LIQUEFIED NATURAL GAS (LNG) RECEIVING TERMINAL AND ASSOCIATED FACILITIES

- RESPONSE TO COMMENTS PROVIDED BY THE ACE EIA SUBCOMMITTEE -

1. *COOLING WATER SYSTEM AND IMPACTS ON MARINE LIFE*

Total Residual Chlorine and Temperature

The cooling water system has been described in the EIA and consists of an intake supply which will draw seawater into the Open Rack Vaporiser system (ORV). Within the ORV the seawater will warm up the LNG and in so doing become cooled. When the seawater is discharged from the ORVs it then gravity flows through an open culvert to the discharge point underneath the LNG jetty. As seawater flows through the culvert its temperature can be expected to increase, although no account for this has been taken in the assessment.

Chlorine is added to the water as it enters the seawater intake system in order to keep the ORV free of biofouling organisms. Once added to the seawater system, chlorine is diluted and a residual concentration of chlorine remains within the discharged water. This is termed Total Residual Chlorine, or TRC. In countries such as Japan, ORV systems typically operate with a TRC concentration of 0.5 ppm within the discharged waters. In Hong Kong, the discharge standard under the *Water Pollution Control Ordinance* (WPCO) Technical Memorandum is currently 1 ppm.

For the LNG terminal, CAPCO has agreed to discharge a maximum TRC concentration of 0.3ppm. Although a conservative approach has been adopted (i.e. a continuous discharge at the maximum concentration), potential impacts to marine life through such a discharge have been modelled to assess environmental acceptability.

The results of this modelling and the impact assessment of effluent containing TRC and reduced temperature have been addressed in both the Marine Ecology (*Section 9*) and Fisheries (*Section 10*) Impact Assessments in *Part 2* of the *EIA Report*. The Water Quality Impact Assessment, in which the results of the modelling used to predict the pattern of dilution and dispersion of temperature and TRC in marine waters at South Soko is discussed in *Part 2 Section 6* of the *EIA Report*.

The results of the modelling exercise were compared and evaluated against applicable standards (i.e. the Water Quality Objectives (WQOs) as well as relevant internationally applicable criterion for marine ecological and fisheries assessments). The criteria adopted have been taken from Environmental Impact Assessments (EIA) previously approved under the *Environmental Impact Assessment Ordinance (EIAO)* in the Hong Kong SAR and international guidelines.

No exceedance of any of these criteria have been predicted to occur at identified sensitive receivers as a result of either the construction or operation of the LNG terminal and associated facilities at either the South Soko or Black Point sites.

In terms of the potential impacts through discharge of cooled water, it is also considered important to note that the ambient temperature of the waters surrounding South Soko Island ranges significantly throughout the year due to Hong Kong's subtropical conditions. Data from the EPD recorded between 1996 and 2006 indicate that the minimum temperature of these waters has been recorded at 15.4°C; whereas the maximum is 29.8°C (*Section 6 Table 6.4*). Marine organisms that utilise these waters may therefore be expected to be acclimatised to such thermal change. As such, a comparatively small difference of 2°C below ambient, which the discharged waters assimilate to within 200m of the discharge point, would not be expected to result in significant impacts to marine ecology or fisheries resources.

Furthermore, the maximum temperature difference at the closest sensitive receiver (False Pillow Coral on South Soko Island) has been predicted to be less than 1°C below ambient, which, on the basis of the range of natural fluctuations in water temperature discussed above, would not be expected to result in adverse impacts to these sensitive receivers.

The relevant sections of the EIA that explain the conservative assessment of the impact of cooled water and residual chlorine on marine ecology and fisheries have been extracted and are presented in *Attachment A*.

Underwater Sound

Underwater sound at the intake head will be minimal as water will flow through the intake by means of gravity. The only sound generated through extraction of seawater will be from the pumphouse, which will be located on existing land within the LNG terminal footprint. On this basis, disturbance to marine ecology, such as cetaceans, through underwater sound generated by the seawater intake and outfall system is not expected to occur. It is is also considered important to note that the findings of a two year marine mammal survey, the results of which are presented in the *Annexes* to *Section 9*, indicate that very few sightings of marine mammals have been made in the direct vicinity of either the intake or outfall systems.

