturated condition[15].

It is understand that the nitrated nitrogen formed by oxidation of inorganic compounds by autotropic bacteria, espectially nitrifying bacteria, may be more than nitrate nitrogen used by green algae for their photosynthesis. The equations are as follows :

Autotropic bacteria

$$\underbrace{NH_3}_{\text{inorganic compound}} + \text{Oxygen} \xrightarrow{\text{Nitrosomonas}} NO_2^- + \text{energy} \qquad (5\text{-}1)$$

$$NO_2^- + \text{Oxygen} \xrightarrow{\text{Nitrobacter}} \underbrace{NO_3^-}_{\text{nitrate nitrogen}} + \text{energy} \qquad (5\text{-}2)$$

Green algae

$$CO_2 + PO_4 + \begin{Bmatrix} NH_3 \\ \text{or} \\ NO_3^- \end{Bmatrix} \underset{\text{Dark reaction}}{\overset{\text{Photosynthesis}}{\rightleftharpoons}} \text{New cell growth} + \overbrace{O_2}^{\text{dissolved oxygen}} \qquad (5\text{-}3)$$

Refers to these equations it is reasonbly to interpret that if most of the amminia nitrogen (NH_3-N) is converted to nitrate nitrogen by autotropic bacteria, then, the dissolved oxygen formed bt algal photosynthesis may be insignificant. Rapidly decreasing in DO while NO_3-N is obviously increased as shown in Figure 282 indicates that large amount of dissolved oxygen in the stream is used by autotropic bacteria to convert ammonia nitrogen to nitrate nitrogen Increasing in NO_3-N while DO is continuously decreased show the inefficiency of algal photosynthesis in that stream, and reveals that the stream is overloades by the pollulants from Haadyai municipality during the dry season.

In the point of veiw of the correlation of light penetration with up and down distance along the stream as shows in Figure 283, the maximum light penetration is lower than 2.5 ft. in April, 1977, and may be only a few inches in June, 1977, while the the light penetration of 1.0 ft. in May, 1977 seems to be average values. It is stressed that most of the depth of water at Klong U - Tapao exceed 2 meters (about 7 ft-), therefore, with the light penetration less than 2.5 ft., the photosynthesis by algal at the bottom of the klong is, ofcause,defected. In the otherhand, the algal growth at these stations is very small. The brown color og water everywhere along the stream as records in Table 44 also, confirms such interpretation,

Again, refers to Figure 283, the light penetration is likely decreased at station O then begins to be increased at station IP and B for April and June, 1977 respectively,. It is doubted, however, by interview of the technician at the intake pumping station (station O) of Haadyai waterwords the fact is that large amount of the sludge from sedimentation and sand filter tanks in the water supply plant is usually recharged to Klong U - Tapao neare by the station O. The sludge, ofcause, contain with alum and lime cause highter turbidity at station O then induce the suspended solids in the klong to deposite at some distance a along downstream from the intake pumping station yields the lower turbidity (or higher in light penetration) as the final result. The light penetration in May, 1977 is recorded to be constant at 1.0 ft, this is due to the heavy rainfall, may be a few days before collection of water samples. The runoff water washes the large amount of suspended solid, usually soil particles then discharge derectly to the klong. The recharge of the sludge from the waterworks have noinfluence to the light prenetration because of very small amount compares with the runoff water.

By observation, the algal bloom is found everywhere in Klong U - tapao at Tambol Ku Tao near by the estuary. This is evident that most of the nutrients from Haadyai are useful for primary production at the zone near by the estuary of the klong, say, about 8 kilometers downstream from the town.

As the results, Klong U - Tapao it self acts. as the huge sedimentation tank. The organic pollutants in the fresh wastewater from Haadyai municipality, therefore, are induced to deposite at the bottom of the klong and the water pollution problem due to anaerobic condition could be expected in the dry season.

Additional investigation on the water qualities is studied by the authors as shows in Table 8-8 leading to the reccommendation that the raw water at the intake station of Haadyai waterworks should not be used for water supply without neccessary treatment to reduce the BOD value from 4.10 mg/l to 3.0 mg/l or less than in order to achieve the good water qualities according to WHO standard of surface water.

Furthermore, the 0.037 mg/l of arsenic compounds is found at the waterworks (station O). It is preferably to assess that the tin mines along the upstream discharge their washing water contain highly suspendsolids and some amount of inorganic arsenic compounds, to Klong U - Tapao. Although the arsenic content does not excess 0.05 mg/l the maximum level for the purpose of

water supply according to the U.S. Public Health Service standard[17] however, the existence of very high turbidity of the stream is still the serious problem and need some relevant remedy. Removal of abnormal high turbidity yields the higher capability of algae for its photosynthesis, in order to achieve the higher water qualities of the klong.

