Review of the Environmental Impact Assessment for the Proposed Bin-nan Industrial Complex, Tseng-wen Coastal Plain, Taiwan

G. Mathias Kondolf and Jeffrey Hou

Department of Landscape Architecture and Environmental Planning
University of California
Berkeley CA 94720 USA
7 March 1998
Report No. CEDR-01-98

Available from the *Center for Environmental Design Research*
390 Wurster Hall
University of California
Berkeley CA 94720
Tel 510 642 2896

Abstract

The proposed Bin-nan Industrial Complex would consist of a petrochemical plant and a steel mill to be located north of Tainan City, Taiwan. The proposed complex is controversial because it would be sited in the Chi-gu wetlands, one of the last large lagoons on the west coast of Taiwan, threatening a productive fishery that employs 16,000 people. This wetland is also the wintering habitat for half of the world's population of the endangered Black-faced Spoonbill (*Platalea minor*). The industrial complex would require most of the water potentially available in southern Taiwan and produce CO_2 emissions equivalent to 31% of Taiwan's total CO_2 emissions in 1990. We reviewed the Draft Environmental Impact Assessment Report (EIA) for proposed Bin-nan Industrial Complex (which was prepared by the project developer), related literature, EIA laws in Taiwan, and the EIS for the Ma-chia Dam, a dam proposed to increase available water supplies in southern Taiwan. We also conducted field reconnaissance in the Chi-gu wetland area and the region from which water supplies would be drawn. We evaluated the degree to which potential environmental and socio-economic impacts were addressed. The EIA did not analyze (or in many cases even mention) potentially significant environmental and socio-economic impacts of the proposed project. Some effects were dismissed as insignificant without supporting evidence. The EIA dismissed potential impacts on the Black-faced Spoonbill because no birds were observed on the footprint of the proposed complex during daytime observations. The EIA did not consider the nocturnal feeding range of the birds or the potential effect of routine or accidental releases from the complex upon birds and other wildlife in the area surrounding the complex. The EIA did not analyze alternative development scenarios that might provide greater economic returns and employment with potentially less environmental impact. With the very limited water supplies in southern Taiwan, the commitment of virtually all the present and potentially available water resources in southern Taiwan to the Bin-nan Complex would mean that opportunities for alternative development, such as high tech industries, would be forgone. Similarly, replacement of the natural areas at Chi-gu with an industrial complex and its attendant air and water pollution would lower the quality of life in the area and thus make the region less desirable for tourism or for location of companies (such as high technology firms). Despite the enormous water requirement for the Bin-nan complex, its EIA did not address the potential impact of diverting those waters from the Kao-ping River valley. The EIA did not address the potential impact of increased CO_2 emissions on Taiwan's ability to meet the internationally agreed emission reduction targets. Under Taiwanese law, the Environmental Protection Administration is required to reach a decision on the proposed Bin-nan Industrial Complex based on the information presented in the EIA. However, our study indicates that the EIA for the Bin-nan Industrial Complex was incomplete and inaccurate in its assessment of many environmental impacts. Thus, we recommend the government of Taiwan conduct or commission an impartial, comprehensive, scientifically-based environmental and socio-economic impact assessment prior to reaching a decision on the proposed project.

Key Words: Environmental impact assessment, petrochemical, wetlands, Taiwan, Tseng-wen River, Black-faced Spoonbill (*Platalea minor*), CO_2 emissions.

Introduction

The Bin-nan Industrial Complex, to consist of a petrochemical plant, steel mill, and industrial port, is proposed for the Tseng-wen Coastal Plain north of Tainan City on the southwestern coast of Taiwan. The project has attracted substantial opposition in Taiwan and overseas in large part because it would impact wintering habitat for half the world's population of the Black-faced Spoonbill (*Platalea minor*) and would reduce the area of the existing lagoon that supports an important coastal fishery.

As presently proposed, the industrial complex would require much of the remaining available fresh water in Southern Taiwan. Chen Tan-San, the magistrate of Tainan County, has withheld his support for the project unless its water demand can be reduced by 68 percent (China Times 1997c:03). Another source of controversy has been the emissions of CO_2 expected from the industrial complex, which would equal 31% of Taiwan's total CO_2 emission in 1990 (Commerce Times 1997b). In addition, the complex would threaten the fishing and aquaculture industry of the Chi-gu wetlands, which employs 16,000 people. Air pollution from the complex would affect the region's environmental quality and would increase costs of filtering air twelve-fold at the nearby Tainan Science Park (K-H. Hsieh 1997) .

The government's decision on whether to approve the project is to be based on the environmental impact assessment (EIA) prepared by the developers for the project. The Environmental Protection Administration (EPA) is expected to reach its final decision on the EIA in the coming months. In addition to the Bin-nan EIA, an EIS was prepared by the Water Resources Bureau of the Ministry of Economic Affairs for the proposed Ma-chia Dam, which may supply part of the water needed by the industrial complex.

In December 1997, a confrontation between police and local fishermen opposed to the proposed complex put the controversy squarely in the national spotlight (China Times 1997b: 07). Although the issue has become controversial and politicized, the government's decision must legally be based on the EIA. Accordingly, we undertook a third party, academic review of the environmental assessment to evaluate the degree to which potential environmental impacts were addressed in the EIA for the proposed Bin-nan complex and for the proposed Ma-chia Dam. Our specific purpose in this study was to review environmental impact requirements under Taiwanese law, to identify potential impacts of the projects, and to systemically review the environmental assessments to determine the extent to which these potential impacts were analyzed.

Methods

We compiled basic background information on the geomorphology, hydrology, and economy of the Tseng-wen Coastal Plain, and the Chi-gu Wetlands. We conducted field reconnaissance in the Chi-gu wetlands and elsewhere in Tseng-wen Coastal Plain. We also conducted reconnaissance along the Kao-ping, Ai-liao, and Mei-nung Rivers, which would be affected by proposed dams and diversions, some of which are not officially acknowledged as water sources

directly for the Bin-nan complex, but which would augment water supply in southern Taiwan and are believed by many to be probable future water sources for the complex (Liu 1997).

We reviewed the Taiwanese Environmental Impact Assessment Act of 1994 (EPA 1994, 1995) for specific requirements for impact assessment. From experience with large industrial and water development projects in Taiwan and elsewhere, we identified a number of potential impacts of the proposed Bin-nan complex. (Our listing of potential impacts is not comprehensive, especially as it would not include complex chemical reactions outside our area of expertise.) We then identified the types of analyses that would be required to assess the potential for the listed impacts, and reviewed the EIA for the Bin-nan complex itself and the EIS for the Ma-chia Dam (as well as reviewing the Bin-nan Environmental Impact Statement, EIS, an earlier document). We searched the documents to determine how the potential impacts were considered (if at all) and the evidence and analyses used to assess the magnitude of the potential impacts. Based on this analysis of the documents, we evaluated the degree to which the EIAs actually considered potential impacts of the proposed projects.

The Tseng-wen River drains 1,180 km^2, flowing 138 km from the Ali Mountains westward to the Taiwan Strait, and debauching about 15 km north of Tainan City (Figure 1). Typical of rivers in Taiwan, the Tseng-wen has a high sediment load, reflecting the rapid geological uplift, shattered, eroding, subduction-trench lithologies, and intense typhoon rainfalls (Hwang 1994). Because of historically high sediment loads, the Tseng-wen River channel has been unstable, laterally shifting its course up to 25 km since 1800. Deposition along the coast has been rapid, causing westward extension of the coastline of over 6-km since 1900, up to 17 km since 1700 (Chang 1997). As documented by J-C. Chang (National Taiwan Normal University), the formerly extensive Taichiang Lagoon has decreased in size since the 17th century, due mostly to natural sedimentation from the 17th to 19th century (Figure 2), and to development of salt evaporation pans and aquaculture ponds mostly in the 20th century (Figure 3).

The remnant 115 km^2 of open water, the Chi-gu Lagoon, is a tidal bay with important runs of eel (order *Anguilliformes*), milkfish (*Chanos chanos*), and tilapia (*tilapia sp.*), as well as aquacultured oyster (family *Ostreidae*) and hard clam (*Mercenaria sp.*). In this area, including the townships of Chi-gu, Chiang-chun, and Pei-men, nearly 9000 ha of aquaculture ponds have been developed for production of eel, tilapia, milkfish, grass shrimp (suborder *Dendrobranchiata*), mud skipper (*Cololabris satra*), grass carp (*Ctenopharyngoden idella*) (Figure 4) (Taiwan Fishery Bureau 1994). Altogether, Tainan County's coastal fishery (including aquaculture) generates annual revenues of over NT$ 3.2 billion and employs 16,000 people (Taiwan Fishery Bureau 1995). In addition to aquaculture ponds, salt evaporation ponds occupy 2,820 ha of the wetland area (Figure 5). Tourism has gained importance in this area, with popular temples in Nan-kuen-shen, Ma-tou, and Hsue-chia drawing over 4.5 million visitors annually (Housing and Urban Development Bureau 1996), accompanied by increasing numbers of visitors to the wetlands areas to see spoonbills and other birds.

The Black-faced Spoonbill

The area around Chi-gu Lagoon and Tseng-wen estuary constitutes the most important wintering habitat for Black-faced Spoonbill (Figure 6), providing habitat for more than half of the world's total population. The Black-faced Spoonbill winters in Taiwan, southern China, and Vietnam. Known breeding (summer) habitats are principally islands off the west coast of Korea, but the populations observed at these sites are considerably less than the total estimated population, suggesting that other breeding areas are located possibly in remote areas of eastern Russia and northeastern China (Figure 7).

The Black-faced Spoonbill is a globally threatened species, listed as 'critical' by Birdlife International and as an 'endangered species' by the Council of Agriculture in Taiwan (Collar et al. 1994; Severinghaus et al. 1995). Black-faced spoonbills were first recorded in the Chi-gu coastal area in 1925 by a Japanese ornithologist. The current population in the world is estimated to be around 530 to 590 (Wild Bird Society of Japan 1997). In 1994, 286 individuals were recorded in Chi-gu, compared with 72 and 23 in Hong Kong and Vietnam, respectively (Wild Bird Society of ROC, 1996; Dahmer and Felley, 1995). In November 1997, a record 291 individuals were reported in Chi-gu by the Wild Bird Society of ROC (China Times 1997a).

The wintering population of Black-faced Spoonbills in Taiwan roost principally on the tidal mud flat and aquaculture ponds north of Tseng-wen River and south of the Chi-gu Lagoon. The main roosting site encompasses an area of about 280 hectares (Yen et al. 1994) (Figure 5). Every year, flocks of the birds arrive in late September and stay till early April. The tidal shallow water of the area provides abundant food source for the birds, including small-size fish, prawns and shrimps (Severinghaus et al. 1995).