2. *SEAWATER INTAKE IMPACTS TO FISHERIES SPAWNING GROUNDS AND NURSERY AREA*

Regarding the potential impacts to fish eggs and juvenile fish as a result of seawater extraction for the operation of the LNG terminal at South Soko, the findings of the assessment have concluded that impacts are not expected to be significant. The seawater intake head is to be located in an area which has a typical abundance of fisheries resources, i.e. it has similar characteristics to extensive areas of the southern waters of Hong Kong.

In addition, the maximum volume of water proposed to be extracted for the operation of the seawater intake is approximately 18,000m^3 hr^{-1}, which is similar in scale to the volume extracted by other the cooling water intakes in Hong Kong. For example the Central Reclamation Phase 3 waterfront system will extract an average of 20,137.5 m^3 hr^{-1}.

The LNG terminal volume of extracted water is relatively low when compared to the average hourly volume of 323,280 m^3 hr^{-1} (wet season) currently extracted as part of the operation of the existing Hong Kong Electric Power Station on Lamma Island. This facility is located within the same fisheries spawning ground and nursery area as the South Soko terminal [(1)].

The relevant sections of the EIA that explain the impact to fish eggs and juvenile fish as a result of seawater extraction for the operation of the LNG terminal at South Soko have been extracted and are presented in *Attachment B.*

3. *COMPARISON OF DISSOLVED METAL CONCENTRATIONS IN WATER AND UPDATED AUSTRALIAN ASSESSMENT CRITERIA*

A summary of international standards for the assessment of dissolved metals and micro-pollutants in marine water is presented in *Table 1*. These have been collated from United Kingdom (UK), the United States (US) and Australia.

Regarding the release of dissolved copper in marine sediments into surrounding marine water, concentrations recorded through elutriate tests of water and sediment samples collected around the South Soko terminal and along the submarine pipeline route are presented in *Part 2 – South Soko – Annex 6D* and extracted to *Table 2*. During the elutriate test, the sediment and the seawater are mixed and then centrifuged and the copper concentrations in the water are recorded. As such, the values shown in *Table 2* are the summation of background concentrations, i.e. existing conditions, and the concentration of dissolved copper released from the marine sediment.

(1) ERM - Hong Kong, Limited (1998) Fisheries Resources and Fishing Operations in Hong Kong. For the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Additional calculations have been made to assess the effects of copper released from the sediments under two conservative scenarios. Firstly, the maximum concentration of Copper in marine sediment has been identified (Urmston Road with 75 mg Cu kg^{-1} – see Table 7.4 of *Part 2 – Section 7* of the *EIA Report*) and the maximum SS concentration above ambient recorded at this location (0.4 mg L^{-1} see *Table 6.22* of *Part 2 – Section 6* of the *EIA Report*). Based on these values, the maximum concentration of Copper that would be expected as a result of dredging at this location has been calculated to be 0.03 μg L^{-1}.

For the second approach, the location where the maximum SS concentration above ambient was recorded (Pak Tso Wan with 11.5 mg L^{-1} (after mitigation) see *Table 6.32* of *Part 2 – Section 6* of the *EIA Report*) and the maximum concentration of Copper in marine sediment at this location (14 mg Cu kg^{-1} see *Table 7.4* of *Part 2 – Section 7*). Based on these values, the maximum concentration of Copper that would be expected as a result of dredging at this location has been calculated to be 0.16 μg Cu L^{-1}.

When compared with the Australian Assessment Criterion (*Table 1*) both of the above predicted values would be below the allowable levels. It is very important to note that the assessment criteria for copper presented in *Table 1* are based on long term or chronic exposure. Works associated with the construction of the LNG terminal and associated facilities are, however, relatively short term and localised.