47.4 Water Quality of Lake Songkla Near by Songkla Municipality

As insufficient information is available on such subject as water qualities and pollution surces, it cannot as yet be interpreted in details about the assessment of pollution loads from Songkla municipality. However, preliminary study of water quality as dissolved oxygen by Nachaingmai[3] (1977). and the location of various stations can befound in the Figure, 61, which indicates the DO values with the maximum of 8.1 at station 1 and the minimum of 6.0 mg/l at station 4. These DO values exceed 5 mg/l, the minimum DO allows to maintain good fish populations according to the quality criteria for water of U.S. Environmental Protection Agency (U.S.E.P.A.) so the water qualities sum to be quite good. However, the order of water at these station is unpleasurable, so it is affirmation that the lake is contaminated by pollutants from the town.

Additional investigation on the water qualities are also carried out by the authors as shown in Table 72.

The study found that the BOD at station S.2 was 20.2 mg/l indicated the polluted water condition at that zone according to WHO Standard of surface water. With the minimum BOD value of 2.02 mg/l at station S.1, the water quality at station S.1 is considered to be quite good. Difference in these BOD values shows the impact of the pollutants from Songkla municipality to the lake's environment. Again, the mitrogen to phosphorus ratio N : P in the range of 1 : 92 to 1 : 100 at station S.2 and S.2 respectively, confirm such understanding.

The outhors also, investigate for the water quality at Klong Pha Wong, the important industrial area of the fish mills about 9 kilometers south from the town along the highway joins between Songkla and Haadyai. There are about six fish mill factories locate near by the klong and drain their washed water directly (may be, without any treatment) to the stream. With the small amount of the stream in Klong Pha Wong as dillutant, it is no doubled that the Klong is heavely polluted as indicates by the 97 mg/l as the BOD value of sampling water in that stream at station S.3. unfortunately, the water quality studies at some distances downstream

from the industrial area along the klong to Lake Songkla at Ban Tao Phao. It are not available, it is only in the future program at the time of writing the report. So the impact of the pol lutants from these factories to the lake's environment is still doubt.

The authors, recently took the sampling water of the fresh wastewater from the two fish mills located nearby the seaside and, of the sea water at seaside at Tambol Kao Seng, 3 kilimeters south from Songkla municipal area the results of the study are shown in Table 50.

Based on the limit available results, it is quite properly to report that the sea water qualities are damaged by the factories according to the BOD values of the effluents are very high. However, it should be kept in mind that the further study need to be done in order to abtain the degree of impact.

48. Methodology

48.1 Meteorology

Data on runoff water and rainfall in the catchment of Lake Songkla were collected from the Department of Roual Irrigation and the Department of Meteorology. Records on solar radiation, evaporation and humidity were obtained from the Department of Meteorology.

6.2 Hydrology

Hydrological data for Lake Songkla and the tributary rivers were collected from the Report on the Preliminary Survey of the Thale Sap Basin Project, the Department of Habour and the Royai Irregation Department (RID) respectively,

Six of the current gauging stations were placed in operation in 197 and are being operated by the RID. Rating curves for these stations have been partially established. Lake levels have been recorded at Songkla from 197 to t97. There are actually 2 stations operating in the lake in recent years.

48.3 Water Quality Monitoring

48.3.1 Laboratory and Field Equipment.

(1) Laboratory

The temporary water quality laboratory was ficilitated by the Department of Chemistry, Prince of Songkla niversity and equipped through NEB funds in 1977. The building having an area of 72 m^2 comprises with laboratory space and office space was originally desigued for a limited limnological (basic ally monitoring) program for the needs of Pollution Loading Survey of Lake Songkla (PLSLS) study. Extensive additional laboratory support was given under the present project to the monitoring of industrial effluents ; domestic sewage and feed lot effluents ; lake water pollution monitoring ; and the primary productivity study.

The laboratory is fully airconditioned equipped with an 24,000 BT ., air conditioner that is sums to be insufficient to keep the whole laboratory operate properly because of the 27^{o}C as the control room temperature by the full capacity of the air conditioner is likely to be too high.

(2) Equipment

Field observations, sampling and laboratory analysis were facilitated with the following major equipment.

(a) Transportation

1 (12 feet) speed boat (furnished by NEB), the office vehicles and Land Cruiser are facililated by Prince of Songkla University (PSU)

(b) Field Equipment

1 water sampler ; 1 water flowrate meter ; 1 AO salinometer ; 1 Hach spectrophotometer model DR/2 ; 1 secchi disk , 1 camera.