Because most foraging activities of black-faced Spoonbill occur at night (Hu and Wang 1995), relatively little is known about their exact foraging range. Three birds with radio transmitters were recorded traveling as far as 9 km from roosting sites to foraging sites at Chi-gu (Wang and Chen 1997). In field research between 1993 and 1994, a total of 37 counts were recorded in an area 19-km south of the main roosting site (R-S. Ong 1997). However, based on foraging range of other ciconiiforms, a range of 35 to 40 km from the roosting site would be expected (Coulter 1997). This would encompass the entire Tainan County coast, including the site of the proposed Bin-nan industrial complex. The Taiwan Agriculture Council has proposed a reserve that would encompass part of the spoonbill roosting area north of the Tseng-wen River, but no attempt has been made to protect the feeding areas (Y-T. Ong 1997). South of Tseng-wen River, recent and ongoing constructions of the Tainan Technological Industrial Complex has already eliminated numerous salt ponds and fish ponds that were once foraging habitat of the Black-faced Spoonbills.

The Proposed Bin-nan Industrial Complex

The Bin-nan Industrial Complex proposed for the Chi-gu district of Tainan County, Taiwan, would consist of a petrochemical plant, a steel mill, and an industrial port. This would be a very large facility, with an estimated annual production value of NT$ 335.8 billion (US$ 10.5 billion) and a total investment of about NT$ 414 billion (US$ 12.9 billion) (Great East Asia Petrochemical Co. et al. 1997).

The proposed petrochemical plant (to be built by the Great East Asia Petrochemical Co., a subsidiary of the Tuntex Corporation) would be the seventh such plant constructed in Taiwan, and the second largest in the country, with a naphtha cracker and oil refinery, and an anticipated production of poly (ethylene terephthalate) (PET), ethylene, propylene, butadiene, and other petrochemical products. As reported in the EIA (Great East Asia Petrochemical Co. et al. 1997), it would occupy 893 ha. As with other such facilities in Taiwan, it would be located along the coast to provide shipping access and process water (Figure 8). The Compact Integrated Steel Mill (to be built by the Yieh-lung Corporation) would have an anticipated annual production of over seven million tons of steels and, according to the EIA (Great East Asia Petrochemical Co. et al. 1997) would occupy 845 ha. The industrial port would be a joint development (between Tuntex and Yieh-lung) exclusively to import materials and export products to and from the complex, and would occupy 921 ha according to the EIA (Great East Asia Petrochemical Co. et al. 1997), up from the 542 ha reported in the EIS (Great East Asia Petrochemical Co. et al. 1996).

The plant would require approximately 117 million m^3 of water annually, which would be drawn from rivers to the east and south via a complex of new and existing dams and diversions (Figure 8).

Requirements for Environmental Impact Assessment (EIA) in Taiwan

Taiwan did not have a formal EIA procedure until the Environmental Impact Assessment Act was passed by the Legislative Yuan in 1994. Under the act, development activities likely to produce adverse environmental impact are subject to the EIA review. The listed activities range from road building to construction of industrial complexes, and the listed 'adverse impacts' include a variety of pollution, 'impact on rational use of natural resource', 'destruction of natural landscape and ecology, and social, cultural and economic environment' (EPA, 1994).

The EIA procedure is administered by the Environmental Protection Administration (EPA) and consists of two phases. Under the requirement for the Phase One, the developers are to submit an Environmental Impact Statement (EIS) that contains a description of the proposed development, existing conditions of the area under the potential impact of the proposed project, the potential impacts themselves, environmental protection strategies, and alternative proposals. Proposed projects considered likely to have major environment impacts by the EPA's EIA Review Committee are required to enter a second phase of assessment (EPA, 1994).

At the beginning of Phase Two, the developers are required to display the EIS for at least 30 days and hold public hearings. The EPA will then decide on development alternatives and the scope of the EIA. Afterwards, the developers are to submit a draft of final EIA that includes a description of the proposed development, description of existing conditions, primary and secondary impacts from development activities, prediction, analysis, and evaluation of environmental impact, mitigation and prevention strategies, alternative proposals, a comprehensive environmental management plan, and response to comments by local residents and other government agencies. An official on-site inspection and a local public hearing are to take place before submittal to EPA for final review and decision (EPA 1994). As of the time of this writing (February 1998), the Bin-nan project was in the final stages of environmental review, with the official on-site inspection and local public hearing already completed.

Environmental regulations in Taiwan including the EIA procedure have been widely criticized by both the public and developers (Chiu 1995). The legitimacy and fairness of the EIA procedure have been challenged, with the public hearing requirement characterized as merely procedural, not allowing for meaningful public participation. The government authority is often viewed by the local residents as biased toward the developers, while developers have viewed the regulations as setting excessively high standards and significantly increasing the cost and time of development (Chiu 1995).

International Standards for Scope of Environmental Impact Assessment

To be meaningful, an assessment of environmental impacts should consider not only immediate, on-site impacts, but also off-site and cumulative effects as well (Holling 1984). Therefore, because major water developments would be required to supply the industrial complex, the potential effects of these projects (including effects on other areas, from which water is taken) should be considered. International development agencies (such as USAID, the Asian Development Bank, the World Bank, and the Organization for Economic Cooperation and Development) have recognized the potential for water development projects to negatively affect the environment and thus require full environmental impact studies for such projects (Lintner 1988, OECD 1986).

Environmental Impact Assessment for the Bin-nan Complex

The EIS (which precedes the EIA under Taiwanese law) for the Bin-nan complex was published in February 1996 (Great East Asia Petrochemical Co. et al. 1996). The draft EIA (for the petrochemical plant, steel plant, and harbor) was published in June 1997 (Great East Asia Petrochemical Co. et al. 1997). In addition, an Environmental Impact Statement was prepared for the Ma-chia Dam (MOEA 1997), but these documents were not linked and did not refer to one another.

Review of the Environmental Impact Assessment

Potential Environmental Impacts of the Bin-nan Industrial Complex and Their Assessment in the Bin-nan Complex EIA - Part 1

Potential environmental impacts of the Bin-nan industrial complex and its ancillary water development projects are listed in **Table 1**. This list is not comprehensive, but the listed impacts are all-possible and require consideration based on experience in Taiwan and elsewhere. The analyses required to assess the potential for these impacts are also listed, along with a description of what actually appeared in the EIA.

Direct and Indirect Displacement of Wetlands and Existing Economic Activity

The plants and harbor would occupy over 2,600 ha, directly displacing existing habitats and land uses. In addition, service roads and commercial and industrial development related to or stimulated by the complex would likely occupy many ha. Moreover, a major coastal highway planned for within 5 km of the coast to service the industrial complex would occupy a large surface area and would likely induce further development in the wetland area. While there is no Taiwanese law specifically protecting wetlands in general, specific wetlands may be protected as fishery resource protection areas under the Wildlife Conservation Act (1989, revised 1991) or as Nature Reserves under the Cultural Heritage Conservation Act of 1982.

To analyze the potential impacts of direct and indirect displacement would require detailed mapping of habitats and existing land uses on the site and surrounding areas, and calculation of loss of habitat (and other uses) in a regional and national context. In assessing the relative significance of this impact, the historical and present existence of similar habitats should be considered, because the importance of the remaining habitat in Chi-gu would be proportionately greater to the extent that similar habitats have been lost elsewhere in Taiwan. Moreover, the importance of the Chi-gu wetland as habitat for the Black-faced Spoonbill should be gauged with reference to the standards of the Ramsar Convention, which designates wetlands that support 1% or more of a species as "wetlands of international importance" (Carp 1980). The Chi-gu wetland supports about 50% of the world's population of Black-faced Spoonbills, exceeding the Ramsar Convention's standard by about fifty folds. The EIA did not address the fact that half of the world's population of Black-faced Spoonbills depends on the Chi-gu wetland.

The EIA dismissed the habitats to be displaced by the industrial complex as insignificant, despite the finding of several other designated rare birds in the area, including Osprey (*Pandion haliaetus*), Eastern Collared Pratincole (*Glareola maldivarum*), Little Tern (*Sterna albifrons*), Brown Shrike (*Laniu cristatus*) and Black-billed Magpie (*Pica pica*) (Great East Asia Petrochemical Co. et al. 1997, p. 5-333). No off-site impacts on nearby habitats were considered in the EIA.

The loss of jobs resulting from changed land use was dismissed as to be compensated by creation of new industrial and construction jobs (Great East Asia Petrochemical Co. et al. 1997:6-350 - 6-352; 6-396). No analysis was presented regarding the likelihood that people currently employed in fisheries and aquaculture would be suited to working in the industrial became unemployed, or were forced to move elsewhere.

Table 1. Potential Environmental Impacts of the Proposed Bin-nan Industrial Complex and Their Analysis in the Environmental Impact Assessments

Potential Environmental Impact	Analysis Required to Evaluate	Consideration in EIAs
Direct and indirect displacement of wetland habitat, salt ponds, and aquaculture ponds by industrial complex	Mapping of habitats on site, calculation of loss in context of regional and national trends	EIA dismissed the habitats as insignificant (p.6-246 - 6-248). No off-site impacts on nearby habitats were considered. EIA stated that expected loss of salt and fishery jobs will be compensated by increase of new industrial and construction jobs (p.6-350 - 6-352).
Reducing area of lagoon will reduce tidal prism and alter estuarine circulation pattern.	Model estuarine circulation with reduced lagoon volume, assess distribution of water velocities and salinity.	EIA concluded that with loss of 30% of existing area, the lagoon ecology would function in the same way, except only in reduced scale (p.6-307).
Noise of petrochemical plant, steel plant, harbor, and associated truck traffic may disturb birds, other wildlife, and impair tourism and amenity values of region.	Estimate noise levels of various industrial activities and truck traffic on site and in surrounding area, analyze response of birds, other wildlife, and humans from published research and field studies in Taiwan.	EIA estimated on-site noise levels from industrial activities and related truck traffic in area, but did not explicitly address noise levels in surrounding habitats beyond the 50-decibel line, stating that this level was the regulatory standard (p.6-224 - 6-225). No analysis of response to noise of birds, other wildlife, or human was presented.
Routine wastewater discharges and aerial emissions may weaken or kill birds, fish, and other organisms, or may degrade their habitat.	Contaminants, their concentrations, potential pathways, and possible doses to ecological receptors must be analyzed.	No 'significant' number of terrestrial wildlife was found on the proposed site during the survey period, so potential impact was considered to be insignificant (p.6-248). The EIA did not analyze potential effects of discharges on adjacent habitats nor loss of food sources for wildlife.