It is also considered important to note that elutriate test results show that copper concentrations vary from 1.9 μg L^{-1} to 2.9 μg L^{-1}. Ambient concentrations of copper in marine water range from < 1 μg L^{-1} to 5 μg L^{-1} and hence the results of the elutriate tests are within the normal background range.

As such, impacts to marine ecology and fisheries due to the release of copper from marine sediments are not expected to occur.

Table 1 Assessment Criteria for Dissolved Metals and Micro-Pollutants

Parameter	Reporting Limit (µg L-1)	Water Quality Criterion adopted in the EIA (µg L-1)	UK Assessment Criterion (µg L-1) [a]	Australian Assessment Criterion (µg L-1) [b]				USEPA Assessment Criterion (µg L-1) [c]		International Literature (µg L-1) [e]
				Level of Protection (% species)				*Saltwater*		
				99%	*95%*	*90%*	*80%*	*CMC* [c]	*CCC* [d]	
Arsenic	1	25	25	-	-	-	-	69	36	-
Cadmium	0.5	2.5	2.5	0.7	5.5	14	36	40	8.8	-
Chromium (III)	5	15	15	7.7	27.4	48.6	90.6	-	-	-
Chromium (VI)				0.14	4.4	20	85	1,100	50	-
Copper	1	5	5	0.3	1.3	3	8	4.8	3.1	-
Lead	2	25	25	2.2	4.4	6.6	12	210	8.1	-
Mercury	0.2	0.3	0.3	0.1	0.4	0.7	1.4	1.8	0.94	-
Nickel	2	30	30	7	70	200	560	74	8.2	-
Silver	1	2.3	2.3	0.8	1.4	1.8	2.6	1.9	-	-
Zinc	10	40	40	7	15	23	43	90	81	-
Total PCBs	0.01	0.03	-	-	-	-	-	-	0.03	-
Total PAHs	0.1	3 [i]	-	50 [h]	70 [h]	90 [h]	120 [h]	-	-	-
TBT	0.015	0.1	-	0.0004	0.006	0.02	0.05	0.42	0.0074	0.1
Alpha-BHC	0.01	0.0049	-	-	-	-	-	0.0049 [f]		-
Beta BHC	0.01	0.017	-	-	-	-	-	0.017 [f]		-
Gamma BHC	0.01	0.16	-	-	-	-	-	0.16	-	-
Delta-BHC	0.01	-	-	-	-	-	-	-		-
Heptachlor	0.01	0.053	-	-	-	-	-	0.053	-	-
Aldrin	0.01	1.3	-	-	-	-	-	1.3	-	-
Heptachlor epoxide	0.01	0.053	-	-	-	-	-	0.053	-	-
Alpha Endosulfan	0.01	0.034	-	-	-	-	-	0.034	-	-
p, p'-DDT	0.01	0.13	-	-	-	-	-	0.13	-	-
p, p'-DDD	0.01	0.00031	-	-	-	-	-	0.00031 [f]		-
p, p'-DDE	0.01	0.00022	-	-	-	-	-	0.00022 [f]		-
Endosulfan sulfate	0.01	89	-	-	-	-	-	89 [f]		-

Notes:

(a) Her Majesty's Inspectorate of Pollution (HMIP) (1994). Environmental Economic and BPEO Assessment Principles for Integrated Pollution Control.
(b) Australia and New Zealand Guidelines for Fresh and Marine Water Quality (2000). Trigger values for toxicants at alternative levels of protection.
(c) National Recommended Water Quality Criteria (2006). The Criteria Maximum Concentration (CMC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. CMC is used as the criterion of the respective compounds in this study.
(d) National Recommended Water Quality Criteria (2006). The Criteria Continuous Concentration (CCC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. (Source: USEPA)
(e) Salazar, M.H. and Salazar, S.M. (1996). "Mussels as Bioindicators: Effects of TBT on Survival, Bioaccumulation, and Growth under Natural Conditions" in Organotin, edited by M.A. Champ and P.F. Seligman. Chapman & Hall, London.
(f) No saltwater criteria for this chlorinated pesticide were defined by USEPA. The water quality criterion to protect human health for the consumption of aquatic organisms is provided for reference.
(g) "-" denotes no water quality criterion is defined in the guideline or standard.
(h) Only trigger value for naphthalene is set in the revised standard.
(i) The Australian Water Quality Guidelines for Fresh and Marine Waters, Australian and New Zealand Environment and Conservation Council (1992), was adopted in the EIA Report with reference to the approved EIA of Wanchai Development Phase II (2001).

