4 ENVIRONMENTAL BASELINE OF THE AREA

Baseline data being presented here pertain to the physical, biological and socio-economic environment of the area where the proposed LNG Jetty and land based terminal will be located, constructed and operated. Proposed location of project lies within the boundaries of Port Qasim Authority and very near the Korangi Fish Harbour. Information available from electronic/printed literature relevant to baseline of the area, surrounding creek system, Port Qasim as well as for Karachi was collected at the outset and reviewed subsequently. This was followed by surveys conducted by experts to investigate and describe the existing socio-economic status, and physical scenario comprising hydrological, geographical, geological, ecological and other ambient environmental conditions of the area. In order to assess impacts on air quality, ambient air quality monitoring was conducted through expertise provided by SUPARCO. The baseline being presented in this section is the extract of literature review, analyses of various samples, surveys and monitoring.

4.1- Physical Environment

4.1.1- Climate

The coastal meteorology and hydrography of Karachi is controlled by the seasonal change in the north Arabian Sea i.e. monsoonal system. The data collected from various studies along the coast show the influence of NE and SW monsoon winds. A general summary of meteorological and hydrological data is presented in following section to describe the coastal hydrodynamics of the area under study.

A- Temperature & Humidity

The air temperature of Karachi region is invariably moderate due to presence of sea. Climate data generated by the meteorological station at Karachi Air Port represents climatic conditions for the region. The temperature records for five years (2001-2005) of Karachi city are being presented to describe the weather conditions. Table 4.1 shows the maximum temperatures recorded during the last 5 years in Karachi.

Summer is usually hot and humid with some rainfall. The mean maximum temperature recorded is 32°C while the mean minimum winter temperature is 10°C. There are occasion when the coastal belt is in the wake of heat wave and the maximum temperatures exceeds 40°C but this happens only a few times in the year and last for as short duration usually not exceeding three days at maximum. When this study was conducted the region experienced a high

Table 4.1: Mean Monthly Maximum Temperature °C

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2001	27.2	29.6	33.1	34.6	35.1	34.8	32.1	32.3	33.1	36.0	33.5	30.4	32.6
2002	27.0	28.1	33.3	35.4	35.6	35.1	32.2	31.0	31.3	36.5	32.7	28.1	32.2
2003	27.6	28.5	32.3	36.6	35.7	34.8	34.1	33.5	32.5	37.0	32.2	28.3	32.8
2004	26.6	29.9	36.2	35.4	36.8	35.6	33.5	32.6	32.8	33.7	30.7	29.4	32.8
2005	24.9	26.2	31.4	35.3	35.4	36.1	33.2	33.2	34.2	35.2	33.1	28.2	32.1
2006	26.0	31.3	31.8	34.0	34.6	35.3	33.8	31.0	34.2	35.0	33.4	26.3	32.2
2007	26.9	29.4	31.4	37.7	36.0	36.4	N/A	N/A	N/A	N/A	N/A	N/A	33.0

Source: Pakistan Meteorological Department

Table 4.2: Mean Monthly Minimum Temperature °C

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2001	11.5	14.9	19.6	23.8	28.1	29.0	27.1	26.5	25.9	24.4	18.6	15.8	22.1
2002	12.8	13.8	19.5	23.9	27.0	28.2	29.6	25.6	24.8	22.5	17.7	14.9	21.7
2003	12.7	16.9	19.8	24.2	26.5	28.2	23.6	27.0	25.3	20.9	15.2	12.0	21.0
2004	12.9	14.5	19.1	24.8	27.3	28.8	27.5	26.3	25.3	22.4	18.0	15.4	21.9
2005	12.3	11.3	20.3	23.0	26.4	28.3	27.2	26.6	26.6	22.9	18.9	13.0	21.4
2006	11.7	18.1	19.6	24.5	27.5	28.5	28.3	26.3	26.8	25.7	19.4	14.0	22.5
2007	13.0	17.3	19.7	24.7	27.6	28.6	N/A	N/A	N/A	N/A	N/A	N/A	21.8

Source: Pakistan Meteorological Department

temperature which touched 44°C (as on 23rd June, 2007). The Average minimum temperatures recorded are shown in Table 4.2.

Humidity may reach up to 90% during a monsoon spell. NE monsoon brings relief from the hot and sultry summer weather. The mean summer relative humidity recorded by Meteorological Department at Karachi is 60-65% while the mean winter relative humidity is 25-30%.

Weather conditions over Pakistan had already indicated warming and rise in day temperatures by 0.5°C - 0.8°C at a few places in southwest Balochistan, at isolated places in upper Sindh and to be falling by 2°C at 9 out of 18 Meteorological Centres in the Country, while remaining practically unchanged elsewhere in the region.

Night temperatures have also risen by 2°C - 3°C at a few places in upper Sindh, at isolated places in north Balochistan, at an isolated place in lower Sindh, south Balochistan.

These were 2°C above normal at an isolated place in upper Sindh and were 3°C below normal at an isolated place in northeast Balochistan and nearly normal elsewhere in the region.

The year 2007 has been rather unusual in that the total duration of bright sunshine, remained above normal in the country. It ranged for 6 to 9 hrs/day with an increasing trend from North to South. The intensity of solar radiation ranged from 19 MJ/m² to 23 MJ/m²/day with an increasing trend from North to South. Solar Radiations remained above normal in the country except Sargodha and Quetta.

More sunshine means more heat and implying more warming of land and the sea. Consequently Arabian Sea witnessed above normal heating and onset of early monsoon season.

The air temperature prevailing at Karachi City and its adjoining coastal areas are generally high throughout the year. During winter the range of variation of temperature is large for Karachi Coast specially in respect of maximum and minimum temperatures. The air temperature range of Karachi has an average annual range of about ~6°C to ~42°C. The mean air temperature along the coast varies from 24°C to 31°C throughout the year. The highest temperature (40°C or above) occurs in May, June and October. The minimum temperature may fall as low as 5°C to 7°C during night and 18°C to 20°C during day in January. The average annual temperature during summer months is 26°C to 35°C, which may rise to above 40°C during day in May/June. During SW monsoon in July and August due to cloud cover the temperature is relatively moderate in Karachi but humidity is high (about more than 70 %).

The humidity along the coastal belt of Karachi is very high. The data recorded by Pakistan Meteorological Department from Karachi city indicate that the monthly average maximum humidity (in the morning at 8 A.M) varies from 74 - 88 % during May to September and the monthly minimum average humidity (in the evening at 5

P.M) varies form 27 - 52 % during October to March.

B- Rainfall

Karachi falls in dry to semi-arid region with rainfall of about 200 mm per year, with most of it falling in July when approximately 82.5 mm rainfall is measured on average. Rainfall is normally in the summer months of July and August, caused by south-westerly monsoon. There is also meagre rainfall during winter months of December and January with approximately 12.4 mm in January on an average.

Rainfall record available for Karachi, which is given in Table-4.3 shows that only 2 to 3 months get the heavy rainfall while during the rest of the months the precipitation is extremely low. Karachi falls in the semi-arid climate zone.

Since Karachi is situated in a semi - arid climate zone therefore the annual rainfall is quite low. The average of two decades (70s & 80s) shows that it varies between 150 - 250 mm during the year. For Karachi the average number of rainy days / year is less than ten. However, most of the precipitation usually takes place within a short spell of 2 - 7 days. It is estimated that more than 4/5th of the total annual rain fall occurs during the July - August period while the southwest monsoon is on, whereas less than 1/5th of the annual rainfall takes place during winter months (December - February) of NE monsoon. The rest of the rainfall occurs in the form of mild showers or drizzles rarely exceeding 15 mm at a time. Tropical Cyclones contain heavy bands of clouds and cause heavy rains during landfall or sometimes cross along the coast far away but even heavy rainfall is encountered as Karachi received 50 mm rainfall in 24 hours due the Guno storm which hit Balochistan in June 2007.

Discussion on recent developments in monsoon pattern

Because of the increased sunshine and the accompanying rise in temperature of the landmass, Pakistan served as the main heat engine this year to trigger heavy monsoon rains all over the Indo-Pakistan region.

Such rise in temperature on the one hand indicates onset of low-pressure zone, which can attract rain bearing winds in case they are around. It did attract a severe storm indeed since on August 21 sudden heavy rains recorded as much as 80mm in 3 hours, were preceded by dust storm and strong winds.

High heat content of the Arabian Sea that is adjacent to the heat zone of Pakistan was bound to upset the heat balance and hence the water-balance of the region, particularly because it was the destination of the windstorm in late May 2007. This was followed by the Tropical Cyclone Gonu in the first week of June 07, and then by Tropical Cyclone 03A from the south of Mumbai, and thereafter by Tropical Cyclone 04B nicknamed

Table 4.3: Monthly Amount of Precipitation (mm) at Karachi Airort

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2001	0.0	0.0	0.0	0.0	0.0	10.6	73.6	16.2	Trace	0.0	0.0	0.0	100.4
2002	0.0	2.4	0.0	0.0	0.0	Trace	Trace	52.2	Trace	0.0	0.5	0.4	55.5
2003	6.4	21.8	0.0	0.0	0.0	16.3	270.4	9.8	Trace	0.0	0.2	0.0	324.9
2004	13.7	0.0	0.0	0.0	0.0	Trace	3.0	5.6	Trace	39.3	0.0	4.3	65.9
2005	6.6	12.8	Trace	0.0	0.0	Trace	Trace	0.3	54.9	0.0	0.0	17.1	91.7
2006	Trace	0.0	Trace	0.0	0.0	0.0	66.2	148.6	21.9	0.0	3.1	61.3	301.1
2007	0.0	13.2	33.4	0.0	0.0	110.2	N/A	N/A	N/A	N/A	N/A	N/A	156.8

Source: Pakistan Meteorological Department

Yemyin, and then a series of depressions travelling almost directly to the heat zone in Pakistan.

Soon after the beginning of June 07 the tropical cyclone Gonu visited the Coastal area of Oman for the first time in history and set the beginning of destruction over the coastal area of western Balochistan. At this time it seemed that cyclone Yemyin was trekking westward south of Sindh and Balochistan while also weakening, but numerical forecasts were indicating that a big, strong system was developing high up in the sky diagonally on the path i.e. Arabia and Iran and thereby cutting off the impact and almost restraining the cyclonic system to proceed further from the Indus Delta and proceeding towards Karachi. On the night of July 3, 2007 Sindh especially lower Sindh received widespread rains, but luckily Karachi escaped from a high impact of this system. Scattered rains in Sindh with isolated heavy falls in eastern Sindh occurred.

The monsoon activity does not subside until mid September but in 2007 it was more than usual. One of the indicators of its activity is the upwelling that comes along. Upwelling has intensified during this year because of the increased input of sunshine over the land area of Pakistan. This has caused serious disturbances in the current pattern in the Arabian Sea leading to three major cyclonic events.

Accordingly August 10 and 11 of 2007 experienced unusually high rainfall of 107mm in 24 hours as compared with the normal of about 60mm for August. The wettest August ever experienced by the city of Karachi was in 1979, when over 262mm of rainfall was recorded. The record for the maximum rainfall within 24 hours was 166mm of rain on August 7, 1979. The heavy rainfall was thus not unusual particularly because it was caused by the system that travelled from across Rajasthan and lay over Sindh. The monsoon weather system did not move towards Balochistan but the penetration of moist currents from Sindh brought scattered to heavy rain in southern Balochistan, particularly along its coastal regions.

C- Visibility

Visibility depends on weather conditions such as fog, haze, rainfall and dust storms also to a certain extent on the amount of particulate matter present in the ambient urban atmosphere. Weather in Karachi is generally fine throughout the year with visibility ranging up to 10 nautical miles. Haze generally prevails in the morning, which clears by noon. In SW monsoon however, the visibility is reduced to about 2 to 5 nautical miles with sky mostly overcast while in NE monsoon sky is clear and visibility is often less than 1 nautical mile but which dissipates by afternoon. This occurs less than 3 to 4 days a month in winter.

D- Wind Data

Climate of Karachi is characterised by pleasant weather due to sea breeze, which blows all the year round except during local disturbances experienced sometimes in winter and summer months. Table 4.4 gives the data of wind speed records for years 2000-2004 prevailing in the Karachi city.