Routine wastewater discharges and aerial emissions may negatively affect human health.	Contaminants, their concentrations, potential pathways, and possible doses to human receptors must be analyzed.	Anticipated concentrations and dosage to humans were considered to be well below the accepted levels under modeled tests (p.6-329).
Leaks, fires, or explosions in the industrial complex may release high concentrations of contaminants into environment, killing, weakening, or degrading habitat or food sources for birds, fish, and other organisms.	Worst-case scenario analyses must be conducted to estimate dosage of contaminants to organisms in the environment, and the likely persistence of contamination following the exposure event.	EIA stated that accidents will have no impacts outside the complex if proper emergency measures are taken (p. 6-336). EIA did not analyze potential exposure of fish and wildlife to toxic constituents in event of leaks, fires, and explosions, nor did it analyze the loss of fishery industry.
Leaks, fires, or explosions in the industrial complex may release high concentrations of contaminants into environment, negatively affecting human health.	Worst-case scenario analyses needed to estimate dosage of contaminants to humans, the probable health consequences, and the likely persistence of contamination following the exposure event.	EIA stated that accidents would have no impacts outside the complex if proper emergency measures are taken (p. 6-336). EIA did not analyze potential exposure of humans to toxic constituents in event of leaks, fires, and explosions, nor effects of such exposure.
Oil spills from tankers or industrial complex would cause asphyxiation of marine species, prevent movement of small organisms on the surface, damage fish gills and filter feeding organisms, interfere with cellular metabolic processes, and destroy the buoyancy and insulating properties of bird feathers.	Worst-case scenario analyses needed to estimate volumes of oil released and probable area of influence. Estimate of potential cumulative effects of chronic pollution from tanker ballast wastewater.	EIA reported results of computer modeling of extent of oil spill (p. 6-150 - 6-163) and acknowledged potential contamination of sand dune, lagoon and harbor, but did not analyze potential impacts to terrestrial wildlife, water quality, fishery, human health, tourism and amenity value, or long-term ecosystem viability.
Damage to fish populations from industrial contaminants, loss of habitat, and alteration of water circulation patterns caused by construction of the harbor may lead to collapse of fishery and loss of this NT$ 3.2 billion industry.	Aggregate effect of contamination, habitat loss, and harbor-related alteration of circulation patterns on fish must be evaluated to assess likely sustainable levels of harvest under post-project impairment.	EIA stated that compensation will be negotiated and distributed for loss of fishery production (p.6-383), and that development will provide many new jobs (p.6-351).

Loss and contamination of habitat may weaken or kill enough spoonbills that the population is no longer able to successfully reproduce, leading to extinction of the species.	Establish size of minimum viable population of Black-faced Spoonbills. Identify food sources, roosting and foraging grounds and related biological and environmental parameters, and analyze potential on-site and off-site impacts.	EIA dismissed impacts to Black-faced Spoonbills because no spoonbills were recorded on the proposed industrial site. EIA also stated that no foraging activities were found outside the main roosting area, but method and time of survey was not reported (p.6-248). No analysis of off-site impacts on spoonbills reported.
Fossil fuel use by plant will increase CO_2 production of Taiwan, affecting the country's ability to meet requirements of Kyoto Accord to reduce emission levels.	Based on expected production of industrial complex, the production of CO_2 should be estimated and compared with the targeted national emission level. Total economic return should be estimated along with cost of reducing CO_2 production in the nation.	The EIA estimated annual production of CO_2 from the complex at 27.8 million tons, but argued that Taiwan's per capita CO_2 emissions level was less than other industrialized nations, so CO_2 emissions would not produce major impact (p.6-186). The EIA did not mention that emissions from the complex would be equal to 31 percent of Taiwan's total CO_2 emissions in 1990.
Interbasin water transfers will reduce available water in dewatered basin, reducing baseflows, flood flows, and groundwater recharge, affecting aquatic and riparian habitat, water quality, and channel form.	Mean monthly flows, annual hydrographic, and flood frequency curves under natural, existing, and post-project conditions should be analyzed for channels affected by diversions for the project, such as the Kao-ping, Ai-liao, Lao-nung, Mei-nung, Chi-san, and Tseng-wen rivers.	EIA did not discuss potential impacts of inter-basin water transfer. (Also not analyzed in Ma-chia Dam EIS).
Interbasin water transfers will reduce available water in dewatered basin, reducing water available for other uses such as agriculture, other industrial development, and municipal uses.	Water requirements for other human uses (agriculture, industry, municipal) should be quantified. Economic, social, and environmental tradeoffs of using available water for the Bin-nan development rather than for alternative uses should be explicitly analyzed.	EIA stated only that supply has been granted by the Water Resource Bureau, Ministry of Economic Affairs. No analysis of tradeoffs of using water for Bin-nan instead of other uses was presented.

Deposition of sediment in reservoirs will result in shrinking reservoir capacity and release of sediment-starved water, creating a sediment deficit downstream and exacerbating problems of incision and channel erosion caused by gravel mining from river channels. Once the reservoirs fill with sediment, the dams will need to be removed or stabilized to avoid failure and loss of life and property.	Based on observed rates of sedimentation in other Taiwanese reservoirs, expected life of reservoir should be estimated and the costs of dam removal calculated and parties responsible for dam removal identified. The sediment budget of dammed rivers should be calculated, and the history of channel incision analyzed to assess potential impact of further sediment starvation on channel incision and erosion.	Not addressed in EIA.
Conversion of natural habitats to industrial development will eliminate potential for eco-tourism development.	Analyze existing literature and research on eco-tourism for amenity values of natural habitats, preferences of eco-tourists, etc. Estimate loss of potential eco-tourism development opportunities.	EIA did not mention the area's potential for eco-tourism development based on rich natural habitats.
Conversion of natural habitats to industrial development may reduce the attractiveness of the region for location of high-tech industries and other economic developments for which quality-of-life values are important determinants for location of plants.	Analyze relationship between high tech development and availability of environmental amenities. Estimate loss of potential high tech economic development opportunities as a result of decreased environmental amenity values.	EIA did not mention important contribution of and impacts on the area's natural amenity for attracting high-tech industries and other economic developments.
When oil supplies are exhausted in 21st century, petrochemical plant must be converted to alternative use or abandoned. (Note that in event of political disturbance in Middle East, oil supplies may be cut suddenly and unpredictably, rendering the industrial complex inoperable indefinitely.)	Based on realistic figures of oil reserves and consumption rates, project date when petrochemical plant is no longer economically viable, evaluate alternative uses for site and costs of conversion, and evaluate potential costs of environmental clean-up of site. Identify parties responsible for clean up and conversion, and costs of same.	Not addressed in EIA.

Change in Circulation Patterns from Reducing Size of Lagoon

Tidal currents now enter and exit the lagoon via two inlets, maintaining a flow of clean sea water that supports productive oyster beds. This lagoon has the highest water quality of any such water body on the west coast of Taiwan, is important habitat for many juvenile fish, and supports over 200 species of fish and oysters, attracting fishers from other parts of southern Taiwan, including Ping-Tong (Cheng 1997). Construction of the complex would result in closing one of two inlets and would reduce the area of the existing lagoon by 30%, which will reduce the tidal prism (the volume of water flowing in and out of the lagoon in a tidal cycle). These changes would alter estuarine dynamics, potentially affecting lagoon ecology. Dr. Lin Ming Nan, research scientist with the Taiwan Institute for Aquacultural Production, predicted that closure of the inlet (and filling 30% of the lagoon) will reduce circulation and water quality enough to cause collapse of the oyster farms in the lagoon (Cheng 1997). Research on tidal estuaries in the US indicates that as tidal prism decreases, water flow and velocity may fall below threshold levels needed to maintain circulation patterns, resulting in isolation of areas or other changes in circulation patterns (Haltiner and Williams 1987). To assess this potential impact would require that estuarine circulation be modeled with changes in tidal prism, and resulting distributions of water velocity and salinity be assessed.

The EIA reported that computer modeling showed that closure of the northern inlet (and an estimated reduction in tidal prism of 16%) would not adversely affect tidal circulation patterns in the lagoon, and stated that functioning of the lagoon would continue largely unchanged, only reduced in scale (Great East Asia Petrochemical Co. et al. 1996, p. 6-72, 6-107, 6-307). This prediction seems optimistic given that one of the two tidal inlets will be closed off, eliminating through-flow circulation that now maintains lagoon water quality. However, the EIA did not discuss model assumptions and potential errors and did not identify threshold levels below which circulation patterns would be changed. While the EIA modeled biological oxygen demand and complex, and the probable socio-economic effects on their lives if they did work at the plant, suspended solids levels, it did not report any modeling of water temperature, salinity, or other dissolved constituent levels under the post-project circulation regime. Nor did the EIA address potential ecological consequences of the anticipated change in lagoon conditions.

Noise

Noise produced by the petrochemical plant, steel plant, harbor, and associated truck traffic has the potential to significantly affect bird habitats. To analyze the potential impact would require that noise levels produced by various industrial activities anticipated in the Bin-nan complex and by associated truck traffic be estimated, based on published research and, preferably, from on-site measurements at existing industrial plants and highways with industrial truck traffic. To assess the birds' potential response to the noise would require review of any existing literature and collection of field data on the response of the birds to noise levels.

Although the EIA reported anticipated noise levels for various plant activities and truck traffic (Great East Asia Petrochemical Co. et al. 1997 p.6-212 - 6-226), the potential effects of this

noise on wildlife, tourism, and amenity values were not analyzed. In addition, the EIA also did not address the issue of increased noise level from aging facilities.

Routine Wastewater Discharges

Effluents of petrochemical plants contain a variety of contaminants, and treatment is never 100% effective in removing all contaminants. Petrochemical plant effluent contains selenium (refineries are responsible for over 90% of selenium entering northern San Francisco Bay during summer and fall) (CBE 1994a). Selenium bioaccumulates (becomes more concentrated up the food chain), reaching high concentrations in carnivorous birds and humans. Selenium poisoning has resulted in birth defects in birds, deformation of hair and nails in harbor seals, and retarded growth in salmon, and in skin irritations and nervous disorders in humans (CBE 1994a).

Petrochemical plant discharges also contain dioxins, which bioaccumulate and can reach levels in human breast milk such that nursing infants may be exposed to doses 10-20 times greater than the average person in the same environment (Albert 1992). Dioxins are toxic even in small amounts, and have been associated with cancer, reproductive defects, decreased sperm count, diabetes, and decreased birth weight and growth (Albert 1992).

The region's approximately 16,000 fishers and aquaculturists, families for whom fish is an important part of the diet, would be at risk from these chemicals in the water, as would be the consumers of the fish in the region.

The EIA considered the anticipated concentrations and dosage to humans to be well below the accepted levels under modeled tests (Great East Asia Petrochemical Co. 1997. p.6-329). In addition, no 'significant' number of terrestrial wildlife was found on the proposed site during the survey period, therefore potential impact was considered to be insignificant (Great East Asia Petrochemical Co. et al. 1997. p.6-248). The EIA did not analyze potential effects of discharges on adjacent habitats nor loss of food sources for wildlife.

Routine Aerial Emissions

Routine aerial emissions can include dense smoke from burning of chemicals and various chemical contaminants that can pose a health threat to humans, CO_2 gas (discussed below), SOx (43,000 tons/yr), NOx (24,000 tons/yr), and non-methane hydrocarbons (NMHC) from the manufacturing process (Great East Asia Petrochemical Co. et al. 1997, p.6-169 - 6-172). These emissions of SOx would be 250% of current emissions from all sources in Tainan County (Cheng 1997:279).