Table 2 ***Elutriate Test Results***

Locations	Station No.	Copper (Cu) μg L^{-1}
Shek Pik Shore Approach	GV34	2.6
Eastern South Soko	GV43	2.7
	GV44	2.7
Southern South Soko	GV30	2.6
Fan Lau Crossing	CP18	2.4
	DC22	2.7
Lantau Channel	GV19	2.8
	GV18	2.6
West Lantau	GV16	2.6
	GV17	2.3
Lung Kwu Chau and Sha Chau Marine Park	GSH12	2.1
	GSH13	2.9
	GSH14	2.2
	GSH15	2.4
Urmston Road Crossing	GSH8	2.3
	GSH9	2.5
	GSH10	2.2
	GSH11	2.2
Black Point Shore Approach	GSH6	2.5
	GSH7	1.9

Annex A

Supplementary Information on Cooling Water System and Impacts on Marine Life

A1 COOLING WATER SYSTEM AND IMPACTS ON MARINE LIFE

A1.1 COOLING WATER SYSTEM DESIGN

Extracted from **Part 2 - South Soko - Section 3.3.3 - Page 17**.

"In order to provide water for regasification of LNG, seawater will be extracted from Tung Wan via submarine intake. The intake will extend approximately 300 m from the pumphouse to the offshore intake heads (*Figures 3.9 and 3.10*). It is proposed that a typical box culvert design be employed and the intake structure comprises of a precast concrete tower ballasted with mass concrete. The tower would be connected to the seawater pumphouse by submarine pipelines. The foundation will likely comprise a rockfill base placed directly over the rockhead level following dredging by grab dredgers to remove a thin layer of marine deposits beneath. The intake from the tower would be placed at an approximate depth of approximately –3 mPD. A cross-sectional drawing of the conceptual intake is presented in *Figure 3.10*."

A1.2 COOLED WATER IMPACTS - TEMPERATURE

Impacts to Water Quality

(Part 2 – South Soko - Section 6.7.3 - Page 119)

Cooled Water Discharge

Cooled water with a temperature of approximately 12.5°C below ambient will be discharged at the seawater outfall, which is located close to the seabed in the vicinity of the LNG carrier jetty. There are no water quality sensitive receivers in the immediate vicinity of the proposed discharge point.

The maximum flow rate of the discharge is expected to be equivalent to 18,000 $m^3 hr^{-1}$. Compliance with the WQO ($\Delta \pm 2$ °C from ambient) must be achieved at sensitive receivers. The discharge of cooled water has been simulated using computational modelling.

The results from the cooled water discharge modelling are included in *Annex 6G* and have been presented as contour plots showing impacts of cooled water discharges in the vicinity of the outfall. *Figures SK_G01-G02* show the differences of the maximum temperature reduction between the maximum operational discharges and the baseline, representing the most conservative case.

It can be seen from the contour plots that the extent of temperature change from ambient for both the wet and dry seasons is predicted to be confined to the bottom layer, with no impact to the surface layer of the water column and no impact at sensitive receivers. This may be expected as the discharge of cooled water is close to the bottom and the relatively higher density of the cooled water results in weak vertical mixing.

Due to the distance to sensitive receivers, no non-compliance with the WQO has been predicted in either the dry or wet seasons. For the most conservative case (maximum operational discharge, see *Figures SK_G01 and SK_G02*), the temperature change is predicted to be less than 2 °C in both the dry and wet seasons. The temperature change of 2 °C will be confined to < 200 m from the outfall in the dry season and the wet season. The model results indicate that the dispersion of cooled water is rapid and not expected to cause an unacceptable impact.