The wind blows throughout the year with highest velocities during the summer months, when the direction is south-west to west. In winter, winds are of low force from North to Northeast and seldom there is stormy weather. In summer, South West monsoon prevails with wind force ranging between 3.8 m/s and 14.1 m/s on account of low atmospheric pressure due to disturbances. Heavy storms of severe intensity are rare but strong gusts of winds can take place abruptly due to changes in atmospheric pressure. A very recent cyclonic storm passed along Karachi coast in the month of July 2007 resulted in heavy rain and high wind velocity which exceeded 30 m/s on certain occasions. The data on wind speed, experienced in Karachi region

during the years 2000 - 2004 is given in Table 4.4 while wind directions are shown in Table 4.5.

The wind direction during the Southwest (SW) monsoon period is predominantly from the west and southwest and during northeast (NE) monsoon it is from the northeast and north. The wind speed during the southwest monsoon reaches up to 27 knots while the wind speed during the northeast monsoon rarely exceeds 15 knots. The wind rose delineate the percentages of winds from different direction and their intensity (UNESCAP, 1996). Wind intensity at the time when SW monsoon sets in, is much dependent upon the low air pressure system prevailing over the sub continent. The circulation pattern around this low pressure zone determines the force of the wind.

E- Cyclones

The Arabian Sea is known to be frequented by general cyclonic storms and some of these had been among the worst cyclonic storms of the world from their severity point of view, resulting in huge losses to life and property in the coastal areas. A significant number of the cyclonic storms produced in the Arabian Sea move towards north and northeast and some of them land in Pakistan. However most of these cyclones which tend to move towards southern part of the Pakistan coast very often reciprocate towards eastern coast of India. Coastal Sindh is more vulnerable than the west coast of Pakistan to storm surges, associated with the severe cyclonic storm generated in the adjoining Arabian Sea. The available data on cyclones and storm reveals that Pakistan coast is vulnerable mostly during the period from April through June while no storm have ever been observed during January to March (news report).

Tropical cyclones squander between Gulf of Cambay and Karachi. The size of the tropical cyclones is generally 270 -720 Km with an average speed of 7 to 18 Km/hr. Majority of the cyclones land in the vicinity of Indus deltaic creek system creating storm surges of few feet height. In the creek system the tidal range is quite high which is favourable for the amplification of surges. If the peak surge does not occur close to the time of high tide, no major water level oscillations occur in this region. Beside these, the SW monsoon wind also blows in June and adds about 0.3 m of surge to the current tides. Thus very high tidal level over 4.0 m prevailing in the Port Qasim region inundate the creek banks and erode the coastal areas. Such high tides were experienced in 1986, 1990, 1993 and 1999 when heavy damage was recorded in the coastal areas of Badin and Thatta districts.

Severe storms and cyclones seldom cross the coast of Pakistan. Generally the cyclonic storms that emerge in the Arabian Sea and all lines indicating storm trades originating in the Bay of Bengal have been observed either to curve

Table 4.4: Wind Speed (m/s) at 12:00 UTS

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2001	2.6	3.4	4.3	5.6	7.5	8.1	6.8	7.3	5.5	3.7	2.0	2.4	4.9
2002	3.6	3.9	4.0	6.5	8.5	8.2	9.8	7.3	7.7	3.3	2.9	3.2	5.7
2003	4.0	5.0	5.4	5.2	7.7	8.8	6.7	7.1	6.0	3.2	3.1	3.0	5.4
2004	3.4	3.7	4.0	6.0	8.0	9.0	10.0	9.5	7.3	3.8	1.0	2.5	5.7
2005	3.6	4.2	4.8	5.1	7.1	7.5	9.0	6.9	6.4	3.9	2.0	1.5	5.2
2006	2.0	3.0	3.0	6.2	8.0	7.7	8.3	6.2	4.7	4.2	2.2	3.0	4.9
2007	2.0	3.7	4.0	4.0	6.0	6.3	N/A	N/A	N/A	N/A	N/A	N/A	4.3

Source: Pakistan Meteorological Department

Table-4.5: Wind Direction at 12:00 UTS

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	S54W	S43W	S42W	S45W	S46W	S45W	N52W	S59W	S44W	N56W	S45W	S06W
2002	S67W	S52W	S51W	S55W	S51W	S42W	S54W	S45W	S48W	S56W	N54W	S41W
2003	S60W	N50W	S45W	S48W	S45W	S68W	S60W	S47W	S43W	S54W	S50W	S27W
2004	N27E	S46W	S53W	S49W	S52W	S54W	S54W	S62W	S56W	S47W	S45W	N86E
2005	N63E	S51W	S50W	S52W	S63W	S48W	S54W	S49W	S87W	S54W	S52W	N23W

Source: Pakistan Meteorological Department

sharply into the Gulf of Kutch or to cross the Arabian Sea from East to West and end up in the Saudi Arabian Peninsula creating some storm surges at the coast (UNESCAP, 1996). The available data demonstrate that Pakistan coast is vulnerable mostly during the period April - June while no storm has ever been observed during January - March. It has also been observed that the depressions do cross the coast in the month of June and generate winds of 30 - 35 knots. Although movement of cyclones in the Arabian Sea along Pakistan coast is generally in the west / north westerly direction but sometimes these may change the direction and hit the Pakistan. One such example is that of Cyclone 2A of May 1999, which was formed in the Arabian Sea but during the course of the movement changed the direction and hit the coastal area of Badin and caused heavy losses of property and lives. Karachi was in the peripheral area and only showers of moderate intensity were recorded.

F- Storm Surges

Storm Surges are oscillations of the water level in a coastal or inland water body, ranging for the period from few hours to a few days as a result of forces created in the atmospheric weather system. The factors responsible for the generation of storm are the variations in the atmospheric pressure coupled with the wind accompanying the meteorological disturbances which produce normal and tangential stresses along the sea surface and induce the movement of the sea water as well as an inclination of the sea surface.

The peculiar topography, shallowness of the water body, combined with a large tidal range, makes the storm surges more dangerous. By transferring the wind energy into the water the surges get amplified, an effect which is noticed to be more pronounced in the shallow coastal water. In the process of movement of storm the surge level is predicted on the basis of the wave condition getting developed due to the effects of cyclonic forces.

Indus deltaic creeks are located on the path of cyclones that are generated in the north Arabian Sea during the period from May to October and cross the coast near the Rann of Kutch.

Sometime the cyclones cross the deltaic coast itself. Cyclones generally constitute the strong winds having the speed of over 60 Knots and the central pressure as low as 980 mb. The wind and low pressure creates the storm surges which when combined with high tides, becomes a destructive force in the coastal area. Coastal erosion and inundation are commonly associated with storm surges. Beside the cyclones, several depression with less severe intensity frequently occur in the northern Arabian sea, which are also related with surges. These surges which are about 0.5 m in height, when combined with HHW becomes the potential source of the erosion thus creating high wave in the open sandy coast thereby increasing tide water level favouring tidal inundation.

According to the studies hitherto carried out, the Sindh coast falls in a dangerous zone. In this belt

the frequency of the storm striking the coast is low (for over a 75 year period only four storms struck the coast between 18 and 180 N and only three of these struck between 19 and 200 N). Since the tidal range in this belt is quite high unless peak surge occurs close to the time of high tide no major water level oscillation occurs in this region. In between Dwarka (India) and Karachi there is sparsely populated extensive marshy area known as Rann of Kutch. The frequency of storm in the region is generally low and the tracks are not usually favourable for major surge development.

Tidal data recorded at Qasim as well Karachi ports was obtained and analyzed for the separation of surges on the basis of the recorded values. 1982 was selected for analysis due to the fact that the data for both the parts was available for that particular year. It was observed that maximum surge was never more than 2.0 feet. Analysis of the tidal data on surges for Karachi for the period of fourteen years has been extracted and is mentioned in Table 4.6.

Accordingly, the highest surge of 2.6 feet has so far been recorded at Karachi due to a storm that crossed the coast 80 Km east of Karachi on May 1920. Although most of the storms resulted in the rise of sea level but the surge height never became critical. Nevertheless, the coastal topography being gentle and flat, even a surge of 2.0 feet during spring tide can create flooding.

A relationship between predicted astronomical tide and the time of occurrence of surge was developed by Quraishee in the year 1974 which is considered as fairly applicable to prediction of surge level. When surge occurs at the rising tide, it gets built up whereas during falling tide the interactive effect reduces its intensity.

The PQA site under study is located in the coastal area of Karachi and has a moderate climate typical of subtropical coastal zones lying in the monsoon region. The climate of the macro-environment can be characterized by dry, hot and humid conditions. There is a minor seasonal intervention of a mild winter from mid December to mid-February into a long hot and humid summer extending from April to September.

The records of the Pakistan Meteorological Department for Karachi have been used as the source of data for wind, temperature and precipitation. These have been supplemented by the short term meteorological data obtained during the ambient air quality measurements carried out for this study by the Space and Upper Atmospheric Research Organization, SUPARCO.

Major areas under physical environment that have been considered are; climate, water resources, seismology, topography, geology and soil conditions. The development of physical scenario includes baseline study surveys, literature review and authenticated publish material through national newspapers. However, much emphasis has been given to the baseline study surveys.

4.1.2- Hydrodynamics of Karachi Coast

A- Waves

The waves on Karachi Coast vary with the seasons. During NE winter monsoon when winds are around 10 knots the coastal waters are almost calm and the wave height is less than 1 meter. During SW summer monsoon when the winds are around

Table-4.6: High Tides and Surges recorded in past

Month	Height of Tide (ft)	Height of Surges (ft)
June58	9.7	1.3
July58	8.2	1.3
Oct58	9.6	1.4
Nov58	8.1	0.8
May59	9.9	1.8
Jun59	6.9	1.6
Jun59	9.2	1.5
Jun64	8.6	1.7
Jun70	8.4	2.0

Source: Quraishee G.S et al (1984)

25 knots the waves on the Karachi Coast are more than 4 meters. In the interim month i.e. post SW monsoon and pre SW monsoon the waves are around 1.5 to 2.5 meters.

B- Tides

Tides along Karachi Coast are semi-diurnal but diurnal inequality is also present. The effect of this shows up in daily tidal cycle as there are two High Waters and two Low Waters which also vary considerably from each other in tidal heights. These are classified as HHW, LHW, LLW and HLW. The tides move from west to east i.e. the tide at the Hub River Coast arrives about 20 minutes earlier than Karachi. Similarly the tides at Karachi Harbour arrive at about 10 minutes earlier than entrance of Port Qasim. When tides progress up the Phitti Creek its magnitude increases and there is time lag. The tides reach Port Bin Qasim after 22 minute which is about 20 miles from Karachi and is located about 15 miles up to creek from the sea. At Gharo Creek tides fall down rapidly due to frictional effects and the gradual weakening of the tidal forces. At Gharo 35 miles from the Phitti Creek entrance the tides are almost half of the mean sea tides at the entrance.

C- Seawater Currents

The speed of the current is generally low, about ½ knots. The speed increases up to 1 knot during SW monsoon. The direction of the set is directly related with the prevailing wind system. The set is generally easterly in the SW monsoon and westerly in the NE monsoon. The slight difference in direction in the Western and Eastern part of the Karachi Coast is due to circulatory pattern of the current around gyrals which are usually formed at the center of the sea. There is a clockwise gyre during SW monsoon and anti-clockwise gyre during NE monsoon (Quraishee, 1988). Quraishee (1984, 1988) has also observed the existence of warm core eddies in the offshore areas of Pakistan.

D- Seawater Temperature

According to UNESCAP Report (1996) the average annual sea-surface temperature in near shore waters along Karachi coast ranges between 20.7°C to 29.3°C (Table 4.7). During winter months the temperature range is 20.7°C to 23.8°C where as during summer months the range is between 27.9°C to 29.3°C. In the creeks along Indus Delta the sea-surface temperature generally ranges between 23.4°C to 29.5°C (Table 4.7). Water temperature in tidal channels in the Indus Delta creeks have been reported form 19°C in January to 30°C in June (Harrison et al. 1994, Zaqoot, 2000). The temperatures at a depth of 100 m are lower and generally have an annual range between 19.5°C to 24.5°C.

E- Sea water Salinity

According to UNEP (1986) the salinity ranges from 35.5 to 36.9% in the inshore waters of Karachi and may rise as high as 41 to 42% in the back water and tidal creeks. The average annual salinity in coastal waters along Karachi and Indus Delta ranges from 36 to 36.7% (UNEP, 1996). The monthly distributions of salinity along Sindh coast are presented in Table 4.8.

The tidal channels in Indus Deltaic area are generally hypersaline with salinity range of 38 to 45% over the year except during August and September when due to rainy season the run off from Indus River reduces the sea water Salinity to 26 to 30% (Harrison et al., 1994). The salinity values are low as 28 to 30% were reported by Rabbani and Khan (1988) for Khoar Creek of Indus Delta.