The EIA stated that air pollution would primarily affect Chi-gu, Chiang-chun, Pei-men, and Chia-li, and would not combine with existing air pollution from Tainan City, Yung-kan, Jen-te, Hsin-shih (Great East Asia Petrochemical Co. et al. 1997, p.6-176), and made no mention of the need for additional filtering of air at the Tainan Science-based Industrial Park. The EIA stated that concentration and dosage of contaminants would be below "accepted levels" (Great East

Asia Petrochemical Co. et al. 1997, p.6-329), but presented no analysis of the potential for bioaccumulation in birds and humans, nor of loss of food sources for birds. The section on human health impact also did not address effect on higher-risk groups such as children and elderly populations.

Leaks, Fires, and Explosions

Accidental leaks, fires, and explosions are virtually inevitable at a petrochemical plant. Accident rates at similar facilities in the San Francisco Bay (CBE 1994b) suggest that the Bin-nan plant would be likely to experience an average of 7.5 accidents per year.

Accidents such as recently occurred at the Chevron USA plant in Richmond, California, resulted in aerial emission of black soot containing nickel and vanadium. In a similar release from Bin-nan, this soot could be blown eastward to Highway 17 and adjacent cities, depending on wind direction and strength (Hester et al. 1997). Some of the soot is likely to settle on aquaculture ponds and the lagoon, poisoning fish and oysters. Refinery leaks in the San Francisco Bay area have also resulted in release of hydrogen sulfide gas, which has spread up to 10 km in six hours. A similar leak at the Bin-nan plant would potentially disperse gas southward to the spoonbill habitats, eastward nearly to Highway 17, and northward to Pei-men, perhaps farther. Accidents, leaks, or explosions could potentially lead to the collapse of the fishery and aquaculture industry, and to serious human health problems.

Seventeen scenarios were analyzed in the Bin-nan EIA. However, none was reported to have impact outside the complex (p.6-332 - 6-333). The EIA asserted that accidents will have no impacts outside the complex if proper emergency measures are taken (Great East Asia Petrochemical Co. et al. 1997, p.6-336), but this would appear to conflict with actual experience elsewhere, such as San Francisco Bay.

Oil Spills from Tankers and Petrochemical Plant

Oil spills occur from accidents or tanker leaks, frequently near coastal refineries, where containment and clean-up are difficult due to currents, tides, and complex bathymetry. A 10,000-gallon oil spill in still water will typically have a diameter of 0.6 km in one hour, extending to 6 km in one month (Nelson-Smith 1973), but actual dispersion patterns will depend upon local currents and other conditions. If high tides occurred during a spill, oil could be delivered over beaches, lagoon, aquaculture ponds, and other low-lying areas. The results will be serious damages to the lagoon ecosystem, wildlife habitats and local aquaculture industry.

Being lighter than water, oil tend to form slicks at the surface, which reduce penetration of light, form a mousse-like blanket on the surface that inhibits movement, respiration, and feeding or small animals, and by inhibiting exchange of gases at the water-atmosphere interface, reduces oxygen availability and asphyxiates marine organisms. Hydrocarbons dispersed in water may enter fish gills, causing suffocation, and filter-feeding organisms (such as barnacles and bivalves), causing death. Oil penetrates feathers of marine birds, elimination buoyancy and

insulation normally provided by the feathers, disabling birds and causing hypothermia. In the North Sea and North Atlantic, an estimated 450,000 seabirds have been killed by oil pollution (Nelson-Smith 1973).

To analyze the potential effects of an oil spill would require that oil spills of various sizes at various possible locations (offshore as well as within the harbor) be modeled under various conditions (winter vs. summer, spring high tides, storm surges, etc.) to determine the potential areas affected. The specific features of the proposed oil spill response equipment and program should be identified in detail. Even with sophisticated containment and clean-up equipment, a state-of-the-art response program, and assuming nothing goes wrong in the containment operation, however, 100% containment will not be possible under most conditions. The resources present in the potentially affected areas should be identified, and potential impacts estimated. For example, the bird populations present at different times of the year should be established as a basis for calculating their vulnerability to oil spill impacts. Moreover, the long-term environmental, social, and economic impacts of the oil spill, such as potential collapse of the fishery and aquaculture industry, or extinction of the spoonbill, must be considered.

The EIA reported that an oil spill could contaminate the marine environment, the harbor, and nearby sand dunes, and lagoon, especially during typhoons that would demand emergency actions (Great East Asia Petrochemical Co. et al. 1997, p.6-158). The EIA also indicated that oil concentrations could be high enough to kill fish and other organisms, but presented no analysis of the extent of potential oil-spill effects on birds, aquaculture, and other components of the environment. In the section on marine wildlife, the EIA stated that oil concentrations would not exceed 5 ppm outside a radius of 2.5 km in the harbor and 1.5 km outside the harbor, then stated only that concentrations less than 100 ppm would not have significant effect on the commercial fishery.

Beyond this general statement, no analysis of potential impacts on marine ecology was reported. The EIA only reported that spill could cause loss of marine organisms within the concentrated zone (Great East Asia Petrochemical Co. et al. 1997, p.6-261). In the terrestrial wildlife section of the EIA, no mention was made of possible effects of oil spills (Great East Asia Petrochemical Co. et al. 1997, p.6-249).

Loss and Contamination of Habitat and Extinction of the Black-faced Spoonbill

Contaminant releases and loss of habitat may impact the Black-faced Spoonbill population to the point that the remaining population is no longer viable and the species becomes extinct. At under 600 individuals, the world's population of Black-faced Spoonbills is small, and as such it is vulnerable. It is even more vulnerable by virtue of its concentration in several small areas. Although we lack sufficient information on spoonbill life history parameters (such as breeding grounds, reproductive success, sex ratios, and winter mortality) to calculate the minimum viable population, it is plausible that the current population is close to or under this level, so that any catastrophe (such as an industrial accident or oil spill) could reduce it below a viable level. Effects of catastrophes are greater upon small populations (Ewens et al. 1987).

The loss of foraging grounds to the industrial complex, highway, airport, and related developments would reduce the carrying capacity of the Chi-gu wintering area. Construction of another industrial complex now underway to the south of the Tseng-wen River has evidently reduced the available foraging habitat already.

Potential impacts on the spoonbills were dismissed in the EIA because no spoonbills were observed on the site of the proposed industrial complex itself (Great East Asia Petrochemical Co. et al. 1997, p.6-248). No analysis of potential effects of the plant operations and attendant impacts on the spoonbill was presented. The EIA did not address the effect of potential oil spill on the roosting and foraging habitats of Black-faced Spoonbill. Instead, it stated that the plant was 9 km away from the main roosting site, and would therefore constitute no direct impact (Great East Asia Petrochemical Co. et al. 1997, p. 6-268). In addition, the EIA failed to reference the existing literature on Black-faced Spoonbill in Chi-gu that reported a larger foraging range than what was reported in the EIA. For example, R-S. Ong (1997) reported observation of Black-faced Spoonbill foraging in Long-san fish ponds and Chi-gu salt ponds close to the proposed Bin-nan development site.

Potential Impacts of the Bin-nan Industrial Complex

Potential Environmental Impacts of the Bin-nan Industrial Complex and Their Assessment in the Bin-nan Complex EIA - Part 2

CO_2 Emissions

According to the EIA, the petrochemical plant will produce 14.7 million tons of CO_2 annually, the steel plant 13.1 million tons (Great East Asia Petrochemical Co. et al. 1997). Together, these plants would produce the equivalent of 31% of Taiwan's total 1990 CO_2 emission (Hsieh, K-H. 1997; Commerce Times 1997b) (25% according to the draft EIA).

The December 1997 UN Framework Convention on Climate Change (the 'Kyoto Summit') required that industrial nations reduce CO_2 emissions to below 1990 levels by 2012. Taiwan was not included as an industrialized nation under the Kyoto agreement and was therefore not obliged to comply. However, according to government document (EPA 1997), Taiwan will likely be included in the next round of negotiation. Taiwan's CO_2 emissions in 1990 ranked 15th among the 37 industrialized nations (C-C. Hsieh 1997b), with an 8% annual rate of increase (China Times 1997d). It has been estimated that in 2000 the total emission in Taiwan will already surpass the 1990 total level by 98% and per-capita level by 115% (C-C. Hsieh 1997b). To reduce the CO_2 emission to 1990 level in year 2010 would require a 34% reduction of Taiwan's GDP (Commerce Times 1997a). It was also estimated that based on the reduction cost of NT$45,000 per ton of CO_2, the total reduction cost for the Bin-nan Industrial Complex would exceed its GDP contribution by 10.27 times (C-C. Hsieh 1997b).

To properly analyze the potential effect of the Bin-nan plant on national CO_2 emissions and Taiwan's effort to cut emissions to 1990 levels would require that total CO_2 production in Taiwan be estimated, this figure be compared with the target emissions level, and the costs of altering industrial or transport processes (or reducing industrial production) be estimated for each source of CO_2 in the nation so that tradeoffs can be made in context of overall CO_2 emissions goals.

The EIA acknowledged that annual production of CO_2 from the complex would reach 27.8 million tons, but argued that Taiwan's per capita CO_2 emissions level was less than other industrialized nations, so CO_2 emissions would not produce a major impact (Great East Asia Petrochemical Co. et al. 1997, p.6-186). This argument is problematic because, according to the Kyoto Protocol, the binding agreement will be based on the country's total amount of CO_2 emission, not the per-capita amount. The EIA did not mention that emissions from the complex would be equal to 31% of Taiwan's total CO_2 emissions in 1990, and did not indicate how Taiwan could build and operate the Bin-nan complex and still reduce CO_2 emissions to 1990

level by 2010. The EIA did not address the cost of reducing CO_2 emission, nor potential global ecological consequences if the increase in CO_2 emissions was not reversed.

In February 1998, the developer of the petrochemical plant announced the consideration of eliminating the oil refinery component of the development scheme and thereby reducing the CO_2 emission by approximately one half (from 1,468 million tons/yr to 783 million tons/yr). However, the developer's decision is contingent upon the government's upcoming energy policy decision (China Times 1998). Even with the reduction, the total emission is still a formidable 20 million tons/yr, more than 20% of emission at 1990 level.

Inter-basin Water Transfers

The effects of inter-basin water transfers can be significant (e.g., Meador 1992), and this would certainly be the case with the Bin-nan project given the large quantities of water needed by the project, about 117 million cubic meters of water per year. Given the very limited supplies of water in southern Taiwan (Hsu 1995) and the increasing demand from new and proposed industrial complexes, urbanization, etc., construction of new reservoirs and pipelines is proposed to augment the existing water supply infrastructure (Figure 8). These new dams and diversions would alter flow regimes in affected rivers of southern Taiwan, such as the Kao-ping, Ai-liao, Lao-nung, Mei-nung, Chi-san, and Tseng-wen rivers. To understand the nature and extent of these hydrologic changes would require analysis of mean monthly flows, annual hydrographic, flow duration, and flood frequency curves under natural, existing, and post-project conditions, and analysis of potential changes in temperature regimes, pollutant loads, and resultant effects on river ecology, including geomorphic channel change.