Impacts to Marine Ecology

(Part 2 – South Soko - Section 9.5.2 - Page 29)

Cooled Water - Temperature

Cooled water with a decreased temperature of approximately -12.5°C from ambient will be discharged at the seawater outfall, which is located at the sea bed on the south coast of South Soko Island. The flow rate of the discharge is equivalent to 18,000 $m^3 hr^{-1}$ (peak flow). The discharge will be compliant with the WQO (*Part 2 Section 6*). The potential impacts of this discharge are principally related to the ecological effects in a zone of reduced temperature near the point of discharge. Impacts will be limited to a relatively small area in the bottom layer of the water column (*Part 2 Section 6*). The results from the cooled water discharge modelling obtained for both the wet and dry seasons have shown that the temperature change is predicted to be confined to the bottom layer with little or no impact to the surface layer.

As such impacts within the intertidal zone will not be expected as there is little or no impact to the surface layer of the water column (intertidal zone). In deeper water or the subtidal zone, impacts to the benthos are expected to be minor as the extent of the affected area is small.

Impacts to Fisheries Resources

(Part 2 – South Soko - Section 10.5.2 - Page 21)

Discharge of Cooled Water

Induced temperature changes to natural aquatic habitats have been proven to have detrimental effects on the physiology of fishes. The decline in temperature has the potential to alter the rate of development of fish embryos, larvae and gonad maturation. A slower growth rate means that fish larvae remain longer in the delicate early development stages, potentially increasing mortality [1]. The altered development of gonad maturation could ultimately reduce the spawning success of fish species and the altered mechanism of muscle development [2] could potentially reduce the chance of survival of juvenile fish.

Cooled water with a temperature of approximately 12.5°C below ambient will be discharged from the LNG terminal's seawater outfall located near the bed layer of the water column. The results of the water quality modelling in *Part 2 Section 6* have predicted that a temperature change exceeding the WQO of +/- 2°C will remain in the bed layer within approximately 200m of the outfall in the dry season and approximately 70m in the wet season.

The results presented in *Part 2 Section 6* indicate that the impacts to seawater temperature caused by the open circuit process are predicted to be localised. Furthermore, from a review of the results of the *Ichthyoplankton and Fish Post-Larvae Survey* presented in *Annex 10* it emerges that the sensitivity of the fisheries resources in the proximity of the proposed LNG terminal is medium-low due to the comparatively low density of fish larvae and post larvae recorded, thus further reducing any potential adverse effects of the localised temperature change.

It is therefore expected that the cooler water discharge will not cause unacceptable impacts to the fisheries resources.

A1.3 COOLED WATER - ANTIFOULANT

Impacts to Water Quality

(Part 2 – South Soko - Section 6.7.4 - Page 126)

Residual Chlorine Dispersion

Residual chlorine in the marine environment can be harmful to marine organisms only if concentrations exceed tolerance levels. It has been found that harmful effects begin to occur at concentrations above 0.02 mg L^{-1} in water [3]. The discharge limit for residual chlorine is 1.0 mg L^{-1} according to EPD's *Technical Memorandum for Effluents* issued under *Section 21 Water*

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(1) (1) Houde, ED (1987) Fish Early Life Dynamics and Recruitment Variability. P. 17-29. In Hoyt, RD (ed). Proceedings of the 10th Annual Larval Fish Conference held in Miami, FL May 18-23, 1986. American Fisheries Society Symposium 2. American Fisheries Society, Bethesda. MD.

(2) (2) Govoni, JJ (2004) The Development of Form and Function in Fishes, and the Question of Larval Adaptation. American Fisheries Society, Bethesda, MD.

(3) (3) Langford, TE (1983) Electricity Generation and the Ecology of Natural Waters. Liverpool University Press, Liverpool.

Pollution Control Ordinance, *Cap 358*. There is no value specified in the WQOs for the Southern WCZ, nor for any other WCZ. The criterion value of **0.01 mg L^{-1}** (daily maximum) at the edge of the mixing zone has been chosen as the criterion against which to assess the results from the computer modelling of chlorine dispersion, which is also the criterion adopted in the approved EIA Report for the 1,800 MW Gas-fired Power Station at Lamma Extension [(4)].