Inside Karachi Harbour from Lyari River mouth to the mouth of Manora Channel the Salinity values in the range of 25 to 34% has also been reported (Zaqoot, 2000).

F- Suspended load

The suspended matter in the Indus Deltaic creeks in the vicinity of Karachi ranges from 25 to 178

ppm (Harrison et al., 1994, Zaqoot, 2000). The higher values are found during southwest monsoon. The suspended load also shows variations due to degree of turbulence during a tidal cycle. During December, 1999 the suspended matter concentration from tip of Gizri Creek to Jhari and Gharo Creek ranged between 60 to 81 ppm with exceptionally high value at Lat Basti which was reported 248 ppm (Zaqoot, 2000).

The suspended matter in offshore areas of Karachi generally ranges between 3 to 120 ppm (3 to 15 ppm from October to January and 90 to 120 ppm from April to September).

4.1.3- Geomorphology

The near shore macro-environment of the proposed LNG facility area comprises a number of creeks, islands, wetlands, marshes and mangrove forests and forms the westward extension of the Indus delta. Korangi, Kadiro, Phitti and Gharo are the main creeks. The Malir River drains into the Gizri Creek.

Developments in the Indus delta margin extending from Korangi Creek to the Rann of Kutch, have greatly modified its environment, particularly the geomorphology. The Indus River had built a large delta by pro-gradation and not in the too distant past, it was among the largest river deltas in the world, covering an area of approximately 29,500 sq. km a series of barrages and dams raised on Indus for irrigating the land in the north has reduced the regular flow of sweet water as well as sediment through the river. The greatly reduced river flows and the embankments that were raised to contain flood flows have reduced the active delta which is currently restricted to approximately 200 sq. km on the coastline between Shah Bunder on the east and Keti Bunder on its west. This recession is delta was mainly due to loss of sediment, which the river used to deposit on the entire coastline on its east and west.

The numerous estuaries and creeks connecting to the sea which characterize the tidal delta and marshy mud flats, do not receive the same quantities of nutrients that they used to get in the past to support the growth of mangroves and

Table 4.7 Monthly distribution of temperature along the Pakistan Coast (UNESCAP, 1996)

	Jan Temp.		Feb Temp.		Mar Temp.		Apr Temp.		May Temp.		Jun Temp.	
	Air	Sea	Air	Sea	Air	Sea	Air	Sea	Air	Sea	Air	Sea
Indus delta	19.2	23.6	20.2	23.8	24.3	24.9	29.0	27.0	29.5	27.9	30.0	29.5
Karachi	19.2	23.5	20.5	23.8	24.0	24.8	27.0	26.5	29.0	27.9	30.0	29.3
Gwadar	18.3	20.2	19.5	20.2	22.3	22.0	27.5	24.2	30.1	26.5	31.2	28.3
	Jul Temp.		**Aug Temp.**		**Sep Temp.**		**Oct Temp.**		**Nov Temp.**		**Dec Temp**	
	Air	Sea	Air	Sea	Air	Sea	Air	Sea	Air	Sea	Air	Sea
Indus delta	29.5	28.7	28.0	28.5	26.5	27.0	27.0	27.8	23.5	26.5	19.5	23.4
Karachi	29.3	28.0	28.0	28.0	28.5	27.3	27.2	27.0	27.5	24.4	27.0	20.7
Gwadar	29.2	27.3	28.5	28.0	29.4	28.3	27.0	28.0	23.1	25.3	20.1	23.2

Table 4.8: Monthly distribution of salinity along the Pakistan Coast (UNESCAP, 1996)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Indus Delta	36.1	36.15	36.5	36.4	36.5	36.6	36.7	36.61	36.48	36.47	36.5	36.2
Karachi	36.0	36.2.	36.5	36.5	36.5	36.6	36.7	36.6	36.5	36.5	36.5	36.2
Gwadar	36.05	36.26	36.53	36.55	36.58	36.65	36.74	36.68	36.59	36.55	26.54	26.3

aquatic life. The salinity of the water within the estuaries area that used to be lowered due to the input of freshwater from the Indus is now restricted to the occurrence of floods. The dry weather flows from land are loaded with pollutants within the zones of urban and industrial activity. The Gizri and Korangi Creeks receive the polluted drainage water from the Malir River and other drains.

4.1.4- Geology

Geological investigations for the Bin Qasim area suggest the presence of only Middle and Upper Tertiary rock formations comprising fresh, and slightly weathered recent and sub-recent shoreline deposits. Principal constituents of the deposits are the inter-bedded sandstone and shale together with subordinate amounts of large size gravels or conglomerate.

The creek area is covered with mudflats supporting mangrove vegetation and does not exhibit much geological and pedological diversity. The information, as per Geologic Survey of Pakistan, reveals that in the project area and its adjoining areas only the middle and upper tertiary formations are present. The formation found in the area is fresh and slightly weathered, recent and sub recent shoreline deposits. These deposits are derived from Gaj / Manchhar formations of lower Miocene to Middle Miocene / Upper Miocene to Pliocene age. Similar deposits are found all along the coastal belt of Karachi and adjoining areas. The seabed is predominantly sand and silt while the sediment of the delta is fine grained and resembles the soil from the continental shelf at the mouth of the Indus delta. The gravels or conglomerates are poorly transfixed with medium to coarse brown sand and are derived from Manchar Formations of Pleistocene age. The Gaj formation consists of mostly limestone with subordinate shales and sandstone. The limestone is hard, sandy and extremely fossiliferous. This formation overlies Nari formation which consist of harder limestone beds and shales.

Conformably overlying Gaj formation is Manchhar formation. Similar Manchhar formation exists all along the coastal areas of Karachi and best exposed in Clifton, Ibrahim Hydri, Gizri, Korangi and Landhi areas. This formation is composed of sandstone, clay beds, cemented sand and gravel (pseudo Conglomerate). Sandstone is thick, porous and friable and also contains bands of conglomerate. The clay has various colours including grey, brown, chocolate and orange, however the most widely occurring clays are of light brown and dark grey in colour. Sandy layers are also found inter-bedded with clay and gravel.

The mudflats are recent deposits of the delta area while soil cover is the drift type that has been slightly withered with time and marine activity. It seems to have been transferred with the flood flows from Malir River on the west and the Indus on the east.

4.1.5- Coastal Geology and Geomorphology

The coastal zone of Karachi is highly dynamic area where a number of marine and terrestrial processes are responsible for changes taking place along the coastal belt.

The coast of Karachi is situated between the Cape Monze, a high cliff projecting into the Arabian Sea and the Korangi Creek. The coastline of Karachi metropolitan is about 90 km long. It is generally oriented NW-SE. On the western side, it is bounded by the Hub River and on the east by the mangrove swamps and creeks of the Port Qasim area. The Lyari and Malir Rivers are the seasonal streams which flow during SW monsoon. The rain water from Karachi and its adjoining area drains in the Arabian Sea. The prominent feature of Karachi coast are shallow lagoons, raised beaches, marine terraces and dune fields. Four major inlets, Manora Channel (Karachi Harbour), Korangi Creek, Phitti Creek, and Khuddi Creek invaginate the coastline. A small crescent shaped sand bar exists at the mouth of the Korangi Creek. The

Cape Monze beach is an example of raised beaches along the coast of Karachi. The eastern coast has tidal creeks with mangrove and mud flats. In the region the seabed is generally smooth. The bed slope has a low gradient and is in the order of 1/500 to 1/1000 (Government of Pakistan, 2005).

Based on physiographic features Karachi coastal area can be divided into three different regions viz. A) West Coast, B) South coast and C) Southeast coast which are described below

A- West coast of Karachi

The coast, west of Manora breakwater to Buleji consists of sand beaches, (Manora, Sandspit and Hawks Bay) rocky protruding points separate these beaches form each other. From Bulleji to Cape Monze the coast consists of hard conglomerate and shale cliffs. Beyond Hawks Bay towards west up to the Cape Monze, the unconsolidated sandy clays are exposed to coastal weathering and erosion. Small rivers supply sediments to the coast during the rainy periods. The rivers are the predominant sources of sediment to the sandy beaches The Lyari delta is well protected from the direct influence of the ocean surf by the belt of sand.

B- South Coast

The southern coast of Karachi lies between Keamari to Korangi Creek mouth and includes fine sandy beaches of Clifton and Defence Housing Authority (DHA) with a very low angle of beach slope resulting in large shallow inter-tidal and sub-tidal areas spreading up to 1-5 km. The coastal features of Clifton and DHA beach have been greatly modified and considerable area from Korangi - Clifton has been reclaimed by filling, low marshy lands. The coastal belt of Karachi from Karachi Harbour inlet at Keamari along Clifton and DHA Beach extending up to Gizri Creek is 14 km long.

It has a very gentle surface gradient of about 1:50. The Clifton beach is largely composed of dark, grey silty materials with minute flakes of mica. The fine micaceous sand drifted from the mouth of the river Indus by the strong littoral currents. The sand, after it compiles on the beach by the waves is blown inland in large quantity by wind action. Further east of Clifton there are agglomerations of Ghizri hills. The beaches of Karachi are a source of recreation for the local habitants and attract large number of people.

C- Southeast Coast

The Southeast coast of Karachi coastline lies between Korangi creek inlet and Khuddi Creek. It encompasses coastline of four islands; Bundal Island, Buddo Island, Miran Island and Khuddi Island and two large and deep openings towards sea the Phitti Creek Mouth (Approach channel of Port Qasim) and the Khuddi Creek Mouth. The eastern coast has tidal creeks with mangrove and mudflats which are linked with a network of creeks of Indus Delta. The sea bed at the eastern and south eastern coast, is generally smooth and regular as depicted by the bed contours. The led slope is gentle, usually being in the order of 1/500 to 1/1000.

4.1.6- Stratigraphy and Lithology

The hills skirting the shoreline between Cape Monze and Korangi are composed of alternating beds of limestone, clay and sand stone of Oligocene to Pliocene epochs. The stratigraphic sequence exposed in the area is:

A- Nari formation

The name comes from the Nari River. This is entirely marine but marks the beginning of great influx of sandstone and shale which caused the sea to retreat south west. The formation consists mainly of sandstone and shale with subordinate limestone and conglomerate. The limestone is principally in the limestone is principally in the basal strata and is not present in all regions.

B- Gaj formation

The formation is exposed in low relief hillocks. It is

more resistant than the overlying Manchar formation. Calcareous sandstone and limestone are most conspicuous and they are gradational. Mainly it is a marine assemblage but also has fluviatile or estuarine components demonstrating the influence of fresh water environment near the end of the Miocene age. Sequence: - Limestone Shale Limestone / sand stone.

C- Manchar formation

The formation is exposed in the mountain fringe. In the vicinity of Karachi it underlines a terrain of low relief. It is mainly composed of sandstone and shale with subordinate amounts of conglomerate in the top part. Sandstone predominates in the lower half and shale in the upper half which increases towards the coast. Sandstone is gritty, crumbly and soft bedded. In its upper part, at places it has thin veneer of Dada Conglomerate of Pleistocene epoch. In the vicinity of Gaj north of Karachi it is entirely fluviatile but near the coast it is marine or estuarine. The regional relationship of the rocks show that they were deposited in a relatively narrow trough, which opened southward to the sea, and that the shore receded south as the trough was filled. Manchar beds are the main reservoirs (aquifers) of sweet ground water on the main land.

4.1.7- Seismic Information

Karachi is situated close to the junction of three tectonic plates (Indo-Pakistan, Arabian and Eurasian Plates). The significant faults in the vicinity include Ran of Katch Fault in east and Pub-Null Fault in west. The Rann of Kutch-Karachi fault, also known as Karachi-Jati-Allah Bund fault, passes close to the Eastern Industrial Zone of Port Qasim. It has three other segments namely the Jhimpir fault, the Pab fault, and the Surjani fault. These are the infra-plate active faults that pose major earthquake hazard in the Indus delta and the estuaries of the passive continental margin. The orientation of the Rann of Kutch fault is roughly east-west; it is 225 km in length and is responsible for the production of earthquakes of considerably high magnitude of up to 7.6 M on Richter scale and of IX to X intensity on the Modified Mercali (MM) scale. The Pab fault on the other hand is 135 Km in length and is oriented north-south. On the basis of the study of the seismic potential of the active faults viz. Rann of Kutch and Pab faults over their entire length, along with analysis of historical and instrumental records of the Pakistan coastal zone the risk factor for this region is estimated to be 7.7 to 8.2 M for the former and 7.2 to 7.8 M for the later.