No analysis of the potential impacts of water supply projects linked to the Bin-nan complex was presented in the EIA, nor was any reference made to impact analyses for specific dams. The EIA for the Bin-nan project (Great East Asia Petrochemical Co. et al. 1997, p.4-9) stated that adequate water supply had been granted by the authorizing agency: "[The Ministry of Economic Affairs, Water Resources Bureau] has clearly stated on 30 October 1996 that in the early phase, the Bin-nan Industrial Complex will be supplied by Tseng-wen, Wu-san-to, and Nan-hua Reservoirs; in the final phase, the complex will be supplied by the Lao-nung Diversion Project and Yu-Fong Dam." However, potential impacts of diverting water from these rivers to the Bin-nan complex were not addressed. Moreover, the EIA for the Tseng-wen Reservoir diversion has evidently not been approved because of potential impacts on the Nan-tze Creek Fish Protection Zone (Su 1997).

Although not mentioned in the Bin-nan EIA as a future water source, the Ma-chia and Mei-nung Dams are widely viewed as likely future sources for the Bin-nan complex under an integrated network of water supply (Liu 1997). Both the Ma-chia Dam and Mei-nung Dam would have a number of impacts and currently face strong oppositions from the ethnic communities in whose regions they would be built. However, the Bin-nan EIA did not discuss potential impacts of these proposed dams, nor were their EIAs referenced in the Bin-nan EIA.

Reservoir Sedimentation

Taiwan has among the highest erosion rates in the world, with denudation rates of 20 mm/yr reported for the Central Range. The result is that sedimentation poses a serious threat to sustainability of water supplies from reservoirs (Hwang 1994). To address this potential impact requires analysis of rates of reservoir sedimentation, strategies for removing or otherwise managing sediments, and costs of decommissioning dams when full of sediment. Moreover, there are downstream effects of trapping sediment in reservoirs and releasing sediment-free water, which may exacerbate conditions of sediment starvation caused by extensive in-stream gravel mining in many of these channels (Kondolf 1997) (Figure 9).

The Bin-nan EIA did not mention and nor present any analysis of potential reservoir sedimentation rates, the impacts on water supply in the future, the projected dates when the reservoirs would have filled with sediment nor of how the dams would be decommissioned, nor impacts of exacerbating sediment starvation conditions downstream.

Alternative Development Opportunities Forgone

Conversion of existing natural habitats to industrial complex not only eliminates many existing uses (with their associated environmental, economic, and social benefits), but also precludes alternative development opportunities. For example, tourism is now the world's largest industry, 'surpassing automobiles, petroleum, and weaponry', employing 204 million worldwide and accounting for 10% of total GNP (The Ecotourism Society 1996). The tourism industry is experiencing growing demand in Taiwan, and there is strong potential for eco-tourism development in the region, based upon the existing popularity of the temples in Nan-kuen-shen, Ma-tou, and Hsue-chia, the growing popularity of bird-watching in the Chi-gu wetlands, and growing interest in visiting local villages and markets on the part of the increasingly urbanized population in Taiwan. For example, in the small fishing harbor of Wu-chi, Taichung, a direct fish market and seafood mall attract thousands of visitors, generating gross monthly revenues of NT$ 54 million (about US$ 1.7 million) and a monthly net income of NT$ 100,000-150,000 (about US$ 3,000-5,000) for a typical vendor in the market (Peng 1996). Conditions (and thus opportunities) are similar at Chi-gu. In the U. S., bird watchers spent $5.2 billion in 1991 on goods and services related to bird feeding and watching; bird related tourism accounted for 16,200 jobs in California and 13,900 jobs in Florida (Bird Conservation 1997).

The ecosystem upon which the birds depend would likely be compromised by the Bin-nan complex, and the attractiveness of the region to tourists would be greatly reduced by such an industrial plant and its associated developments and pollution, potentially reducing visitorship to the existing temples as well as foreclosing opportunities for future expansion of tourism. Even if the spoonbills were somehow unaffected by the Bin-nan complex, it is probable that the numbers or diversity of other birds present would be reduced, making the site less attractive to bird watchers.

Hester et al. (1997) analyzed the potential future economic effects of the Bin-nan complex versus eco-tourism development alternatives (including a seafood market, beach recreation,

bird-watching, and continued aquaculture and fishing) based on job-to-visitor ratios developed from case studies elsewhere (Hannigan 1994, Sinclair and Page 1993, France and Towner 1991, Poirer and Wright 1993). They concluded that with a total annual visitorship of 6 million (a 25% increase over current visitorship to the temples), an average of 24,000 to 38,400 jobs could be generated by ecotourism development (Hester et al. 1997), contrasted with an estimated 30,930 jobs anticipated at the Bin-nan industrial complex (Housing and Urban Development Bureau 1996).

The conversion of a largely natural landscape to an industrialized landscape is also likely to make the area less desirable for location of high-technology industries and other industries employing a skilled work force for whom quality of life is an important consideration.

Competition for water is intense in southern Taiwan, with numerous planned developments competing with existing developments (**Table 2**). Because the Bin-nan complex (as presently proposed) would pre-empt the majority of the present and potentially available water resources in southern Taiwan, its development would preclude other developments such as expansion of high-technology industries. In the newly developed Tainan Science-based Industrial Park nearby, managers of high-technology firms have expressed concern about pre-emption of available water supplies by the Bin-nan complex (Cheng 1997).

Table 2. Water Demand of New and Proposed Industrial Developments in Southern Taiwan. (Cubic meters per day) (adapted from MOEA 1996)

	Water Demand M^3Day^{-1}					
Projects	**Year 2001**	**Year 2011**	**Year 2021**	**Year 2031**	**Description**	**Developers**
1. Binnan Industrial Complex	224,120	320,000	320,000	320,000	Contains Petrochemical Plant No. 7, Steel Mill, industrial port	Tuntex Corp., Yei-Lung Corp.
2. Tainan Science-based Industrial Park	36,000	140,000	140,000	140,000	Advanced high tech milieu with research and manufacturing facilities.	National Science Council
3. Tainan Technological Industrial Complex	31,000	75,000	75,000	75,000	High tech research and manufacturing, agricultural and bio-technology	Bureau of Industry
4. Greater Hsin-Yin Industrial Complex	0	19,600	19,600	19,600	Mixed-use industrial zone	Bureau of Industry
5. Ao-Ku Industrial Complex, Chia-Yi	20,080	35,452	35,452	35,452	General industrial zone	Bureau of Industry
6. Kang-San Industrial Complex, Kaohsiung	9,039	18,078	18,078	18,078	General industrial zone	Kaohsiung City Government
7. Do-Lio Industrial Zone expansion	14,400	14,400	14,400	14,400	Expansion of existing general industrial zone	Bureau of Industry
8. Tainan Hsin-Chi	7,650	9,000	75,000	75,000	General industrial zone	Bureau of Industry
Total (M^3Day^{-1})	*342,289*	*631,530*	*631,530*	*631,530*		

To analyze the potential impacts of alternative economic alternatives foregone by development of the Bin-nan complex requires that economic and environmental analyses be conducted for a range of alternative development scenarios. Specifically, the consequences (economic, social, and environmental) of choosing petrochemical and steel development over both the maintenance of the existing fishery and aquaculture and the potential development of high tech industry and eco-tourism, must be analyzed.

The EIA evaluated four types of alternatives: a 'no-development' alternative and alternatives based on different locations, technologies, and environmental protection measures. The latter alternatives dealt with only technical issues under the presumed development framework, and were not truly alternative development proposals in that they lacked a comprehensive discussion of potential benefits and impacts. Only the first two types of plans, the 'no-development alternative' and 'locational alternatives' dealt to some degree possibilities for alternative development of the site.

However, all the presented alternatives received negative evaluation. The 'No-development' alternative was described as having 'long-term negative impact on the nation's overall economy', and is 'disadvantageous to the efficient use of land and creation of jobs' (Great East Asia Petrochemical Co. et al. 1997, p.8-2). The possible alternative locations in the nearby Yun-lin and Chang-bing industrial complexes were rejected mainly for higher development and construction costs, unavailability of a large tract of land, and lack of appropriate and convenient port (Great East Asia Petrochemical Co. et al. 1997, p.8-5 - 8-8). No alternative developments such as tourism and development of advanced agriculture and aquaculture were evaluated, neither were issues of compatibility with existing and proposed high technology industries.

Potential Environmental Impacts of the Bin-nan Industrial Complex and Their Assessment

Potential Environmental Impacts of the Bin-nan Industrial Complex and Their Assessment in the Bin-nan Complex EIA - Part 3

Flooding of Riverine Habitats

Construction of Ma-Chia Dam would eliminate riverine habitats in the mainstem Ai-liao and tributaries over a distance of at least 15 km. To analyze the ecological impact of flooding over a long reach of the river would require that the existing aquatic and riparian habitat be identified and quantified. Surveys of aquatic and riparian species (and upland species utilizing the riparian zone seasonally) should be conducted. Migrations of fish that might be affected by dam construction should be identified.

The EIS acknowledged that the construction would displace habitats of existing aquatic and terrestrial species, including 3 officially recognized endangered species, 20 rare species and 10 species recommended for conservation (MOEA 1997, p.8-44, 8-57, 9-16). Among the total of 33 species, population of 7 species will be particularly impacted by the proposed dam (MOEA 1997, p.9-16). The endangered species include an endangered fish, *Varicorhinus barbatulus*, and terrestrial species such as Mountain Hawk-eagle (*Spizaetus nipalensis*), Maroon oriole (*Oriolus traillii*), Hundred-pace snake (*Agkistrodon acutus*), Chinese pangolin *(Manis pentadacyla*), Crab-eating mongoose (*Herpestes urva*), Heymonsi's pigmy frog (*Microhyla heymonsi*), Taiwan coral snake *(Calliophis macclellandi formosensis*), and Asia coral snake *(Hemibungarus sauteri*) (MOEA 1997, p.9-16 - 9-22). However, it concluded that the impacts on terrestrial species would be insignificant both because the impacted area would be limited and the species would migrate elsewhere by the time the construction was completed (MOEA 1997, p.8-46 - 8-47). The EIS also claimed that impacts on aquatic species would be limited since upstream population is relatively small and that the dam would not significantly alter stream flow during dry seasons. In wet seasons, reduced stream flow would actually help reduce the effect of fish being flushed downstream (MOEA 1997, p.8-56). The conclusion seems over optimistic specifically given the estimated loss of 25-35% of the existing population of *Varicorhinus barbatulus* in the Kao-ping watershed.