The water quality impacts due to chlorine discharges have been assessed using computational modelling (see *Water Quality Method Statement* in *Annex 6A*). The results from the chlorine simulations are presented as contour plots of mean and depth averaged chlorine concentrations for the spring and neap tidal periods in the wet and dry seasons. The contour plots are provided in *Annex 6H*. *Figures SK_H01-08* present the maximum operational discharges, while *Figures SK-H09-16* show the fluctuating operational discharges. Both discharge rates appear to result in a similar pattern of residual chlorine dispersion.

The dispersion results obtained for both the wet and dry seasons have shown that the majority of the residual chlorine is contained within the bottom layer, with little or no chlorine in the middle and the surface layers. This indicates that the release of the chlorine near to the seabed and the relatively higher density of the cooled water, in which the chlorine is discharged, results in weak vertical mixing.

The model used the assumption that the terminal would discharge total residual chlorine at a maximum concentration of 0.3 mg L^{-1}. This concentration is similar to that for most power stations in Hong Kong and is below the EPD's limit of 1.0 mg L^{-1}.

Based on the predictions, the maximum extent of the > 0.01 mg L^{-1} contour is <300 m from the discharge point during the dry season and <100 m during the wet season (*Figure SK_H01* and *Figure SK_H05*). These areas were defined as the "mixing zones".

Due to the small extent of the plumes, and the fact that no sensitive receivers would be affected, no unacceptable water quality impacts from residual chlorine discharge are expected to occur. The short duration peaks of residual chlorine discharge will also not contribute to any unacceptable adverse impacts. The assessment confirms the environmental suitability of the proposed discharge.

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(4) [(4)] ERM - Hong Kong, Ltd (1999) EIA for a 1,800MW Gas-fired Power Station at Lamma Extension. Final EIA Report. For The Hongkong Electric Co., Ltd.

Impacts to Marine Ecology

(Part 2 – South Soko - Section 9.5.2 - Page 29)

Cooled Water - Antifoulants

There are considerable operational and ecological issues caused by organisms within, and passing through industrial water systems and, these problems can be costly (5). Mussels, oysters and other marine organisms growing within cooled water circuits have resulted in losses in thermal efficiency and even total shutdowns. To counteract settling and actively growing fouling organisms, cooled water circuits are usually dosed with antifoulants (typically chlorine in the form of sodium hypochlorite). The discharge of the resulting (chlorinated) effluents may in turn have effects on the habitat beyond the outfall.

The effluent from the cooled water system will contain traces of antifoulant at a concentration of approximately 0.3 mg L^{-1}, which is below the EPD's (6) statutory limit of 1.0 mg L^{-1}.

Values for observed toxic effects of chlorine are available from the literature and can be used for reference purposes *(Table 9.6)*. For the majority of organisms the toxicity of residual free chlorine depends on the concentration and exposure time. Short exposure to high concentrations often leads to lethal effects as do long term exposures to low concentrations (7).

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(5) (5) Langford TE. 1983. Electricity generation and the ecology of natural waters. Liverpool University Press.

(6) (6) Technical Memorandum Standards for Effluents Discharged from Drainage an Sewerage Systems, Inland and Coastal Waters, Water Pollution Control Ordinance, Cap 358.

(7) (7) Redrawn after Mattice and Zittel. 1976. Site Specific Evaluation of Power Plant Chlorination. *Journal of Water Pollution Control*, 48:(10) 2284-2308.