(c) Laboratory Equipment

1 double-beam / visible light spectrophotometer ; 1 Kjeldahl apparatus ; 1 pH meter ; 1 microscope* ; 2 ovens ; 2 fume hoods* 1 vacuum pump* ; 1 analytical balance ; 60 BOD bottles and a number of smaller items such as suction filters ; magnetic stirrers ; mixers ; electronic calculator; glassware ; chemicals ; distilled water*

(d) Office Equipment

1 electric typewriter.

(e) Supply, Repair and Maintenance

Some supplies, that were supposed to be provided by the Lake Songkla Project (LSP) locally, such as chemicals or filters, were either so prohibitively expenxive in the local market, available in tiny quantities only, or of low grade quality so that a number of planned tasks could not be carried out or only to a limited extent.

A major peoblem was the maintenance and repair of laboratory and field equipment, mainly due to slow administrative actions and delayed delivery of imported spare parts and equipment by some foreign firm. sually, a three months delay could be considered as quick action. Repairs could be

done locally as far as spare parts are available.

* facilitated by PSU. only

48.3.2 Staff

The technical staff of the laboratory consists of 5 persons of various disciplines. The positions and the number of personel are as fellows :

Section :	Positions :	No :
Chemistry :	Research Chemist	1
	Lab. Girl	1
Engineering :	Research Environmental Engineer	2
Microbiology :	Research Microbiologist	1
Bacteriology :	Research Bacteriologist	-

Certain peroids of understaffing caused some constraints on the work. sually staff from the microbiology and engineering sector had to fill in temporarily slots in the bacteriologist sector.

The staff of engineering sector was rotated more or less regularly so that one person was able to take over the work of another in case of absence.

48.3.3 Sampling Location / Sampling Frequency

All limnological sampling stations in the streams through out Phatthalung, Haadyai and the sampling stations at Songkla.

At Phatthalung, the tributary stream stations P.1 to P. were established in 1978, the station P.6 in 1979 and monitored through the present project.

At Haadyai, the sampling stations at Klong U - Tapao, number 0 to 7 were established in March, 1979 however, only station no. 0, U 4 and U 8 were monitored through the present project.

At Songkla, the sampling stations, S.1 to S.3 were established also in March, 1979 and monitored through the present project.

These sampling stations were selected according to (i) water contribution, (ii) urban, industrial or agricultural drainage area, and (iii) accessibility.

The sampling frequency of every 4 weeks is considered sufficient for the study during the peroid of 1978 - 1979. Sampling gaps are generally due to breakdown of cars, boats and occasionally due to rough weather conditions.

48.3.4 Parameters Analyzed / Method Applied

The parameters analyzed during the project for lake water, small river water samples, fresh wastewater samples from various sources as well as the frequencies of analysis of the individual parameters.

The analytical methods applied were mainly adopted from the APHA, AWWA and WPCE Standard methods, 14th Edition with some modifications and are described in detail in Annex.

48.3.5 In Container Measurements / Sampling Methods / Preservation.

(a) In container Measurement

The Hach instrument or other portable instruments were used to measure pH, conductivity / salintiy in container.

Transparency was determined by Secchi disk (white and blace) readings.

Other parameters were analysed by chemical methods

(b) Sampling Methods

Water samples for chemistry, bacteriology were collected with a IBP type water sample at 0.5 meters depth for all station where the depth of water bot exceed 1.5 meters. The basic rule for sampling methods established by the authors was that the depth of water collecting shoukd be one-third, half and two-third depth of water in that stream

Preservation water samples were collected with plastic bottom and preserved by following :

1. Use Chloroform 5 ml/100 ml. water for determination of acidity, alkalinity, salinity, conductivity, sulfate, carbondioxide.

2. Use Conc. H_2SO_4 5 ml/1000 ml. water sample for determination of Nitrate, Nitrite, Ammonia, orthophosphate

3. Use saturated $MgCO_3$ 10 ml/1000 ml. water sample for determination of chlorophyll

4. Rse $MnSO_4$ conc. 50 % 1 cc. and Alkalide-Iodide-Azide 1 cc per 100 ml water sample for determination of D.O.

5. Steriling glass bottles were provided for bacteriological samples These samples were keep cool until analysis.

49. Conclusion

Pollution Loading Survey of Lake Songkla considered about wastes that discharge into the Klongs runing to the lake. The wastes include liquid and solid waste from municipalities and industries, oil spillage from ships, turbid water discharged from mining, and solid waste comprising refuse from processing of fish and shellfish. The surveyings are interested in Pollution Loading in 3 regions. The first, the klongs through Phatthalung municipality discharge to Thale Luang (upper part of Lake Songkla) as results of domestic waste. The second, the Klong U - Tapao through industrial Eactories and Haadyai municipality discharge to Thale Sap Songkla (lower part of Lake Songkla) a results of composite waste. The third, the water quality in Thale Sap Songkla shore effect by Songkla municipality and Klong Phawong (the fish mill 3 one of Songkla),