Decaying vegetation in reservoirs may lead to water quality problems, including anoxia resulting from the oxygen demand of vegetative decay (Ploskey 1985), and accumulation of high mercury levels in fish resulting from transformation of inorganic mercury into methyl mercury by bacteria feeding on decomposing matter in the reservoir (Rosenberg et al. 1995, Harper 1992). To analyze these potential impacts would require quantification of the vegetation existing in the proposed inundation area, analysis of the costs of complete clearing (usually

considered prohibitively expensive), and analysis of potential oxygen demand of decaying vegetation that would remain in the reservoir. In addition, the concentrations of inorganic mercury, the potential for its transformation into methyl mercury, and the potential for bioaccumulation should be analyzed. These potential impacts were not considered in the Ma-chia Dam EIS.

Landsliding

The potential for landsliding within the reservoir may be increased because reservoir waters would saturate rocks and reduce effective stress. However, this potential effect was dismissed in the Ma-chia Dam EIS. According to the EIS, the hill slopes at the proposed site were stable and only showed minor landslides (MOEA 1997, p.8-5). However, on a field inspection in May 1997, Kondolf (a geologist) observed numerous fresh landslide scars on the river's north canyon wall (Figure 11) and inspected shattered bedrock on the south wall. Certainly, with the active tectonism and shattered rock at the site, significant landslides would seem likely. The potential for landslides within the reservoir is particularly important because landslides create large waves, which can propagate downstream and sweep over the dam. Over 2,600 people were killed by such a landslide-induced wave at the Vaiont Reservoir in Italy in 1963 (Kiersch 1964).

Downstream Hydrologic Changes

Downstream of the reservoir, the flow regime would be altered. Summer floods would be reduced because of reservoir storage effects and both winter and summer flows would probably be reduced because of the diversion.

Reduced winter low flows would probably have impacts on aquatic ecology and water quality, in large part because the river's pollutant load would be less diluted and thus more concentrated. This could result in widespread dieoff of species and long-term replacement of desirable species with less desirable (but more pollution tolerant) organisms. Moreover, the reduced water quality may require installation of expensive water treatment facilities by industrial and municipal diverters, at potential costs of NT$ hundreds of millions. The Ma-chia Dam EIA did not analyze these potential impacts.

Reduced summer floods (combined with sediment trapping in the reservoir) would change the sediment transport regime, potentially affecting channel form and stability, groundwater levels, river ecology, and water quality, as observed on many other rivers (Petts 1984, Williams and Wolman 1984, Ward and Stanford 1995).

To analyze these potential impacts would require that the hydrologic effects of the proposed dam and diversion, pre- and post-project mean monthly flows, hydrographs, flood frequency curves, and flow-duration curves for the Ai-liao River be presented. These hydrologic analyses were not presented in the Ma-chia Dam EIA.

The EIS stated that discharge volume would be greater than the baseflow during the dry season. In the wet season between May and October, the impact would still be insignificant because of

limited change in flow volume (MOEA 1997, p.8-21). However, no supporting evidence was presented in the EIS concerning the estimated impact. The EIS specifically stated that impact on downstream water quality would be insignificant because of limited change in flow volume (Ministry of Economic Affairs 1997. P. 8-29), but again provided no supporting evidence. In addition, the EIS did not take into account the potential cumulative effect of reduced flow resulting from other new and proposed water diversion projects in the Kao-ping River watershed, nor did it address the impact of sediment-starved water.

Reduced Groundwater Recharge

The dam is likely to reduce groundwater recharge to the alluvial valley east of the Kao-ping River, west of the mountain range, and south of the present course of the Ai-liao River. Geologically, this area consists of alluvial fan deposits from the Ai-liao River, Lin-pien River, and smaller drainages, and alluvial deposits of the Kao-ping River along the west. Maps dating from the 1930s (during Japanese occupation) show that the Ai-liao River formerly split into at least eight distributaries channels over its alluvial fan. These channels provided extensive groundwater recharge. The Japanese constructed a levee that cut off all these channels along the south and west parts of the alluvial fan, confining all flow of the Ai-liao River to its present northwestward course. Eliminating the multiple distributary channels reduced groundwater recharge, but some recharge probably continues through the bed of the Ai-liao River.

Flow in the Ai-liao River (and thus groundwater recharge) would be reduced by Ma-chia Dam because water would be diverted from the reservoir by a pipe. To analyze the potential magnitude of this groundwater effect would require field measurements of longitudinal changes in river flow and groundwater measurements, estimation of current recharge rate from Ai-liao River and expected reduction. These analyses were only partially presented, and the potential effect was dismissed in the Ma-chia Dam EIS (MOEA 1997, p.8-21 - 8-23). The EIS stated that recharge rate through river bed would actually be greater in the early phase of the operation and that reduced recharge could be compensated by reduced groundwater demand downstream because of the availability of water from the reservoir (MOEA 1997, p.8-23).

Reservoir Sedimentation

As noted above, dams trap sediment, a particularly serious problem in Taiwan with its unusually high erosion rates (Hwang 1994). It was reported in the Ma-chia Dam EIS that the proposed dam would trap 8.8 to 9.7% of the total sediment load in the Kao-ping River watershed (MOEA 1997, p.8-23). In response, the EIS stated that there would be a low-level outlet in the dam for flushing sediment (MOEA 1997, p.8-25). Such management strategies have been applied successfully elsewhere in Taiwan (Hwang 1994). However, the Ma-chia Dam EIS did not address the potential downstream impacts of storing sediment for release as a pulse.

Lack of Integration and Synthesis in EIAs

The Bin-nan EIA did not explicitly connect various effects of the industrial complex and potential ecological responses as well as socio-economic impacts. For example, in a section on

oil spills, the EIA discussed the extent of oil spills, but did not analyze the degree and extent to which the oil spill would impact ecological resources. In the section on marine ecology, the EIA stated only that oil concentrations would be less than 5 mm outside a radius of 1.5 km outside the harbor (2.5 km within the harbor), and that concentrations below 100 ppm would not have significant effects on the commercial fishery (Great East Asia Petrochemical Co. et al. 1997, p.6-261). Despite the statement in the oils spill section of the EIA that oil could foul beaches, sand dunes and the Chi-gu lagoon, the section on terrestrial wildlife discussed species present on the proposed industrial site only, and did not mention possible impacts of an oil spill. In addition, the EIA also did not address the extent of oil spill impact on fishery and aquaculture industry and potential economic loss.

Similarly, the EIA section on noise predicted noise levels (only out to a 50-decibel line) (Great East Asia Petrochemical Co. et al. 1997, p.6-224 - 6-225), but the section on wildlife did not discuss potential effects of noise on specific birds and other wildlife.
The effects of the water development projects proposed to supply the Bin-nan complex were not mentioned in the Bin-nan EIA, nor was the EIS for the Ma-chia Dam or any other water project mentioned or linked to the Bin-nan EIA in any fashion. Thus, the related impacts of water projects and industrial complex were not integrated, but treated as unrelated projects in the environmental impact assessments.

The absence of any analysis to integrate or synthesize project effects on the environment means that the links between the effects of the complex (e.g., oil spills and noise) and the potential responses of ecological resources did not appear in the EIA. The potential effects of the complex were reported separately (if at all) and not explicitly linked to the sensitive receptors.

Potential Environmental Impacts of the Ma-chia Dam and Their Assessment in the Ma-chia Dam Environmental Impact Statement (EIS)

Ma-chia Dam is proposed for construction on the Ai-liao River upstream of the town of Shue-men (Watergate), above the site of a diversion constructed about 60 years ago during the Japanese occupation. Water would be diverted from the dam through a pipe across the Kao-ping River Valley alluvial plain to an aqueduct, where it would be available for transmission to other areas, including the Bin-nan Industrial Complex.

Seismic Safety

The dam would be located about 4 km east of the Tsao-chou fault that forms the abrupt boundary between the tectonically active mountain range to the east and the alluvial plain to the west. The rapid uplift of the mountain range and sharp topographic break across the fault

suggest that this fault is active, potentially compromising dam safety. The Ma-chia Dam EIS stated that the design of the dam is based on a MCE (maximum credible earthquake) of magnitude 7.2, but the basis for this value was not explained. Larger earthquakes often occur in regions of subduction zones, such as Taiwan.

As reservoirs fill with water, the weight of the water can induce earthquakes, increasing the frequency of earthquakes in seismically active regions or inducing earthquakes in previously quiescent areas (Gupta 1992). Filling of the reservoir behind Ma-chia Dam could trigger earthquakes, potentially increasing the existing seismic risk.

The Ma-chia Dam EIS stated that since the proposed reservoir is not directly sited on a fault, dangers of structural damage as result of seismic activities need not be considered (MOEA 1997, p.8-5 - 8-6). The EIS also stated that the Tsao-chou fault did not appear to be active based on sampling from core drilling and study of past records (MOEA 1997, p.8-6). While it acknowledged that the assumption was still a matter of academic debate, the authors of the EIS nevertheless asserted that 'academic debate should not be an obstacle to construction practice' (MOEA 1997, p.8-7). On the issue of reservoir-induced seismicity, the EIS stated that such instances were rare and often small in scale, and therefore would not constitute major impact (MOEA 1997, p.8-7 - 8-8).

Flooding of Aboriginal Villages

Construction of Ma-chia Dam can be expected to have consequences upstream and downstream. Upstream, the reservoir would flood two aboriginal villages, Kochapogan (Hao-cha) and I-la, and five aboriginal historical sites between 500 and 2000 years old (Office of Council Member Zhou G-C. 1997)(Figure 10 and 11). To analyze the potential social, cultural, and economic effects of flooding these villages and forcing the aboriginal peoples to move from their ancestral homes would require a socio-economic analysis of the villages, identification of potential relocation sites, assessment of potential opportunities at the new sites, and evaluation of the social and cultural impacts of forced relocation.

The Ma-Chia Dam EIS stated that a resettlement plan was being prepared and that the government should provide welfare and job-search assistance (MOEA 1997, p.8-80). However, the costs of resettlement of designated funding source, nor details of implementation were presented. The EIS however provides no assessment of the impacts of forced relocation on the indigenous communities. In regard to historic sites, the EIS stated that no historic landmark was found on the proposed site, but did acknowledge that part of old I-La village would be inundated and that more research was needed to minimize impact (MOEA 1997, p.8-84 - 8-85). It did not address the aboriginal tribes' claim to their ancestral homeland.