Table 9.6 *Toxic Responses of Marine Organisms to Residual Free Chlorine in Discharges* [8]

Organism	Toxic Responses	Cl (mg L^{-1})
Phytoplankton	Photosynthesis of marine phytoplankton depressed by 70-80%	0.02-0.04
Zooplankton	Short term exposure has led to rapid but temporary responses demonstrated through depression in metabolic rate and reproductive activity.	0.01
Oyster Larvae (*Ostrea edulis*)	Tolerant of short term exposure with no demonstrated toxic response.	0.2-0.5
Barnacle Larvae (*Elminius modestus*)	Tolerant of short term exposure with no demonstrated toxic response.	0.2-0.5
Lobster Larvae (*Homarus americanus*)	Respiration rate increased after 60 minute exposure to 0.1 mg L^{-1} and after 30 minute exposure to 0.1 mg L^{-1}.	0.01 0.1

Concentrations of residual chlorine typically diminish rapidly with time and distance from the discharge point [9]. The modelling exercises conducted for the water quality assessment (reported in *Part 2 Section 6*) indicate that residual chlorine concentrations exceeding 0.01 mg L^{-1} are only likely to occur within 300m of the outfall and are mainly confined to the bed layer of the water column. These predicted increases do not exceed tolerance thresholds established in the literature (0.02 mg L^{-1}) and are in accordance with those levels recommended in previous studies in Hong Kong (0.01 mg L^{-1}). As a result, impacts to marine ecology as a result of potential concentrations of residual chlorine are not expected to occur.

Impact to Fisheries Resources

(Part 2 – South Soko - Section 10.5.2 - Page 23)

There are potential operational issues caused by the growth or encrustation of marine organisms on the open loop vaporization system (i.e., pipes, valves etc.). Operationally, the colonization of marine organisms such as algae, bryozoans, molluscs and cirripedes within cooled water circuits could result in losses in thermal efficiency and reduced reliability of the system (including total shutdown). To counteract settling and growth of marine organisms, cooled water circuits are typically dosed with chemicals (usually sodium hypochlorite). Such chemicals are known as antifoulants and they inhibit the growth of organisms within the circuit by creating unsuitable living

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(8) ([8]) Information gathered from references contained in Langford TE. 1983. Electricity Generation and the Ecology of Natural Waters

(9) ([9]) Mattice JS & Zittel HE. 1976. Site specific evaluation of power plant chlorination. Journal of Water Pollution Control. 48 (10): 2284 - 2308.

conditions. A secondary consequence of this form of treatment is associated with the discharge of the treated seawater into the marine environment.

Research has been conducted internationally on the effects of chlorine discharges on marine ecological and fisheries resources. The international review provides data which can be used as a benchmark to evaluate potential impacts. Work on the toxic effects of chlorine on fish eggs and larvae has indicated that abnormal development may occur at concentrations of 0.31 to 0.38 mg L^{-1} [(10)]. However, behavioural studies have indicated that adult fish will avoid areas where concentrations of free residual chlorine in the water exceed 0.035 mg L^{-1} [(11)].

The proposed LNG terminal is predicted to discharge residual free chlorine at a concentration of < 0.30 mg L^{-1}. This concentration is below EPD's discharge limit of 1.0 mg L^{-1} [(12)].

Concentrations of residual chlorine have been shown to diminish rapidly with time and distance from the discharge point [(13)]. A concentration of residual chlorine of 0.01 mg L^{-1} (daily maximum) at the edge of the mixing zone is the criterion used in the *Water Quality Assessment* (*Part 2 Section 6*). The modelling exercise conducted in the assessment indicates that maximum residual chlorine concentrations exceeding 0.01 mg L^{-1} are only likely to occur within 300 m of the outfall and are mainly confined to lower layers of the water column. These predicted increases do not exceed tolerance thresholds established in the literature (0.02 mg L^{-1}) and are consistent with levels recommended in previous studies in Hong Kong (0.01 mg L^{-1}).

Consequentially, significant impacts to fisheries resources as a result of the discharge of chlorinated water are not expected to occur.

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(10) [(10)] Morgan RP & Prince RD (1977) Chlorine Toxicity to eggs and larvae of five Chesapeake Bay fishes. Transaction of the American Fisheries Society. 106 (4): 380 - 385.