The Geological Survey of Pakistan has, however, defined the area of Port Qasim, where the site under study is located, to fall in a Seismic Zone 3 region. This suggests the possibility of moderate to major seismic hazard i.e. probability of earthquakes of intensity V to VII MM scale and possibility of higher than VII also exists.

From the charts published, seismic risk factor of 0.3 is therefore, advisable and is incorporated in the design for constructions and installations in the coastal zone, for operational basis earthquakes (OBE) pertaining to damage due to moderate level earthquakes (MM-V to VII). The seismicity in the Karachi and at Project site is considered to be low. According to the published data the Project area lies in zone of low seismic activity, with acceleration ranging from g/20 to g/15. A factor of 1/15g will, on the other hand, have to be taken for a maximum credible earthquake (MCE). The design of the LNG terminal will take these values into consideration.

The coastal areas of Karachi also cover the Indus Deltaic region and the seismic activity in the Indus Deltaic region is mainly due to active faults. The northern flank of Indus Delta is delimited by an E-W-fault. This tectonic lineament shows signatures of reactivation during Pleistocene and is also well evidenced by frequent seismicity.

The earthquake hazard in the Indus Delta and the estuaries on the passive continental margin is mainly from intra-plate active faults, particularly the Rann of Katch Fault and Pab Fault and their strands. The most spectacular effect of the active fault of Rann of Kutch which grazes the vicinity of Karachi was due to the severe earthquake of June, 1891. It resulted in the 6m uplift of 16km vide and 81 km long tract of

alluvial land which blocked an eastern branch of the Indus River and therefore the locals called it Allah Band (Oldham, 1926). Using aerial photographs scientists identified complex series of faults in the region of Sindh Coast between Karachi and Rann of Kutch. The main faults thus identified are generally oriented easterly, and slightly concave to the north. They roughly parallel the inferred zone of rupture for the 1819 event (Quittmeyer etal. 1979).

A list of earthquakes with inland epicentres, since 1977 to date which affected the Indus Deltaic Creeks are given in Table-4.10. Under the influence of these earthquakes creeks depths and orientation changes, new islands emerge and sometimes existing alleviated areas are eroded.

Dr. Iqbal Mohsin (2005) in his book 'Zalzala, 8 October, 2005' has mentioned about two sever earthquakes in the vicinity of Karachi; one in the year 1050 at Bhanbore in which 0.15 million casualties are reported and the other in the year 1668 at Pipri near Steel Mill which was only 60 km away from Karachi however the details of this are not available. He has also referred the earthquake of Bhoge in the year 2001 in which Ahmedabad was 300 km towards east and Karachi was 300 km towards west, however fortunately Karachi remained safe. According to Iqbal Mohsin (2005), presently Karachi is in Zone 3 of Risk zones in the light of Geological Survey Map (1984). He also refers that in 1997, US Geological Survey and UBC have included Karachi in the list of those cities which come under the category of Risk 4 zone.

Table 4.9: Geological Formations

Formation	Age
Manchar Formation	Pliocene
Gaj Formation	Miocene
Nari Formation	Oligocene to early Miocene

4.1.8- Tsunami

The available records do not show major damages to have been caused by tsunamis, the impulsively generated seawater waves that are a result of underwater earthquakes, along the Pakistan coast. There is, however, evidence of one generated by an offshore earthquake of intensity 8 M in 1945, which caused a 1.2 m tsunami in Port Qasim area but led to only minor damages. The risk factors from tsunamis are very significant for installations on the coast but the same are minimal within the creek system.

4.1.9- Soil

The inter-tidal zone is covered by soft clayey silt to varying depths. The on-shore area is covered by dune sand and silty sand and gravel. Samples of sea bed soil were however collected and tested in the laboratory for soil classification.

4.2. HYDROLOGY AND HYDROGEOLOGY

4.2.1- Impact of River Discharge

The Indus Delta represents a major example of negative effects of the progressive reduction in fresh water discharge over a period of many years. Historical records indicate that the distribution of mangroves in the Indus Delta has significantly changed during the past several hundred years with the shifting pattern of the river (Snedaker, 1984). Until recently the Indus River had a largely river-dominated estuary but increased utilization of the river for agriculture etc. has resulted in discharge to the Arabian Sea only during the summer southwest monsoon. During remaining nine to ten months the Indus River has no estuary due to elimination of the river discharge (Schubel, 1984). As a result, the mangrove ecosystem has been adversely affected. Some decades ago the area of mangrove cover in the active Indus Delta has been estimated at about 250,000 ha (Khan, 1966, Mirza et al, 1973). The mangroves are degrading rapidly caused by a number of factors such as cutting, browsing and by reduced silt laden river water. These forests which covered 263,000 ha in

1977 have recessed to about 160,000 ha in 1990 (Kela, 1999, IUCN, 2005).

This is probably the most serious problem focusing mangroves of Indus Delta, therefore the salinity value of 40 ppt or more is common in mangrove areas. Although there exist no previous records of salinity values in the area for past some decades, but it was appreciably lower since rice was once cultivated in Keti Bunder in the vicinity of mangrove stands (Saifullah, 1982). Due to hyper salinity and nutrient impoverishment decline in mangrove is now visible everywhere. Early dense and extensive forest has changed to stunted growth of trees and reduction in forest area.

Dams and diversionary barrages also affect bed-load and suspended transport of sediments by capturing this material and preventing its uniform dispersal over mangrove areas during flood season. Thus the mangroves are deprived of an annual silting (and input of inorganic nutrients) and the depositional character of the mangrove environment is severely altered. Further, in the absence of flushing, distributary rivers in delta regions become silted and cease to function. The filling and death of distributary rivers has occurred and is taking place in such major river deltas as the Ganges and Indus. When dams and barrages are constructed the mangroves below the dam are subject to a variety of stress conditions which leads to shifts in species dominance, reduced structural complexity and lowered productivity which is quite evident in mangroves of Indus Delta including Port Qasim area in the vicinity of Karachi.

The macro-environment of Port Qasim includes an extensive creek system, some mangrove forest and islands. The delta has receded and retreated towards the southeast and the remnant of estuaries has developed into a complex system of sea water creeks separated by mud flats and small islands. The mudflats are fine-grained deltaic sediments having close similarity to the continental shelf deposits at the mouth of the delta. The mud flats and the small islands in the vicinity of the proposed site are low and are submerged during high tide.

The site of the proposed jetty is located on Kadiro Creek, which serves as the navigation channel of Port Qasim and having links with the Korangi/Phitti Creek system near the Port, it provides the main connection to the open sea. Maintenance dredging is carried out at locations in the main navigational channel to Port Qasim, and also in the immediate vicinity of the wharves, to maintain access and navigable depths.

4.2.2- Sources of Water Pollution

The coastline of Karachi is increasingly highly

Table 4.10: List of Earthquakes in Indus Deltaic region and surroundings within latitude 23.0 - 25.0 ON and longitude 67.5 - 71.0OE

DATE	LAT. (ON)	LONG. (OE)	DEPTH (km)	MAGNITUDE (RICHTER SCALE)
26-09-1977	25.4	68.2	33	4.5
25-11-1982	25.6	67.9	33	4.9
17-12-1985	24.9	67.4	33	4.9
24-12-1985	24.8	67.6	33	4.7
10-09-1991	24.4	68.7	33	4.8
19-09-1991	24.3	68.7	33	4.7
23-04-1992	24.3	68.8	33	3.7
24-12-1992	25.2	67.7	33	3.6
05-02-1993	24.6	68.9	33	4.3
26-01-2001	23.4	70.32	17	7.6

polluted with a variety of hazardous substances of industrial, municipal and agriculture origin, yet there are no proper monitoring or treatment facilities to mitigate their harmful effects. The levels of pollutants particularly heavy metals have already crossed the limits of natural oceanic concentrations (Bruland, 1983) in the vicinity of Karachi such as Karachi Harbour, Sandspit, Korangi creek and creeks adjoining Port Qasim.

The Indus Delta creeks in the vicinity of Karachi and Karachi city have progressively become the Centre of major socio economic activities in the country Karachi is not only the major industrial centre but it also has two ports (Karachi and Port Qasim) which play vital role in the development of the economy of the country. It is estimated that about 262 MGD of sewage is generated in Karachi from industrial and domestic sources. Of this 111 MGD is contributed through municipal and the remaining from industrial sources (approximately 6000 units). Out of this waste only 20% is treated and the rest is discharged into coastal waters untreated. It is estimated that Lyari and Malir Rivers contribute 60% and 25% of the total pollution load of Karachi where as 15% of the pollution load is directly discharged into the adjacent open sea coast or to the Gizri, Korangi and Gharo creeks. In the proximity of the creeks adjoining Port Qasim area major industrial complexes include Korangi Industrial area (KIA), Landhi Industrial Trading Estate (LITE), Port Qasim Industrial Area and Pakistan Steel Mill. The KIA is located adjacent to Korangi-Kadiro creeks, LITE is situated close to the Kadiro-Gharo creeks and Steel Mill is located on the Gharo creek. Coastal villages such as Ibrahim Haidri, Rehri, Lut Basti are also present in this area. Thus the entire Korangi creek, Phitti creek, Kadiro creek and Gharo creek form an inter-related system of creeks receiving bulk of the domestic and industrial wastes in the south-east of Karachi. The major pollutants entering into the creek areas are summarized in Table-4.11.

A- Heavy Metal Pollution

Some studies conducted during 1999-2000 on Heavy metals in Mangroves Habitat and Oil pollution in the vicinity of Karachi have shown higher concentration of heavy metals in various components of mangroves and fauna inhabiting Korangi Creek, and sediments collected from these localities (Saleem et al. 1999, Zaqoot, 2000, Saifullah et al. 2002, 2004). Mangrove habitat serves as sink for heavy metals. The sediments are the major trap of metals followed by mangrove plants. The order of accumulation in different section's of habitat is from sediment to pneumatophores to bark to leaves to twigs to flowers. According to Williams et al., (1996) detrital silicates and sulphides are the principal carriers of iron and other heavy metals and therefore make sediment a long-term contaminant sink. The concentration of copper, iron and nickel in various components of mangrove habitat are presented in Tables 4.12-4.16.

B- Oil Pollution

The studies on oil pollution prior to Tasman Spirit incident show that sediments of Karachi Harbour are generally heavily polluted with oil. The concentration of oil and grease in sediments collected from the creek areas is not as high as found in Karachi Harbour. The concentration of oil in creeks adjoining Port Qasim ranges from 16.25 mg/kg to 81.25 mg/kg. The highest concentration was found in the sediments collected from Gizri creek. Korangi creek sediments are also contaminated by oil and grease which could be attributed to fishing activities at Ibrahim Haideri. The sediments of other creeks adjacent to Port Qasim area have not been found polluted with oil to the same level as Karachi Harbour. The level of oil and grease is very low there and the environment is also not threatened by oil pollution so far (Zaqoot, 2000).

The level of total oil and grease in sediments in the vicinity of Port Qasim are presented in Table -4.16.

The seawater samples collected from Gizri creek showed considerable effect of oily wastes mostly

released from industrial wastes and Pakistan Refinery effluents discharged through Malir River. Lower degree of oil pollution was observed in the creeks adjoining Port Qasim area such as PSO Jetty, Phitti-Korangi creek, Jhari creek, Chara creek and Gharo creek (Zaqoot, 2000).

In 2003, on 27th July an oil tanker MT Tasman Sprit grounded off Karachi Pot Trust near the entrance channel. During August, 2003, approximately 31,000 tons of Crude Oil spilled from this grounded oil tanker and spread along Clifton beach. Scientific investigations to assen the damage to the natural resources as a consequence of the oil spill was undertaken by Pak-EPA under the Ministry of Environment, Government of Pakistan. The results as summarised were presented at a "National Symposium on Natural Resource Damage Assessment of Tasman Sprit Oil Spill" at Karachi on 30-31 May, 2005. Some of the information presented regarding pollution due to Tasman Spirit Oil Spill along Karachi Coast from August - December, 2003 is presented in Table-4.17.

The oil concentration in surface and deeper water column ranged between 1 to 9 ppm as seen from the Table-17. The intertidal area as expected shows higher concentrations which are gradually decreasing towards deeper waters.

Similar trend was also observed in sediments of intertidal area to deeper waters along the coast of Karachi (Table -4.18).