Table 3. Potential Environmental Impacts of the Proposed Ma-chia Dam and Their Analysis in the Environmental Impact Assessment

Potential Environmental Impact	Analysis Required to Evaluate	Consideration in EIS
Earthquake-induced failure could cause loss of life and property downstream.	Estimation of maximum credible earthquake (MCE), estimation of accelerations at site.	EIS estimated an MCE of 7.2 (p. 8-10), but did not state basis of this value. In an active subduction complex such as Taiwan, larger earthquakes could typically be expected.
Weight of water filling reservoir could induce earthquakes.	Evaluation of isostatic effects, using published studies on reservoir-induced seismicity and local data.	EIS dismissed the potential effect of reservoir-induced earthquakes, saying such instances were rare and often small in scale and therefore would not constitute major impacts (p. 8-7 8-8). EIS stated that the structure would be adequate to withstand such impact (p. 8-10).
Flooding of two aboriginal villages, forced relocation of aboriginal peoples.	Identification of existing cultural resources, evaluation of social and economic impacts of forcing local communities to relocate.	EIS stated that a resettlement plan was being prepared (p. 8-80), but provided no assessment of the impacts of forced relocation on the aboriginal community.
Loss of aboriginal ancestral lands and archeological artifacts.	Archeological survey to identify potential sites, excavation and analysis prior to inundation.	EIS stated that no historical landmark was found on the site but acknowledged that part of Old I-la would be inundated that more research was needed to minimize the impacts (p. 8-84 8-85).
Flooding of at least 15 km of river (aquatic and riparian) habitats.	Mapping and identification of river habitats to be lost, surveys of vegetation, wildlife, fisheries.	EIS acknowledged existence of 23 rare and endangered wildlife species (p. 8-44, 8-57, 9-16), but asserted that impacts would be insignificant because of limited change in habitats (p. 8-46 8-47, 8-56).
Decaying vegetation in reservoir can lead to anoxia, and decomposing bacteria can produce methyl mercury, which can bioaccumulate, leading to serious water quality problems.	Quantification of vegetation expected to remain and decay in reservoir, calculation of oxygen demand, and analysis of potential methyl mercury production.	Not addressed in EIS.

Landslides in the reservoir (natural or reservoir-induced) can create large waves that could overtop and/or destroy dam, sending large flood wave downstream.	Analysis of existing landslides to determine volumes displaced, frequency of movement, probable size of waves created in reservoir, and potential effect on dam.	No analysis presented. EIS dismissed the effect of reservoir-induced landslides by asserting that the slopes were stable and only showed minor landslides (p. 8-5).
Reduction in river flows during winter baseflow period would affect aquatic ecology and water quality, due to reduced dilution of river's pollutant load. Reduced water quality could require installation of water treatment systems by downstream users, potentially costing NT$ hundreds of millions.	Field measurement and analysis of current river flows, pollution loads, and water quality, and modeling of future pollutant concentrations based on projected post-dam river flows. Evaluation of impact on aquatic ecology and water quality.	EIS stated that discharge volume would be greater than winter baseflow (p.8-21). EIS also reported limited impact on downstream water quality because of limited change in flow (p. 8-29), but provided no supporting evidence.
Reduced flows during summer high flow period will reduce periodic disturbances important for aquatic ecosystems, affecting channel form and riverine food webs.	Analysis of dam-induced changes in peak floods, calculation of change in shear stress exerted on bed, resultant change in disturbance regime, sediment transport, and channel form.	EIS reported limited reduction in summer flow (p. 8-21), and that reduction would benefit aquatic wildlife by reducing the effect of fish being flushed downstream (p. 8-56).
Diversion of water from river into a pipe will reduce flows in the river and thus reduce groundwater recharge.	From field measurements of longitudinal changes in river flow and groundwater measurements, estimation of current recharge rate from Ai-liao River and expected reduction.	EIS dismissed impact of reduced groundwater recharge, and stated that reduced recharge would be compensated by reduction in groundwater demand (p.8-23).
The reservoir will trap all of the sand and gravel transported by the river and most of fine-grained sediment, resulting in filling of reservoir and loss of storage capacity. The sediment-filled reservoir will have to be decommissioned to reduce risk to downstream residents.	Estimation of expected life of reservoir (based on observed rates of sedimentation in other Taiwanese reservoirs) and estimation of decommissioning costs.	EIS stated that a low-level outlet would be installed for flushing sediment (p. 8-25), but did not address potential downstream impact of sudden release of stored sediment as a pulse.
The reservoir will release sediment-starved water downstream, which will alter aquatic habitats and may result in changes in channel form.	Calculation of sediment budget and analysis of effect of sediment starvation on downstream channel form.	Not addressed in EIS.

Summary and Conclusion

The EIA prepared for the Bin-nan Industrial Complex and the EIS of Ma-chia Dam did not analyze (or in many cases even mention) potentially significant environmental, economic, and social impacts of the proposed projects. Some effects were dismissed as insignificant without supporting evidence. The Bin-nan EIA did not acknowledge the threat posed to the endangered Black-faced Spoonbill and nor did it analyze alternative development scenarios that might provide greater economic returns and employment with less environmental impact.

Water supplies are very limited in southern Taiwan and will remain so even with construction of new dams, because most reservoirs are rapidly losing capacity to sedimentation. Because water is so critically important to development, the commitment of virtually all the present and potentially available water resources in southern Taiwan to the Bin-nan Industrial Complex means that opportunities for alternative development, such as high technology industries, are forgone. Similarly, replacement of the natural areas at Chi-gu with an industrial complex and its attendant air and water pollution would lower the quality of life in the area and thus make the region less desirable for tourism or for location of companies (such as high technology firms) whose employees are sensitive to quality-of-life. This tradeoff was not evaluated in the EIA.

Despite the enormous water requirement for the Bin-nan industrial complex, its EIA did not address the potential impact of diverting those waters from the Kao-ping River valley. The Ma-chia Dam EIS did not adequately analyze the effects of the dam and reservoir on local villages upstream and upon channel form, sediment transport, water quality, aquatic ecology, and groundwater recharge.

Under Taiwanese law, the Environmental Protection Administration is required to reach a decision on the proposed Bin-nan Industrial Complex based on the information presented in the EIA. However, the results of our analysis indicate that the EIA for the Bin-nan complex was incomplete or inaccurate in its assessment of many environmental impacts. Where project effects were reported, they were generally not synthesized with environmental information to analyze potential environmental effects of the proposed project. Similarly, the EIS for the proposed Ma-chia Dam did not adequately address potential impacts of the dam.

Until the true extent of potential impacts of the Bin-nan complex (and the dams and diversions likely to supply it with water) can be taken into account, it is unclear how the government can reach a decision that truly considers environmental impacts. We recommend the government of Taiwan withhold approval of the project as currently proposed and commission an impartial, comprehensive, scientifically-based environmental and socio-economic impact assessment to replace the document presently before it.

Acknowledgements

We are indebted to Malcolm Coulter, Deborah Savage, I-Chin Cheng, and Jui-Chin Chang, and Tze-Luen Lin for sharing relevant information, and to Grace Chen and Ke-Ren Chou for help in translation. Barbara Butler prepared the web version of this paper. Manuscript preparation was supported by the Beatrix Farrand Fund of the Department of Landscape Architecture and Environmental Planning, University of California at Berkeley.

References Cited

Albert, P.H. 1992. Oil spill and living organisms. Texas Agricultural Extension Service.
Bird Conservation. 1997. What's a bird worth? By generating billions of dollars in revenue and creating thousands of jobs, birds and birders have become a powerful economic force. *Bird Conservation*. Spring 1997, p.6-8.
Canter, L.W. 1996. Environmental Impact Assessment, Second Edition. pp. 304-342. McGraw-Hill, Inc.
Carp, E. 1980. Directory of Wetlands of International Importance in the Western Palearctic, for the United Nations Environmental Programme (UNEP), Nairobi, Kenya and the International Union for Conservation of Nature and Natural Resources (IUCN), Gland, Switzerland.
CBE (Community for a Better Environment). 1994a. Dirty crude - the first industrial analysis of selenium discharge, plan affecting San Francisco Area. August 1994.
CBE (Community for a Better Environment). 1994b. Chevron - the history of odors, spills, leaks, and accidents. August 1994.
CEDD 1997 (cited in caption for figure 8)
Chang, J-C. 1997. Geomorphological changes on the Tseng-wen
Coastal Plain in southwestern Taiwan. p. 110 in Abstracts, Fourth International Conference on Geomorphology, Bologna, 28 August-3 September 1997, *Supplementi di Geografia Fisica e Dinamica Quaternaria*, Comitato Glaciologico Italiano, Torino.
Cheng, I-C. 1997. Bin-nan Industrial Park ignites war for water in southern Taiwan. *Commonwealth Magazine* October 1997 (No. 197), p.274-281. (in Chinese)
China Times. 1997a. A record number of 291 Black-faced Spoonbills dance in the sky. China Times 15 November 1997. (on the Internet at http://www.chinatimes.com/papers/ctimes/social/ 86111501.htm) (in Chinese)
China Times. 1997b. Bloody confrontation at the Bin-nan Industrial Complex site inspection. *China Times* 9 December 1997, p.7. (in Chinese)
China Times. 1997c. Five conditions and four opinions: the cautious attitude of Chen Tan-San. *China Times* 10 December 1997, p.3. (in Chinese)
China Times. 1997d. Wang Chih-Kan: high energy-consuming industries to supply domestic needs. 16 December 1997. (on the internet at
http://www.chinatimes.com/news/papers/ctimes/focus/86121604.htm)(in Chinese)
China Times. 1998. Tuntex's Petrochemical Plant No. 7 will not produce gasoline. *China Times*. 21 February 1998. (on the internet at
http://www.chinatimes.com/news/papers/ctimes/economy/87022105.htm) (in Chinese)
Chiu, C-T. 1995. Environmental regulatory policies in Taiwan. Su-Shing Publisher, Taipei. (in Chinese)
Collar, N.J., and M.J. Crosby, and A.J. Stattersfield. 1994. Birds to Watch 2; The world list of threatened birds. Birdlife International, Cambridge.
Commerce Times. 1997a. Taking on the impossible mission. *Commerce Times*. 14 December 1997. (on the internet at http://www.chinatimes.com/news/papers/commerce/editor/86121401.htm) (in Chinese)
Commerce Times. 1997b. Limit on CO_2 emissions will impact expansion of petrochemical and steel