(11) [(11)] Grieve JA et al (1978) A program to introduce site-specific chlorination regimes at Ontario hydro generating stations. Pages 77-84 in Jolley RL et al (1978) Water Chlorination. Environmental Impacts and Health Effects, Volume 2. Michigan: Ann Arbour Science.

(12) [(12)] Technical Memorandum Standards for Effluents Discharged from Drainage and Sewerage Systems, Inland and Coastal Waters, Water Pollution Control Ordinance, Cap 358.

(13) [(13)] Mattice JS & Zittel HE (1976) Site specific evaluation of power plant chlorination. Journal of Water Pollution Control. 48 (10): 2284 - 2308.

Impacts to Fisheries Resources (cont'd)

(Part 2 – South Soko - Section 10.6 - Page 24)

Assessment of Environmental Impacts

Nature of Impact:

Discharge of cooled water is not predicted to pose adverse impacts to fisheries resources and discharges of residual free chlorine will be in compliance with the EPD's allowable discharge limit."

Annex B

Supplementary Information on Seawater Intake Impacts to Fisheries Spawning Grounds and Nursery Areas

B1. SEAWATER INTAKE IMPACTS TO FISHERIES SPAWNING GROUNDS AND NURSERY AREA

A1.1 IMPACT TO FISHERIES RESOURCES

(Part 2 – South Soko – Section 10.5.2 – Page 22)

Impingement and Entrainment

The discharge and intake points for the seawater to be used in the proposed open circuit system will be separated to reduce the re-circulation of the cooled water and therefore maximise the efficiency of the heat exchange process.

In order to draw in the warmest water to the vaporisers for optimum efficiency in the regasification process, the seawater intake will be designed to be as high as possible within the water column. The intake structure is made up of a concrete tower ballasted with mass concrete connected to the onshore seawater pump house by a submarine pipeline. The intake will be appropriately screened to reduce the uptake of marine organisms and suspended material. From a fisheries perspective the high volume and velocity of inflowing seawater may have negative effects on fish, fish eggs and crustaceans due to the physical damage caused by collisions with the screen (impingement) and due to their uptake and exposure to the vaporization process (entrainment).

The swimming speeds of juvenile and larval fishes vary greatly but are generally slower than the water velocity of the intake pipe. Owing to their larger size juvenile fish are generally more susceptible to impingement, whilst fish and crustacean larvae and eggs, zooplankton and phytoplankton are more exposed to entrainment, as their small size enables them to pass through the screen [14][15].

Whilst it is acknowledged that the uptake of seawater for the open circuit vaporization process may minimally increase the natural mortality rate of fish larvae, crustaceans and fish eggs due to impingement and entrainment, it has to be noted that the significance of such impacts is strongly dependent on the ecological sensitivity and the productivity of the impacted area.

From a review of the results of the *Ichthyoplankton and Fish Post-Larvae Survey* (*Annex 10*) it is evident that the sensitivity and productivity of the impacted

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(14) (14) Fernando Martinez-Andrade and Donald M. Baltz (2003). Coastal Marine Institute: Marine and Coastal Fishes subject to Impingement by Cooling-Water Intake Systems in the Northern Gulf of Mexico - An Annotated Bibliography. U.S. Department of the Interior.

(15) (15) Turnpenny, A. W. H (1988) Fish impingement at estuarine power stations and its significance to commercial fishing. Journal of Fish Biology, Vol. 33, pp. 103-110.

area is medium-low due to the comparatively low mean fish density characteristic of the South Soko sampling stations. Furthermore, the Survey concluded that:

- There is no significant difference in the spatial or diurnal/nocturnal distribution of fish density and fish egg density at the South Soko sampling stations (*Annex 10*);

- There is no significant difference in fish density and eggs density between the identified sensitive spawning/nursing grounds of southern Hong Kong waters and the non spawning/nursing grounds of western Lantau.

Based on these results, it is estimated that the sensitivity of the spawning area in correspondence of the five sampling locations (including the sampling station at the future intake position – SK1) is medium-low and it is predicted that no unacceptable adverse impacts to the fisheries resources caused by impingement and entrainment will occur.