4.2.3- Physico-chemical Conditions of Creek System

The physico-chemical properties of the Indus Delta creeks are poorly understood. General physico-chemical characteristics of various localities adjoining Port Qasim area during winter are summarized in Table 4.19. Temperature of sea water ranges from 22-25^{o}C during winter and 28 to 29^{o}C during summer (SW monsoon). The pH values ranged 7.43 to 7.83 in the area apposite Lat Basti, Ibrahim Haideri (Korangi creek) and Gizri creek which is slightly on lower side as compared to sea water. The reason for this is mixing of domestic water discharged into the creeks from coastal villages. The density of sea water was found generally in the range of 1.027 to 1.03 and the salinity ranged from 36 to 39% however the tidal channels are hyper saline and the salinity value as high as over 40% is found in these creeks.

Almost similar conditions were also observed in Gizri Creek and Korangi Creek during northeast and Southwest surveys conducted during 2007 (Kidwai, Personal Communication). They also found the temperature at sub-surface depths in these creeks in the range of 19.38 to 29.08^{o}C, Salinity in the range of 36 to 38.91 % and dissolved oxygen in the range of 0.15 to 5.76 ml/l.

Nutrients in the Gharo creek do not appear to be limiting to primary productivity in the channels. If there is any limitation, it is more probably due to turbidity and thus a highly restricted photic zone. The Karachi Harbour, Gizri creek, and Korangi creek receive large quantities of nutrients as part of the liquid waste and garbage being disposed of in these creeks. Gharo creek also receives high nutrient loadings. Higher concentrations of nutrients result in overproduction and utilization of dissolved oxygen in the seawater. This leads to anoxic conditions and eutrophication.

Anoxic conditions prevail in about 40 percent of the bottom areas of Karachi Harbour and about 60 percent of the Gizri creek areas (Rizvi et al. 1999). Eutrophication is conspicuous in the middle and lower parts of Gizri creek. Phytoplankton blooms are common in Korangi/Gizri creeks (Harrison, 1997) and in coastal waters adjacent to Clifton beach (Khan, 1986) and dinoflagellates bloom in the waters of Sandspit beach, and Hawkesbay and along continental shelf of Pakistan (Saifullah and Chaghtai, 1990).

The transparency of water (Secchi disc disappearance depth) depends on the magnitude of turbidity in the Indus Delta. In Khobar creek the light penetration was up to a depth of <1.0 m. The

Table-4.11: Major Industrial Pollulants entering in the Gharo-Korangi Creek System

INDUSTRIES	NO. OF INDUSTRIES BY LOCALITIES				MAJOR POLLUTANTS AS INDUSTRIAL EFFLUENT
	KORANGI	LANDHI	MALIR	TOTAL	
Chemical Industries	13	5	6	24	Various organic and inorganic compounds, Pesticides, insecticides.
Metallurgical Industries	96	105	123	323	Cooling Oils, Acids and Alkaline deoxidizing agents and metal salt.
Oil refineries Industries	2			2	Crude oils, lead compounds, Phenols, Surf active agents, Toxic hydrocarbons
Petrochemical Industries	2			2	Petroleum derivatives, Benzene, Toluene, Heavy aromatic compounds Acetaldehyde,
Tanneries	40	10	20	70	Chrome salts, Sodium salts Organometalic compounds High BOD organic wastes
Pharmaceutical Industries	51	11	10	72	A variety of organic and inorganic compounds
Glass Industries	25	10	5	40	Metal oxides, CO
Textile Industries	100	150	98	348	Metal oxides, Colouring compounds, Wood and cotton Fibres.

(Source: Rizvi,1997)

maximum water transparency in the major creeks of the Indus Delta are 2.5-4.5m in he Gharo creek, 3.0-5.0 m in the Phitti creek and 7.0m in the offshore water during the Jan-Feb. period. The minimum values (0.5-1.0m) of sea water transparency in the Gharo/Kadiro creek, <0.2m in the Phitti creek and 0.2 to >2.0m in offshore area adjacent to the creeks, during the May to August period. The turbidity values in the offshore waters adjacent to the delta are higher during southwest monsoon period than during the rest of the year. Turbidity values are also influenced by the strong tidal flux which reverses its direction during ebbing and flooding. Generally the turbidity is higher during ebb tides, particularly in the shallow creeks. The turbidity is also high within the delta area and in the adjacent coastal waters during river runoff after the rainy season of southwest monsoon.

4.2.4- Nutrient Concentration

The nutrients (Phosphate, Nitrate, Nitrite and Ammonia) play vital role in the food chain of marine ecosystem as fertilizers of the sea and in primary production of coastal and oceanic waters. They support the growth of phytoplankton which serve as the food for zooplankton as well as larval stages and juveniles of fish and crustaceans and also serve as food for filter deeders. As may be seen from Table 4.20 on average nutrient concentration ranges based on NIO data archive, the nutrient concentrations generally increase from Keamari coast towards Gizri creek, suggesting that the coastal waters opposite to DHA beaches are very

Table-4.12: Concentration (ppb) of Cu in water of mangrove habitat of Karachi

Locality	Average conc. + SE	N	Range
Sandspit	1.5 + 0.49	7	1.06 - 3.26
Karachi Harbour	0.61 + 0.18	10	0.02 - 1.86
Korangi Creek	1.17 + 0.87	3	0.06 - 1.94
Port Qasim	3.06 + 0.63	5	1.89 - 5.17
Lut Basti	1.50 + 0.35	7	0.047 - 1.728
Chara Creek	0.78 + 0.49	3	0.31 - 1.79
Miani Hor	0.041 + 0.00	1	-

(Saifullah et al, 2002)

Table- 4.13: Concentration (ppm) of Cu sediments of mangrove habitat of Karachi

Locality	Average conc. + SE	N	Range
Sandspit	48.09 + 2.43	19	28.90 - 65.70
B/Shams	57.60 + 0.0	1	-
Port Qasim	44.02 + 0.07	4	36.70 - 51.20
Lut Basti	69.02 + 8.09	3	56.90 - 85.60
Chara Creek	46.55 + 1.35	2	-
Korangi Creek	48.10 + 0.00	2	42.20 - 54.00
Miani Hor	9.80 + 0.0	1	-

(Saifullah et al, 2002)

Table- 4.14: Average concentration (ppm) of Fe in sediments of mangrove habitats of Karachi, where N is the number of samples, SE in the standard error

Locality	Avg. Concentration (ppm)	+ SE	N	Range
Sandspit	25 624	1778	19	6369-32 440
Baba/Shams Islands	28 120	-	1	-
Port Qasim	27 489	2481	3	22 678-31 148
Lat Basti	23 310	4105	3	17 657-31 545
Miani Hor	1248	-	1	-
Chara Creek	30 067	2515	4	22 640-33 120
Rehri	34 436	2249	2	29 982-34 436
Phitti Creek	16 480	9333	2	7240-25 720
Bkran Creek	23 900	866	2	23 040-24 760
Shamspir	17 060	381	2	13 280-20 840

(Saifullah et al, 2002)

Table- 4.15: Average Concentration Of Ni (ppm) in Surface Sediments along Karachi Coast

Locality	Average Concentration (ppm)
Sandspit	77.1
Baba / Shams Island	58.2
Rehri	52.4
Lut Basti	48.3
Port Qasim	55.1

(Source: Saifullah et at., 2002)

Table-4.16: Concentrations of oil & grease in marine sediments in the vicinity of Port Qasim (Dec, 1999)

Localities	Concentration (mg/kg)
Lat Basti (Korangi Creek)	78.75
Gizri Creek (Opposite Marina Club)	17.50
Phitti Korangi Creek	16.25
Jhari Creek	33.75
Chara Creek	31.25
Opposite Korangi Fish Harbour	20.00

(Zaqoot, 2000)

productive which is also influenced by Gizri creek and Korangi creek waters harbouring mangrove forest which itself is one of the highly productive marine ecosystems.

The nutrient distribution in Karachi Harbour area is presented in Table 4.21. These data show that nutrient enrichment particularly of inorganic phosphate over the entire harbour area which is the influence of industrial and sewage discharges on nutrient salt concentrations in surface and near bottom layers. Excessive nutrient in coastal waters may cause eutrophication in coastal areas.

4.2.5- Heavy Metals in Sea Water and Marine Sediments

Some studies conducted during 1999-2000 on Heavy metals have shown higher concentrations of selected heavy metals in water and sediment samples collected from various localities along Karachi coast. Mangrove habitats in the vicinity of Karachi serve as sink for heavy metals. The sediments are major trap for metals followed by mangrove plants. According to Williams et al. (1996) detrital silicates and sulphides are the principal carriers of iron and other heavy metals and, therefore, make sediments a long term

Table-4.17: CONCENTRATIONS OF TOTAL OIL IN THE WATER COLUMN ALONG KARACHI COAST AFTER TASMAN SPIRIT OIL SPILL

S. No.	Coastal Sampling Zones	Oil Concentrations (ppm) Surface Waters (0.5 m Column)	Oil Concentrations (ppm) Bottom Waters (0.5 m h)	Oil Quantity (tons) (0.5m Column) in 150 Sq km area
1	Zone-1 (Inter-tidal areas)	01 - 09 ppm	15 - 33 ppm	196.964
2	Zone-2 (5-10 meter depths)	02 - 19 ppm	13 - 30 ppm	523.361
3	Zone-3(10-20 meter depths)	02 - 04 ppm	08- 25 ppm	225.102
4	Zone-4 (20-30 meter depths)	02 - 03 ppm	08 - 15 ppm	67.530
	Average Range	02 - 04 ppm	08 - 33 ppm	Total = 1012.957

Table-4.18: CONCENTARATION OF OIL IN THE SEDIMENTS FROM COASTAL WATERS OF KARACHI DURING AUGUST TO DECEBER 2003 AFTER TASMAN SPIRIT OIL SPILL

Sampling Zones	Oil Concentrations (ppm) (19th August to early September 2003 during the Oil-Spill) Surface Sediments (0-10 cm layer)	Oil Concentrations (ppm) (25th October - 10th December 2003) (55 - 65 days after the spill)	
Zone-1	195 ppm	(0 - 10 cm layer) 300 - 2700 ppm	(10 - 30 cm layer) 200 - 1800 ppm
Zone-2 (5-10 meter depths)	195 - 968 ppm	(0 - 10 cm layer) 300 - 800 ppm	(10 - 30 cm layer) 200 - 500 ppm
Zone-3 (10-20 meter depths)	51 - 382 ppm	(0 - 10 cm layer) 300 - 400 ppm	(10 - 30 cm layer) 100 - 300 ppm
Zone-4 (20-30 meter depths)		(0 - 10 cm layer) 300 ppm	(10 - 30 cm layer) 100 - 250 ppm
Average Range	51 - 968 ppm	300 - 2700 ppm	100 - 1800 ppm

Source: NRDA SYMPOSIUM 2005

contaminant sink. The concentration of copper, iron and nickel in water and sediments along Karachi coast are given in Table-4.22 to Table-4.26.

4.3. CREEK SYSTEM HYDRAULICS

4.3.1- Port Qasim Entrance and Navigation Channels

The Port Qasim provides the second port facility for the country. The access to Port Qasim / Phitti Creek is provided through Ahsan Channel, being maintained at 12.4 m depth. Its maintained width increases in-shore from 185 m to 225 m. The 225 m wide inner channel of Phitti Creek from Zulfiqar Bank to Hasan Point and of Kadiro Creek from Hasan Point to the Iron Ore and Coal Berth is maintained at 11.3 m Berth. Vessels of up to 25,000 tonnes can operate to Marginal Wharf where a depth of 10.0 m is maintained.

4.3.2- Tides and Currents

The tides at Port Qasim are predominantly semi-diurnal with a substantial diurnal component. The Mean Higher High Water (MHHW) to Mean Lower Low Water (MLLW) range is about 2.4 m at the port complex while the peak tide over diurnal range is about 3.5 m. The tide levels at Port Qasim are presented in Table 4.27 below. The flow pattern within this large, relatively deep and generally stable creek system around Port Qasim is strongly influenced by tides and the presence of extensive inter-tidal flats.

Tide levels at Port Qasim apply to Gharo Creek from Iron Ore and Coal Berth to Marginal Wharf.

The currents in Gharo Creek show a well-defined ebb bias. In the channel, Ebb currents of up to 2m/s have been measured with corresponding flood currents of up to 1m/s. The strong current corresponds to the large volume of tidal flows.

4.4- ECOLOGICAL ENVIRONMENT

4.4.1- Coastal & Marine Ecosystem

Coastal ecosystems provide a wide array of goods and services. They are the primary producers of fish, shellfish and seaweeds for both human and animal consumption, and they are also a considerable source of fertilizer, pharmaceuticals, cosmetics, house hold products and construction materials. The marine ecosystem provides living and nonliving resource such as fishery resources, oil and gas and mineral resource for mankind.