industry. *Commerce Times*. 21 December 1997. (on the internet at http.//www.chinatimes.com/news/papers/commerce/focus/86122105.htm) (in Chinese)
Coulter, M. 1997. Conservation issues for the Black-faced Spoonbill at the Tseng-wen Estuary, Tainan, ROC. Presentation to the International Conference on Sustainable Economy, Sustainable Ecology, Sustainable City, and Sustainable Lifestyle. Taipei. May 1997.
Dahmer, T.D., and M.L. Felley. 1995. Report on winter range survey of Black-faced Spoonbill, 1994-1995. Ecosystem, Ltd. Hong Kong.
Ecotourism Society. 1996. Ecotourism statistical fact sheet. (on the internet at http://www.ecotourism.org/textfiles/stats.txt)
EPA (Environmental Protection Administration, Taiwan). 1994.
Environmental Impact Assessment Act, promulgated 30 December 1994 by Taiwan EPA, Taipei.(English translation by D.T-C. Tang and R.J. Ferris)
EPA (Environmental Protection Administration, Taiwan). 1995. Implementation Rules of the Environmental Impact Assessment Act, promulgated 25 October 1995 by Taiwan EPA, Taipei. (English translation by D.T-C. Tang and R.J. Ferris)
France, L. and J. Towner. 1991. Tourism without the trimmings. *Geographical Magazine* 63(5):S1.
Great East Asia Petrochemical Co., Lien-Din Steel Co., Yieh-Lung Enterprise, Yieh-Sin Enterprise, Yieh-Lien Steel Co., Yieh-Kam Heavy Industry Co. 1997. Bin-nan Industrial Zone Development Plan - Petrochemical Plant, Compact Integrated Steel Mill, and Industrial Port, Draft Environmental Impact Assessment Report. Taipei, June 1997. (in Chinese)
Great East Asia Petrochemical Co., Lien-Din Steel Co., Yieh-Lung Enterprise, Yieh-Sin Enterprise, Yieh-Lien Steel Co., Yieh-Kam Heavy Industry Co. 1996. Bin-nan Industrial Zone Development Plan - Petrochemical Plant, Compact Integrated Steel Mill, and Industrial Port, Environmental Impact Statement. Taipei, February 1996. (in Chinese)
Gupta, H.J. 1992. Reservoir-induced earthquakes. Elsevier, Amsterdam.
Haltiner, J. and P.B. Williams. 1987. Hydraulic design in salt marsh restoration. p. 293-299 in Proceedings of the National Symposium on Wetland Hydrology, Association of State Wetland Managers, Chicago, September 16-18.
Hannigan, K. 1994. A regional analysis of tourism growth in Ireland. *Regional Studies* 28(2):208-214.
Harper, P.H. 1992. La Grande Riviere: a subarctic river and a hydroelectric megaproject. p. 411-425 in P. Calow and G.E. Petts, eds., *The Rivers Handbook*, Blackwell, Oxford.
Hester, R.T. jr., K. Chen, M. Fainter, J. Hou, A. Huang, V. Jayachandran, Y-L. Kao, D. Murrel, W. Rhyne, and M. Smeltzer. 1997. Sustainable economic development plan for Tainan County coastal area. R.T. Hester jr., project director, with class of Landscape Architecture 205 studio, University of California at Berkeley, May 1997.
Holling, C.S. (ed.) 1984. Adaptive environmental impact assessment and management. John Wiley & Sons, New York, 76 pp.
Housing and Urban Development Bureau. 1996. Tainan County comprehensive plan. Report No. 85-122. Housing and Urban Development Bureau, Taiwan Provincial Government. (in Chinese)
Hsia C-J., J.K-C. Liu, P-C. Hsieh, Y-T. Chiu, H-S. Pan, C-S. Chiang, T-Y. Lin, T-C. Chen, C-W. Yong, and C-K. Chung. 1997. Recreational Fishery Development Plan for the Tainan County Coastal Area. Building and Planning Research Foundation, Taipei. (in Chinese)
Hsieh, C-C. 1997a. Recognizing reduction of CO_2 emissions under the UN Framework Convention on Climate Change, *Liberty Times*. 5 August 1997 (on the internet at http://www.su-save-tidallayoon.org.tw/a3.htm) (in Chinese)
Hsieh, C-C. 1997b. Calmness before the storm ? Impact and Reflection of the ?Framework Convention on Climate Change?. Global Change Magazine. No. 16. 31 December 1997. P.21-29.
Hsieh, K-H. 1997. Analysis and Suggestion for Impact of Bin-nan Industrial Complex on the IC production in the Tainan Science-based Industrial Park. *Report for Public hearing on Impact Assessment of Bin-nan Industrial Complex on the Tainan Science-based Industrial Park*. 15 August 1997. Taipei.

(on the internet at http://www.su-save-tidallayoon.org.tw/a1.htm) (in Chinese)
Hsu, S-K. 1995. Shortage indices for water-resources planning in Taiwan. *Journal of Water Resources Planning and Management* 121(2):119-131.
Hu, C-H., and Y. Wang. 1995. Study on foraging behavior and
ecology of the Black-faced Spoonbills at Chi-gu, Tainan. National Taiwan Normal University, Taipei. (in Chinese)
Hwang, J.S. 1994. A study of the sustainable water resources system in Taiwan considering the problems of reservoir desilting. Taiwan Provincial Water Conservancy Bureau, Taichung City, Taiwan.
Kiersch, G.A. 1964. Vaiont reservoir disaster. *Civil Engineering* 34:32-39.
Kondolf, G.M. 1997. Hungry water: effects of dams and gravel mining on river channels. *Environmental Management*. 21(4):533-551.
Lintner, S.F. 1988. Environmental impact assessment for international development projects. Internal report, the World Bank, Washington DC.
Liu, S-Y. 1997. Ma-chia Dam opens the era of fighting for water. *New Idea Magazine*. Taipei, September 1997. (in Chinese)
Meador, M.R. 1992. Interbasin water transfers: ecological concerns. *Fisheries*. 17(2):17-22.
MOEA (Ministry of Economic Affairs), Water Resource Bureau. 1997. Ma-chia Dam Project Environmental Impact Statement. Ministry of Economic Affair. Taipei. February 1997. (in Chinese)
MOEA (Ministry of Economic Affairs). 1996a. Water supply strategy and schedule for major industrial zones. Water Resource Bureau, Ministry of Economic Affairs. Taipei, 30 October 1996. (in Chinese)
MOEA (Ministry of Economic Affairs). 1996b. Report for hearing on Bin-nan Industrial Zone water demand and supply plan. Water Resource Bureau, Ministry of Economic Affairs. Taipei. (in Chinese)
Nelson-Smith, A. 1973. Oil pollution and marine ecology. Plenum Press, New York.
OECD (Organization for Economic Cooperation and Development). 1986. Environmental assessment and development assistance. OECD Environment Monograph No.4.
Office of Council Member Zhou G-C. 1997. Impact of Ma-chia Dam on Indigenous People. Council of Aboriginal Affairs, Executive Yuan. Taipei, 26 June 1997. (in Chinese)
Ong, R-S. 1997. Wintering Conditions of Black-faced Spoonbill (*Platalea minor*).*Proceedings of Conference on Planning Principles of a Black-faced Spoonbill Reserve*. ROC Wetland Coalition and Wild bird Society of Tainan, 21 November 1995. Published in April 1997. P.32-58. (in Chinese)
Ong, Y-T. 1997. Planning Principles for a Black-faced Spoonbill Reserve. *Proceedings of Conference on Planning Principles of a Black-faced Spoonbill Reserve*. ROC Wetland Coalition and Wild bird Society of Tainan, 21 November 1995. Published in April 1997. P.4-22. (in Chinese)
Peng, L-Y. 1996. Tourism fever in fishing villages. *Commonwealth Magazine* September 1996. (No.184) p.202-206. (in Chinese)
Petts, G.E. 1984. *Impounded Rivers*. John Wiley & Sons, Chichester, UK.
Ploskey, G.R. 1985. Impacts of terrestrial vegetation and pre-impoundment clearing on reservoir ecology and fisheries in the US and Canada. FAO, Rome.
Poirer, R.A., and S. Wright. 1993. The political economy of tourism in Tunisia. *Journal of Modern African Studies*31(1): 149-162.
Rosenberg, D.M. et al. 1995. Environmental and social impacts of large scale hydroelectric development: who is listening? *Global Environmental Change* 5(2).
Severinghaus, L.L., K. Brouwer, S. Chan, J.R. Chong, M. Coulter, E.P.R. Poorter, and Y. Wang. 1995. Action Plan for the Black-faced Spoonbill *Platalea minor*. Wild Bird Society of ROC, Taipei.
Sinclair, M.T., and S.J. Page. 1993. The Euroregion: a new framework for tourism and regional development. *Regional Studies* 27(5):475-483.
Su, H-C. 1997. Statement against the Bin-nan industrial complex. Office of Legislator Huang-Chi Su, Taipei. (in Chinese)
Su, H-C., and C-C. Hsieh. 1997. Nostalgia of the Black-faced Spoonbills. Times Culture Publishing Company, Ltd., Taipei. (in Chinese)

Taiwan Fishery Bureau, 1994. Taiwan Fisheries Yearbook. Taiwan Fishery Bureau, Taipei.
Taiwan Fishery Bureau, 1995. Taiwan Fisheries Yearbook. Taiwan Fishery Bureau, Taipei.
Tseng, L-Y. 1996. Relocate Petrochemical Plant No. 7 and Steel Plant to Save Taiwan's Water Resource. (on internet at http://sisley.ccl.itri.org.tw/robins/econews/sccid/pn/no006.htm) (in Chinese)
Wang, Y., and S-C. Chen. 1997. Wintering habitat use of the Black-faced Spoonbill. *Proceedings of the Wildlife Conservation Education and Management Conference*. p.33-41. Council of Agriculture, Taiwan. (in Chinese)
Ward, J.V., and J.A. Stanford. 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation, *Regulated Rivers: Research and Management* 10:104-119.
Wild Bird Society of Japan. 1997. Proceedings of the Asian International Conference of Black-faced Spoonbill, Tokyo.
Williams, G.P., and M.G. Wolman. 1984. Downstream effects of dams on alluvial rivers, *US Geological Survey Professional Paper* 1286.
Yen, R-D., K-C. Liao, L-J. Chen, C-Y. Liu, Y-S. Jeng, Y. Wang, C-S. Chen, H-M. Cheng, J. Jonks, E.P.R. Poorter. 1994. The Ecological Study of Black-faced Spoonbills (*Platalea Minor*) in Taiwan. Council of Agriculture. 66 pp.

List of Tables

Figure Captions

Map is not necessarily comprehensive and does not show older industrial complexes. (Sources: Hsu 1995, CEDD 1997).

Figure 9. The downstream side of the Kao-ping Bridge over the Kao-ping River, with concrete jacks, sheet piling, and gabions installed to prevent undercutting. The river bed here has incised about 5 m due to intensive gravel extraction. Such problems of sediment starvation are becoming common in southern Taiwan and would be exacerbated by further trapping of sediment by new reservoirs. (photograph by Kondolf, October 1995)

Figure 10. Aboriginal houses decorated in traditional style in Kochapogan (Hao-cha) village. This village, and the I-la village, would be flooded by the proposed Ma-chia Dam. (photograph by Kondolf, May 1997)

Figure 11. Ruins at the historic Old Kochapogan village. The Old Kochapogan was said to be the original settlement of West Rukai tribe. (photograph by Hou, July 1995)

Figure 12. Landslides along north wall of Ai-liao River canyon near the site of the proposed Ma-chia Dam. Large landslides in this shattered rock could produce large waves in a reservoir, potentially overtopping and /or destroying the dam. (photograph by Kondolf, May 1997).