The surface area of Songkla Lake is 1,040 km^2 and the total area enclosed bt the boundaries covers approximately 8,000 km^2. The 26-years (A.D. 1952 - 1977) annual average rainfall in Lake Songkla basin is 1,940.6 mm. The rainfal is decreased in the last 7 years which the annual average rainfall is 1,915 mm. This effects the water quality in klong and Lake about the prevention of pollution and salts intrusion. The water pollution is seriously in Eebruary - March which mean monthly rainfall is 39 mm/month. The salt intrusion is worst in September - October althrough the mean monthly rainfall is 193.5 mm. The reasons are the higher level of the sea at songkla in those times and the lower monthly rainfall before September. The silt transportation into the sea is max in Movember - December when mean monthly rainfall is maximum about 420 mm/month.

The pollution loading in klongs through Phatthalung municipality origins by the minicipal waste and diluted by large quantity of water in klong Lam Pam. The water qualities in Klong Tamman (upstream) at station P.5 before through Phatthalung municipality are good. These are pH = 7.5, D.O. = 5.73 mg/l BOD = 0.81 mg/l, Total alkalinity = 49 mg/l as $CaCO_3$, Total acidity = 10 mg/l as $CaCO_3$, Cl^- = 0.05 mg/l, NO_3-N = 0.7 mg/l, PO_4-P = 0.08 mg.l and Chlorophyll = 0 mg/m^3. The water qualities are worst after through the municipality. The BOD at station P.4 is 19.2 mg/l which is increased 23 times more than before The municipal pollution loading is 14 g BOD/capita-day. The critical Oxygen curve at 10 kilimeters downstream from the municipal at station P.2 is 2.7 mg/l. The water qualities at the station P.1 before discharge into Thale Luang are pH = 7.1, D.O. = 4.67 mg/l,

BOD = 4 mg/l, Total Alkalinity = 50 mg/l as $CaCO_3$, Total Acidity - 20.45 mg/l as $CaCO_3$, Cl^-_3 = 0.6 mg/l, NO_3-N = 0.7 mg/l, PO_4-P = 0.01 mg/l and chlorophyll = 6.315 mg/m^3. So the municipal waste creates the algal bloom at the mouth of the klong through Lake Songkla

Klong U - Tapao flows from the mountain of Malaysia at Amphur Sadao and passes through many village before traversy Haadyai Municipality and then proceeding to Lake Songkla. There are 1 tin mine, 1 soft drink bottling factory, 1 alcohol distillery, 1 sawing factory, 2 ice plants, 3 rubber processing plants, waste from Haadyai Waterworks, solid wastes from Haadyai municipality and waste from Haadyai municipality that disposal to Klong U - Tapao. Water pollution assessment of Haadyai Municipality was studies that equal 0.164 kgs BOD per Capita per day. The D.O. in the stream is generally acceptable at upatream (Station U_1) which equals 6.5 mg/l. The D.O. is droped rapidly after discharge of Haadyai municipal waste and D.O. at station D.P. is nearly zero. While the NO_3-N concentration at that station is maximum. The qualities of water is studied as shows in Table 5. Klong U - Tapao is now anxiously contaminated and preferable say to be heavily polluted in dry seasons.

Water Quality of Lake Songkla Near by Songkla Municipality was studies. The pollution sources are fish market, fishery dwarfs, cold storage factories, gasoline stations, piers for commercial and fishing boats and houses. The BOD at Station S.1 was 2.02 mg/l. While at station 2, it was found to be 20.2 mg/l. It shows the impact of the pollutants from Songkla municiplaity to the lake's environment. The water qualities at Klong Phawong, the important industrial area of the fish mills south from the town is serverely polluted. There are six fish mill factories that locate near the klong. They drain their washed water directly to the stream. The BOD in the klong was found to be 97 mg/l.

50. Recommendation for Further Study

Since this subproject had to be completed within a fixed period, The effects of many variables were not investigated. It should be study further for a year to completed the data. Fer further study, it should

50.1 Find total-N, NH_3-N NO_2-N, NO_3-N and total-Phosphate plus Orthophosphate in water sample and soil sample at the same time. Then study the effect of waste on the stream and posibility of entrofication.

50.2 Find the light penetration by using Secchi Disc in the field. Then find turbidity and S.S. for the relation ships of these parameters which effect the photosynthesis in the stream.

50.3 Find the primary product (algae) of the stream in the field. It will shows the ability of harvesting the lake

50.4 Find the pollution loadings from each of industries and municipalities. Then find the effects of pollutants in the stream.

50.5 Find the relation of COD and BOD

50.6 Find the effect of BOD at various temperatures in incubator and BOD incubated in the stream.

50.7 Find the tidal effect for the qualities of water in the stream.

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