4.4.2- Marine / Aquatic Life

A- Micro-habitat (Phytoplankton)

Noor Uddin (1967a) in one of the earliest studies gave an account of the phytoplankton of coastal

Table 4.19: Average concentrations of some physical and chemical characteristics (Nov- Dec, 1999) in the vicinity of Port Qasim

S. No.	Locations	Parameters						
		S.W. Temp OC	Density kg/m3	Salinity%	pH	D.O. ml/ l	T.D.S ppm	Organic matter mg/l
01.	Gizri Creek (Top End)	21.0	1.025	33.950	8.10	2.298	41231	5.75
02.	Gizri Creek (DHA Cluub)	20.0	1.025	33.400	8.30	3.957	41385	5.93
03.	Korangi Creek (Rehri)	22.0	1.028	37.801	7.8	4.330	33908	2.35
04.	Korangi Creek (Lat Basti)	23.0	1.027	36.00	7.43	0.430	50036	3.91
05.	PSO Oil Jetty	25.0	1.028	37.00	7.70	3.170	42209	4.96
06.	Phitti Creek	22.7	1.029	38.784	7.48	4.250	38972	5.77
07.	Jhari Creek	23.0	1.030	39.207	8.10	3.860	34132	6.72
08.	Chase Creek	23.0	1.030	38.418	8.20	3.060	42508	4.22
09.	Gharo Creek	24.0	1.029	38.443	8.20	3.570	31276	5.48

(Source: Zaqoot, 2000)

waters of Karachi. From the inshore waters of Karachi he reported blooms of 2 - 3 species between December and May. Subsequent studies on phytoplankton also focused on Karachi Harbour, Manora channel, and Korangi Creek and dinoflagellates and diatoms collected by nets from these areas were reported (Hassan and Saifullah, 1971, 1972; Saifullah and Hassan, 1973a, 1973; Hassan 1976; Saifullah and Moazzam, 1978). These authors observed the presence of 8 genera and 52 species of thecate dinoflagllates in Manora Channel. Centric diatoms comprising of 101 species and 30 genera were reported from the highly polluted Karachi Harbour. Based on the net samples collected by the scientists on board the vessel Dr. Fridtjof Nansen during January - June, 1977, Saifullah (12979) reported that dinoflagellates are the most dominant phytoplankter on the Pakistan shelf. He also reported that Ceratuim sp. and Nocilluca scintillans dominated during the NE monsoon while Gonyaulax polyedrea, G. polygramma and G. monocantha dominated during S.W. monsoon. Ceratium was described as the most diverse genus in the inshore area of Karachi, (Saifullah, 1979, Chaghtai and Saifullah, 1988). The occurrence of Noctiluca scintillans bloom forming red tide has been reported by Saifullah and Chaghtai (1990) along Pakistan shelves which were strictly confined to surface waters. They also reported the occurrence of Noctiluca bloom more frequent on Indus Delta shelf as compared to Balochistan. Oscillatoria bloom has been reported to be common in the Arabian Sea (Banse, 1989). Khan (1986) reported a non-toxic bloom of the diatom Asterionella japonica along Clifton beach, Karachi, Saeed et al. (1995) also described seasonal distribution and abundance of phytoplankton in the coastal area of Karachi. They have reported 58 species of phytoplankton. Mansoor and Saifullah (1995) and Saifullah (1999) described new species of Amphisolenia from Northern Arabian Sea bordering Pakistan. Recently Chaghtai and Saifullah (2001) have described 7 species of the genus Gonyaulax an Harmful Algal Bloom organism from Korangi Creek, Manora Channel and continental shelf of Pakistan which includes four new records from the northeastern Arabian Sea Luqman (2005) have reported that species composition of diatoms in Karachi Harbour and outside Manora Channel has changed over last two decades and found new species also. Commonly occurring phytoplankton in coastal waters of Karachi are presented below in Table 4.28.

In Indus Deltaic creeks particularly in mangrove habitat the phytoplankton population has not been studied in detail and very limited information is available (Chaghtai and Saifullah, 1992, 1997, 2001; Harrison etal, 1994 and Mehrun Nisa unpublished results). In mangrove habitat of Sandspit area which represent backwater of highly polluted Karachi Harbour the bloom of Naviclula Cancellata, a pennate diatom was reported for the first time in NE monsoon season (Chaghtai and Saifullah, 1992). Together with this species 6 other diatom species were also reported but this constituted 83%

Table 4.20: Average Concentration (Ranges) of Selected Water Quality Parameters along Clifton and DHA Beach

LOCALITY/BEACH	SELECTED PAMETERS					
	pH	Dissolved Oxygen (mg/l)	Nutrients (µgl-1) PO4-P	NH4-N	NO2-N	NO3-N
1. Keamari (Opposite Oil terminal)	8.3-8.4	4.9-6.6	11-48	17-33	0.56-1.1	7.8-27.0
2. Clifton (Opposite Shirin Jinnah Colony)	8.3-8.4	5.4-9.0	12-68	31-41	1.4-4.9	25-26
3. Clifton Beach (Near Casino)	8.3-8.4	4.7-6.6	11-70	59-60	3.9-5.0	8.4-28.0
4. Opposite Sea View	8.3-8.4	4.8-6.5	16-140	57-110	3.6-11.0	16-59.0
5. Gizri Creek	8.3-8.4	4.6-6.4	36-77	36-160	9.8-14	30-81.0

(Source: NIO Data Archive)

Table 4.21: Nutrient Distribution in Karachi Harbour

Station	Location	Water Level	Average Depth (m)	Nutrient (g ml-1) PO4-P	NO3-N	NO2-N
1	West Wharf	Surface	10	10.35	3.81	2.44
		Bottom		4.28	--	--
2	Fish Harbour	Surface	3	23.25	0.18	0.10
		Bottom		31.25	1.83	1.11
3	Opp. Lyari Mouth	Surface	3	4.60	1.35	0.83
		Bottom		4.70	2.01	1.28
4	Chari Kund	Surface	6	6.70	8.74	5.16
		Bottom		14.0	6.27	3.93
5	Manora Channel	Surface	11	14.05	2.05	1.02
		Bottom		6.05	6.61	4.13
6	Mausa Channel near entrance	Surface	13	4.40	1.19	1.29
		Bottom		3.05	16.31	1.80

(Source: Khan and Saleem, 1988)

in abundance, Phaeocystis which is a colder region species was reported to occur in mangrove habitat of Gharo Creek, off Rehri and Korangi Creek (Harrison etal. 1994; Chaghtai and Saifullah, 1997) and out side Manora Channel (Khan, Unpublished results). The other phytoplankton species recorded along with Phaeocystis were Asterionella sp., Curatuim sp., Coscinodiscus sp. Melosira sp., Navicula sp. Planktoniella sol and Synedra sp. (Chaghtai and Saifullah (1997). In Gharo Creek area the phytoplankton composition was dominated by large centric diatoms (Coscinodiscus sp., Chaetoceros sp., Schroederella sp., Ciorethron sp., Biddulphia sp. , and Rlizosolenia sp.), pinnate

Table 4.22: Concentration of Cu (ppb) in water of mangrove habitat of Karachi

Location	Average conc. + SE	N	Range
Sandspit	1.5 + 0.49	7	1.06 - 3.26
Karachi Harbour	0.61 + 0.18	10	0.02 - 1.86
Korangi Creek	1.17 + 0.87	3	0.06 - 1.94
Port Qasim	3.06 + 0.63	5	1.89 - 5.17
Lut Basti	1.50 + 0.35	7	0.047 - 1.728
Chara Creek	0.78 + 0.49	3	0.31 - 1.79
Miani Hor	0.041 + 0.00	1	-

(SE = Standard Error, N = number of samples)
(Source: Saifullah et al 2002

Table 4.23: Concentration of Cu (ppm) in sediments of mangrove habitat of Karachi

Location	Average conc. + SE	N	Range
Sandspit	48.09 + 2.43	19	28.90 - 65.70
B/Shams	57.60 + 0.0	1	-
Port Qasim	44.02 + 0.07	4	36.70 - 51.20
Lut Basti	69.02 + 8.09	3	56.90 - 85.60
Chara Creek	46.55 + 1.35	2	-
Korangi Creek	48.10 + 0.00	2	42.20 - 54.00
Miani Hor	9.80 + 0.0	1	-

(Source: Saifullah et al., 2002)

Table 4.24: Average concentration (ppm) of Fe in water in different mangrove habitats of Karachi

Location	Average conc. + SE	N	Range
Sandspit	0.09 + 0.025	7	0.020-0.176
Port Qasim	0.099 + 0.039	5	0.016-0.211
Rehri	0.06 + 0.03	3	0.021-0.118
Chara Creek	0.094 + 0.042	3	0.010-0.152
Karachi Harbour	0.042 + 0.114	10	0.019-0.059
Lat Basti	0.115 + 0.031	7	0.012-0.247

(Source: Saifullah et al., 2002)

Table 4.25: Average concentration (ppm) of Fe in sediments of mangrove habitats of Karachi

Location	Average conc. + SE	N	Range
Sandspit	25 624 + 1778	19	6369-23440
Baba/Shams Islands	28 120 + -	1	-
Port Qasim	27 489 + 2481	3	22678-31148
Lat Basti	23 310 + 4105	3	17657-31545
Miani Hor	1248 + -	1	-
Chara Creek	30 067 + 2515	4	22640-33120
Rehri	34 436 + 2249	2	29982-34 436
Phitti Creek	16 480 + 9333	2	7240-25720
Bkran Creek	23 900 + 866	2	23040-24760
Shamspir	17 060 + 381	2	13280-20 840

(Source: Saifullah et al., 2002)

Table 4.26: Average Concentration of Ni (ppm) in Surface Sediments along Karachi Coast

Locality	Average Concentration (ppm)
Sandspit	77.1
Baba/Shams Island	58.2
Rehri	52.4
Lut Basti	48.3
Port Qasim	55.1

(Source: Saifullah et at., 2002)

diatoms (eg. Nitzschia sp., Navicula sp., Pleurosigma sp. and Fragilaria sp) and the dinoplagllates e.g. Prorocentrum (Harrison etal., 1994 and Mehrun Nisa unpublished results). Chaghtai and Saifullah (2001) have reported 27 species of Dinoflagellates from mangrove habitat of Korangi Creek area.

Primary production rates in Korangi Creek and its vicinity

In order to measure the productivity of marine and estuarine environment, the change in rates of the photosynthetic activity is measured to assess the potential of production in a particular area. Rizvi (1999) has mentioned average primary production Rates for Korangi Creek and some other creeks in its vicinity. He has reported that the average net Primary Production Rates were found to be high at Isaro Creek (43.065 mgC/m-3/hour) and Gharo Creek (28.40 mgC/m-3/hour) where as lower Primary Production Rates were observed at Korangi Creek (3 mgC/m-3/hour). Thus it can be seen that Korangi Creek is not very high productive area.

B- Micro-habitat (Zooplankton)

The first account of the distribution and abundance of major groups of zooplankton along Pakistan coast during postmonsoon and premonsoon period was described by Haq et al (1973). They also discussed the hydrographic conditions and their relationship to the distribution of zooplankton and observed three peaks of zooplankton abundance during October to December. Zooplankton biomass was also briefly discussed by Ali-Khan, (1976). Banse (1984) summarized the available information about zooplankton for Northen Arabian Sea. Earlier, Noor-Uddin (1967b) reported Zooplankton counts collected from Karachi Coastal waters particularly Manora Channel. Huda and Ahmed (1988) described zooplankton production in inshore waters of Karachi coast particularly Korangi Creek and found that high biomass production was found during calm period after south west monsoon during September and October. They suggested that decapod larvae were in maximum concentration during post-monsoon period. Ahmed (1999) has reported that copepods, chaetognaths, crustaceans eggs and larvae and fish eggs and larvae dominate in the zooplankton samples collected from near shore waters as well as Indus deltaic creeks. He has also mentioned that the larger Zooplankton such as calanoid copepods, lucifers and chaetognaths which are generally found in upwelling areas were particularly abundant in Gharo-Phitti creek system during June - September. Regarding zooplankton abundance in Keti Bunder area of the Indus Deltaic Creek System, Ahmed. (1999) reported that cyclopoid copepods were the most dominant and calanoids and chaetognaths were second and third in abundance during February, 1980, where as calanoids were most abundant group and cyclopoids and Chaetognaths were second and third during May, 1980. Based on Zooplankton samples collected under NASEER Programme by NIO, Amjad etal, (1995) discussed zooplankton biomass and composition and percentage abundance in relation to other oceanographic parameters for Northeast and Southeast monsoon in northern Arabian Sea bordering Pakistan . They have reported mean zooplankton biomass 89ml/100m^3 and 105ml 100 m^3 during northeast and southwest monsoons respectively. They found that during northeast monsoon copepods were the most dominant group where as Acantharica was dominant during southwest monsoon. Kazmi et al,. (1995) Also gave an account of crustacean larvae in zooplankton samples collected by NIO under NASEER programme and from 20 groups they identified,, crustacean were found in the following descending order: copepods, cladocerans, ostracods, amphipods (hyperiids), lucifers, mysids, cirripeds and euphausids. They reported that copepods were highly abundant and during January 1992 they were found to be 64% of all the zooplankton groups in samples collected off Indus Delta in the oligotrophic environment. Kidwai and Amjad (2000) have described in detail the zooplankton biomass (standing stock), its composition and abundance in eutrophic and oligotrophic environment of the north Arabian Sea during northeast and pre southwest

Table 4.27: Tidal Levels at Port Qasim

Location	MLLW	MHLW	MLHW	MHHW	HAT	LAT
Bundal Island	+0.6	+1.2	+2.3	+2.9	NA	NA
Hasan Point	+0.6	+1.3	+2.8	+2.9	+3.4	+0.6
Port Qasim	+1.0	+1.4	+2.1	+3.4	+4.00	-0.6

Source: Admiralty Chart PAK 20 and PQA Tidal Records
NA: Not Available

monsoons. They identified 38 taxonomic groups out of which copepods were the most dominant group followed by chaetognaths and siphonophores. They also suggested that overall mean biomass changes from northeast to southwest monsoon with higher values observed with the onset of S.W. monsoon.

The Zooplankton biomass for Korangi Creek during 2001 has been reported in the range of 0.76 ml m-3 - 14.82 ml m-3 during southwest and northwest monsoon respectively. Generally the abundance of the total zooplankton was observed higher during pre NE / post SE monsoon periods. For Korangi Creek Huda and Ahmed (1988) have reported that zooplankton biomass was found very high between August and December and low in April. They observed highest peak during September and October.

C- Shrimp Larvae and Juveniles

Shrimp fishery is the most valuable fishery sector of Pakistan. Penaeid shrimps constitute the backbone of marine fisheries industry of Pakistan comprising of 27 species inhabiting Pakistani waters (Hassan, 1992). The distribution and species abundance of larvae of penaeid shrimps in Manora Channel, Indus Deltaic creeks, near shore waters of Karachi and coastal areas of Pakistan have been discussed in detail by Haq and Hassan (1975), Hassan(1987, 1989 ,1992), Hassan and Ahmed (1992), Ahmed (1999). Hassan (1992) mentioned that generally the larvae were distributed close to the coast than in offshore water and were fairly abundant towards southeast of Cape Monze along Sindh coast due to wide and shallower shelf. Hassan and Ahmed (1992) described seasonal abundance concentration and distribution of various larval stages of different species of shrimps. Majid and Khan (1995) discussed in detail the status of shrimp fishery in Pakistan which is a substantial source of foreign exchange earnings and reported that not only the large shimp (jaira and Kalri) were overexploited rather small size shrimp (Kiddi) was also being over exploited.

The summer and winter abundance of juveniles of finfish and shellfish were studied in Korangi area by Ahmed and Abbas (1999) and Ayub and Ahmed (2001). Their study showed a fair abundance of the juveniles of shrimps and fishes at Korangi Creek during winter of 1993-94. They also reported juveniles of Penaeus merguiensis, Penaeus penicillatus and Metapenaeus affinis from Keti Bunder in the winter and spring of 1980 (Ayub and Ahmed, 2001).

D- Macro-habitat (Animal Communities)

The beaches of the creeks adjoining Port Qasim area are mostly muddy - sandy or muddy. Hard bottom beaches are generally absent in this area but occasionally but one may occur. The animal communities in this area inhabiting different creeks are described below:

Korangi Creek (Ibrahim Haidri Beach)

This is muddy - sandy beach with very gradual slope. The beach is greatly affected by anthropogenic eutrophication as it receives domestic effluents, fisheries wastes from a fishing village and heated effluents from a KESC power plant. The animal communities inhabiting this area are presented in Table-4.29.

Suspension feeding /filter feeding bivalves are mostly absent from the beach. Sometimes ago Placuna placenta, the window-pane oyster, and the brachiopod Lingula sp which used to abound on this beach have disappeared. The cause of their disappearance may be either too much siltation or anoxic condition of the habitat. The beach is inhabited by fiddler crabs and mud skippers. In winter the mud flats are covered with Enteromorpha and Ulva mats.

Table 4.28: Phytoplankton species found in coastal waters of Karachi

Sr. No.	Species	Sr. No.	Species
1.	Amphora Salina	48.	Navicula didyma
2.	Amphora sp.	49.	Navicula nobilis
3.	Asteramphaiis sp.	50.	Navicula pusilla
4.	Asterionella japonica	51.	Navicula rectangulata
5.	Bacillaria sp.	52.	Navicula sp.
6.	Bacteriastrum sp.	53.	Nitzschia paradoxa
7.	Bellarochea sp.	54.	Nitzschia closterium
8.	Biddulphia sinensis	55.	Nitzschia sp.
9.	Biddulphia granulate	56.	Nitzschia seriata
10.	Biddulphia mobilensis	57.	Nitzschia longissima
11.	Biddulphia sp.	58.	Peridinium pedunculatum
12.	Cocconeis pseudomarginata	59.	Peridinium sp.
13.	Cocconeis distans	60.	Pinnularia sp.
14.	Cerataulina bergonii	61.	Planktoneilla sp.
15.	Coscinodiscus sp.	62.	Pleurosigma attenuatum
16.	Coscinodiscus perforatus	63.	Pronoctiluca sp.
17.	Chaetoceros curvisetwus	64.	Rhabdonema sp.
18.	Chaetoceros dicharta	65.	Rhizosolenia alata
19.	Chaetoceros teres	66.	Rhizosolenia bergonii
20.	Chaetoceros wighamii	67.	Rhizosolenia castracanei
21.	Ceratium kofoideii	68.	Rhizosolenia clearavis
22.	Ceratium sp.	69.	Rhizosolenia cocklea
23.	Climocodium sp.	70.	Rhizosolenia crassipina
24.	Cyclotella sp.	71.	Rhizosolenia cylindrus
25.	Cymbella sp.	72.	Rhizosolenia habitata
26.	Diploneis sp.	73.	Rhizosolenia imbricate
27.	Ditylium sp.	74.	Rhizosolenia pungens
28.	Dimophysis sp.	75.	Rhizosolenia robusta
29.	Epithemia sp.	76.	Rhizosolenia schrubsolei
30.	Eircampia Zodiacus	77.	Rhizosolenia stolterfolthii
31.	Grammatophora marina	78.	Rhizosolenia setigera
32.	Grammatophora angulosa	79.	Rhizosolenia stylyformis
33.	Grammatophora sp.	80.	Skeletonema costatum
34.	Conyodoma sp.	81.	Spirodinium sp.
35.	Guinardia flaccida	82.	Stephanopyxis sp.
36.	Gyrosigma sp.	83.	Stephanophxis turis
37.	Hemidiscus sp.	84.	Steriatella sp.
38.	Histioneis sp.	85.	Surirella sp.
39.	Leptocylindricus danicus	86.	Schroederella sp.
40.	Licmophora flabellate	87.	Synedra acus
41.	Licmophora sp.	88.	Synedra robusta
42.	Lithodesmium sp.	89.	Thallasionema sp.
43.	Melosira moliniformis	90.	Thallasiosira sp.
44.	Melosira granulate	91.	Thallasiothrix sp.
45.	Mastogloia sp.	92.	Triceratuim sp.
46.	Navicula cancellata	93.	Trichodesmium sp.
47.	Navicula cruciformis		

Bakran Creek of Gharo-Phitti Creek System

This is a long mud-sand flat in the Port Qasim area. It receives effluents from the Port area and from Pakistan Steel Mill as well as anthropogenic contributions from local villages along the delta. It has a gradual slope with mangrove stands towards low tide. Isolated small stunted mangroves occur further upshore. The barnacle Balanus amphitrite is abundant on the leaves of the mangroves Avicennia marina. In this area Enteromorpha and Ulva cover the beach in winter. The animal communities are not very abundant except mudskipper fish, fiddler crabs and the snail Cerithidea cingulata a pollution indicator species. Animal communities recorded from this area are listed in the Table 4.30.

Broekhoven Jetty Beach (Gharo-Phitti Creek System)

This is an unusual beach in the Gharo-Phitti creek system being a hard rocky beach. It has a slight slope and is covered with mud, sand and on some places, oil sheen. This beach shows the greatest diversity of animal species in the area. It is characterized by the presence of a large bed of dead, edible oysters although live oysters are also found occasionally. The beach has a number of invertebrates, such as sea-urchins, ascidians, sponges, colonial coelenterates and ophisthobranch mollusks which are indicative of oceanic conditions. The beach is located about 18 km inland from the open sea in the Port Qasim area. The oceanic influence seems to have reached here because of the greater inflow of water from the sea following the deepening of the Port Qasim navigational channel to accommodate large vessels. The animal communities found in this area are presented in Table 4.31.

Marine Algal Epiphytes in Mangroves of Korangi Creek

In the mangrove ecosystem the producers are the mangroves and marine algae both micro and macroscopic. While the algae are not as large and dominant as the mangroves they nevertheless contribute significantly to the energy budget of the system. The macroscopic algae grow on the lower parts of the mangrove plants mostly on the Pneumatophores with the exception of Enteromorpha intestinalis and Ulva reticulate which form a green mat on the dark mud of the mangrove habitat (Saifullal and Nizamuddin, 1977). Marine algae inhabiting the mangrove area of Korangi Creek and its vicinity have been reported by Saifullah and Taj (1995). They collected the algae from the Pneumatophores of Avicenia marina growing luxuriantly in the Korangi Creek and adjacent areas. They have reported twelve species of marine macro algae growing as epiphytes. That species belonging to the four major groups of algae i.e. Chlorophyta, Phaeophyta, Rhodophyta and Cyanophyta found in mangroves of Korangi Creek are listed below:

i-Chlorophyta

- Boodleopsis Pusilla
- Chaetomorpha gracilis
- Cladophora sp
- Enteromorpha torta
- Rhizoslonium kerneri

ii-Phaeophyta

- Hincksia terminalis

iii-Rhodophyta

- Caloglossa leprieurii
- Herposiphonia secunda
- Polysiphnia abcissa

iv-Cyanophyta (Cyanobacteria)

- Hydrocoleum lyngbaceum

- Lyngbya majuscula
- Phormidium ambiguum

4.4.3- Fisheries

According to Government of Pakistan (2005) fish and fishery related sector engages 1% of the Pakistan's population. The fishery sector generates 1% of Pakistan GDP earning through export of fishery products. Coastal and offshore areas of Pakistan support large fisheries. Fishing grounds for large pelagic species such as tuna, mackerel, sharks etc are located in the offshore waters. Whereas the species like mullet, silver wittings and other small sized demersal fishes specially juveniles of large commercially important estuarine fish are harvested from shallow water in the creek area of Indus as well as enclosed and semi-enclosed bays along the coast of Pakistan.

Ahmed (1983) reported 98 species of fish from mangrove swamps of Korangi-Phitti creek system and backwaters of sandspit. Out of these 98 species 46 species were fingerling or young stages while 52 species were either sub-adult or adult. Mudskippers have adopted themselves to live in this particular environment. Pleuronectiformes which represent bottom living fish move towards this area for their food. Many detritus feeders like clupeids, grey mullets etc. and small carnivorous fish like silver biddies and pony fish find this environment suitable for their living. The order and species wise break-up of the mangrove habitat fish fauna are given in Table-4.32.

In Korangi Creek and the adjoining creeks areas Ahmed (1988) has described in detail four types of fish groups; the permanent dwellers which are few; partial residents; tidal; and seasonal visitors in the mangrove habitat where over 180 species of fish have been reported. As may as 148 species of fingerlings or young stages and juveniles have been reported from the mangrove of Indus Delta (UNESCAP, 1996). More common larvae of fishes described for Korangi Creek and adjoining creeks in Indus Delta belong to the families Mugilidae, Gerreidae, Clupeidae, Nemipteridae, Gobiidae, Sciaenidae, Engraulidae, Sillaginidae and Lutjanidae. Their abundance from season to season varies. There are a number of settlement of fishermen along the creeks of Indus Delta which depend on the fisheries resources of these creeks.

4.4.4- Avifauna of Karachi and Indus Delta

The mangroves of Indus Delta as well as mangrove forest in the vicinity of Karachi provide an ideal habitat for many species of birds either migratory or resident. Karim (1988) reported 48 species of birds over a period of one year from mangroves of Sindh coast. Of these 44 percent were resident and the rest migratory. Khanum and Ahmed (1988) observed 34 species of birds in the Karachi mangrove while conducting four months survey (July - October, 1985) along Karachi coast from Clifton to Hawks Bay including backwaters. They reported 34 species; of these these 12 species were resident and 22 species were migratory. They also observed two predator eagle species which were found in large numbers. Although the migratory birds had started arriving and still they were coming therefore they could not give detail about them in their study. Ghalib and Hasnain (1997) have reported 75 species of water birds belonging to 6 orders and 14 families from Clifton beach. The majority of them are waders or shorebirds such as oystercatcher, avocet, stilt, plovers, whimbrel, curlew, godwit, sandpipers, shanks, turnstones, stint, knot, dunlin, sanderling, etc. Besides the shore birds, egrets, herons, gulls, terns, flamingos are commonly observed at Clifton. Rare water fowls like velvet, Scoter and Red breasted Merganser have also been recorded from this region. IUCN (2005) have reported that there are 57 species of shore birds or waders recorded from

Table 4.29: Animal Communities of the muddy-cum-sandy beach at Ibrahim Haidri in Korangi creek (old delta); ++++abundant, +++ Common, ++ fairly common, + rare; - absent; D-deposit feeder, S-suspension feeder, P-predator, Sc-Scavenger.

Genus/species	Common Names	Tidal Level ft. (approx.)	Abundance	Feeding Mode
Uca Lactea	fiddler crab	4-8	++++	D, Sc
				Sc
U. annulipes	fiddler crab	6-8	++	Sc
Eurycarcinus orientalis	crab	1-3	+	P
Macrophthalmus pectinipes	crab	1-3	+	P
Scylla serrata	crab	-1-2	++	P
Cerianthus sp.	sea anemone	0-3	++	D
Loimia medusa	polychaete	3-6	+	D
Hesione pantharina	polychaete	3-6	+	P
Lycastis indica	polychaete	0-4	++	P
Nemertean worms	nemertean	0-4	++	P
Lingula anatina	brachiopod	4-6	-	S
Croassostrea rivularis	oyster	0-2	+	S
C. gryphoides	oyster	0-2	+	S
C. madrasenis	oyster	0-2	+	S
C. tuberculata	oyster	6-8	++++	S
Placuna placenta	oyster	-1-2	+	S
Dentalium sp.	tusk shell	2-4	+	S
Thais carinifera	snail	0-4	+++	P
Natica sp.	snail	0-4	+	P
Mudskippers	fishes	2-6	++++	P

(From Ahmed ,1999)

Pakistan of which 2 species are vulnerable. These are Sociable plover (Vancellus Gregarious) and wood snipe (Capella memoricola).

4.4.5- Marine Mammals

Marine mammals belong to the order Cetacea and include dolphins, porpoises and whales. In Pakistani waters 12 species of cetaceans have been recorded / observed, out of which 10 species have been recorded from Sindh (IUCN, 2005). The blue whale is an endangered species while humpbacked whale is vulnerable. The marine mammals recorded from Sindh are found in coastal and open ocean waters and do not inhabit in the vicinity of proposed site of LNG jetty at Korangi Creek.

4.4.6- Endangered Species

The Korangi Creek area has once large population of Lingula, the representative of brachiopod occruing on muddy / sandy beaches of Sindh but now it is rarely seen. Similarly windowpane oysters were also commonly found in Korangi creek and

Table 4.30: Animal Communities of the muddy-cum-sandy beach of Bakran Creek (old delta) in Gharo-Phitti creek system; ++++abundant, +++ Common, ++ fairly common, + rare; - absent; D-deposit feeder, S-suspension feeder, P-predator, Sc-Scavenger, H-herbivore.

Species/genus/ group	Common Names	Tidal Level ft. (approx.)	Abundance	Feeding Mode
Balanus amphitrite	Barnacle	9	++++	S
Uca Lectea	fiddler crab	4-8	++++	D,Sc
U. annulipes	"	4-6	++	D,Sc
U. marionis	"	2-6	+	D,Sc
Scylla serrata	crab	-1-2	++	P
Grapsus sp.	crab	2-3	++	P
Nemertean worm	nemertean	2-3	+	P
Pandora flexuosa	clam	2-3	++	D
Natica sp.	snail	2-3	+	P
Nerita sp.	snail	2-3	+	H
Dosinia sp.	clam	1-2	+	S
Pitar nobilis	clam	0-2	+	S
Tellina sp.	clam	2-3	+	S
Solen truncatus	razor clam	0-2	+	S
Telescopium telescopium	snail	0-4	+	H
Loimia medusa	polychaete	5-6	+	D
Cerithidea cingulata	snail	2-6	++++	H
Mudskippers	fishes	2-4	++++	P

(From Ahmed ,1999)

Table 4.31: Animal Communities of the hard substrate beach near Broekhoven Jetty, Port Muhammad Bin Qasim, in Gharo-Phitti creek system; ++++abundant, +++ Common, ++ fairly common, + rare; D-deposit feeder, S-suspension feeder, P-predator, H-herbivore.

Species/genus/ group	Common Names	Tidal Level ft. (approx.)	Abundance	Feeding Mode
Grassostrea rivularis	Oyster	0-1.5	+	S
C. madrasensis	Oyster	0-1.5	+	S
Thais carinifera	Snail	0.2	++	P
Balanus tintinnabulum	Barnacle	1-1.5	++	S
Diodora sp.	limpet	1-1.5	++	H
Glycymeris sp.	pecten	0.5-1.5	+	S
Anomia sp.	Oyster	0.5-1.5	++	S
Hesione sp.	polychaete	0.5-1.5	+	P
Pinna bicolor	mussel	-0.1	+	S
Perna viridis	mussel	1-1.5	+	S
Cypraea sp.	snail	0.5	+	H
Euchelus sp.	snail	0.5	+	P
Ozius rugulosus	crab	0.5	+	P
Sponges	sponge	0-1.5		S
Ascidians	sea-squirt	0-1.5	++	S
Corals (Madrepor.)	coral	0-1.5	++	S
Coelenterates	coelenterate	0-1.5	++	S
Spider crab	crab	0-1.5	+	P
Echinometra sp.	sea urchin	2-3	+	P
Doris sp.	slug	4-6	++	H
Nerita sp.	snail	4-6	+++	H
Lottorina sp.	snail	5-9	++++	H
Alpheus sp.	shrimp	5-6	++	P
Eurycrcinus orientalis	crab	5-6	+	P
Perinereis sp.	polychaete	8-9	++	S
C. glomerata	Oyster	6-7	++++	P
Ocypoda sp.	crab	7-9	++	
Grapsus strigosus	crab	4-7	++	P
Balanus amphitrite	barnacle	8-9	++++	S

(From Ahmed ,1999)

adjoining areas. Presently none of these are easily found in this area and the extinction may be attributed to increase in pollution level in the vicinity of Korangi creek due to industrial and sewage pollution brought through Malir River, Gizri Creek and discharges from industrial areas and coastal villages of Landhi and Korangi etc. There is no designated park for conservation in this region and no endangered and rare species is reported from the proposed site.

4.4.7- Mangrove Ecosystem

Mangrove ecosystem of Indus Deltaic creek system of Sindh province is of great ecological and economic significance. Mangroves play a very important role in the national economy being a source of timber, fuel wood, fodder, honey, fisheries etc. Indus Delta mangrove ecosystem is highly rich in biodiversity, provides, natural breeding and nursery ground for offshore and coastal fishery resources of shrimps and fish, and provides sanctuary for a wide variety of migratory birds and other wild life. In addition to this, ecosystem also plays an important role in shore protection from erosion as well as protection against cyclones and tidal bores.

Mangroves are one of the most outstanding ecosystem of coastal zone of Sindh and this has been ranked as fifth or sixth single largest mangrove area in the world (Snedaker, 1984). The mangroves along Sindh coast are unusual in that they occur in an arid climate. The mangrove ecosystem stretches along the entire Sindh coast from east of Karachi to Sir Creek covering the whole of Indus River Delta past and present. In recent years considerable literature has been published on various aspects of mangrove ecosystem of Sindh province (Devol et al., 1995; Harrison et al., 1995, 1997; Qureshi, 1995, 1999; Saifullah and Taj, 1995; Thompson and Tirmizi, 1995; UNEP, 1996; Haq et al., 1997; Saifullah, 1997, 1998; Saifullah and Rasool 1998; Meadows and Meadows, 1999; Sindh Forest and Wild Life Department, 1999; Meadows and Meadows, 2001; Saifullah et al, 2001, 2002, 2004).

According to UNEP (1996) and Qureshi (1999), the present Indus Delta is spread over an area of 600,000 hectares and 260,000 hectares are covered with mangrove vegetation which has been estimated through satellite imageries. The mangrove of Indus delta of Sindh Coastal areas at present does not receive fresh water continuously which is required for their healthy growth. Mangroves in the vicinity of Karachi receive their fresh water supply from domestic and industrial effluents through Lyari and Malir Rivers and the other mangroves in the delta depend on the fresh water supply from River Indus.

Earlier eight species of mangroves were reported to occur in Indus Delta along Sindh Coast (Saifullah, 1982, UNEP, 1986) which included Aegiceras corniculatum, Avicennia marina, Bruguiera gymnorhiza, Ceriops tagal, Ceriops decandra, Rhizophora apiculata, Rhizophora mucronata, and Sonneratia caseolaris. However, now only four species are found along Singh Coast which are Aegiceras corniculatum Avicennia marina, Ceriops tagal and Rhizophora mucronata (Meynell and Qureshi, 1993; Saifullah, 1997,). Avicennia marina is the most dominant species of the mangrove ecosystem along Sindh coast covering 95-98% of the mangrove forest (Snedaker, 1984; Saifullah, 1997; Qureshi, 1999). Rhizophora mucronata has been reintroduced / planted in Port Qasim Area with the efforts of Sindh Forest Department and IUCN and only the other three species grow naturally in Indus Deltaic area. Aegiceras corniculatum and ceriops tagal have been reported at specific places like Hajamro Creek, Keti Bunder and Shah Bunder area (Saifullah, 1999, Qureshi, 1999). According to Qureshi (1999) the palynological studies of surface and one meter deep soil in Port Qasim area showed that the mangrove flora used to be more diverse and abundant.

Table 4.32: Break-up of Mangrove Habitat Fish Fauna

Species Name	No. of Species
Clupeiformls	15 Species
Scopeliformes	04 Species
Cyprinitbormes	06 Species
Anguillifomes	02 Species
Perciformes	46 Species
Betoniformes	03 Species
Syngnathi formes	05 Species
Mugiliformes	06 Species
Polynemiformes	04 Species
Pleuronectifomes	06 Species
Batrachodiformes	61 Species

Due to shifting of the Indus River discharge towards more southerly course, the formerly tall and productive mangrove of the Karachi region (Khan, 1996) started deteriorating and the larger trees have all but disappeared and water deficit response is evident in the form of reduction in maximum forest height (Harrison et al, 1994). Another noticeable change is reduction in the number of mangrove species and those that persist have a higher salinity tolerances. Avicennia marina is one of the most salt tolerant mangrove species and has adapted to high salinity and may survive in a salinity as high as 90% (Snedaker, 1984; Ahmed, 1992a). Osmoregnlation and other and other strategies that mangrove utilize for survival in hypersaline environment has been evaluated by Ahmed (1992 a). According to Harrison et al. (1994), the salinities greater than normal seawater (35 0/00) leads to stunted growth and gives rise to dwarf trees as mentioned by Saifullah (1997) that due to hyper salinity, decline in mangrove growth is visible every where in Indus Delta. As mentioned earlier the mangrove forest in Indus Delta along Sindh is almost monospecific, which has been suggested to be due to the recent decrease of fresh water discharge from the Indus River (Ahmed, 1992b). The mangrove forest near Lat Basti in the vicinity of Korangi Creek are also healthy because this area also receives fresh water as well as nutrient rich water from coastal communities inhabiting this area. It is also interesting to note that mangroves of the present Indus Delta lining the banks of Khobar and Hajamro creeks are healthier than those found in the other creeks of Indus Delta along Sindh coast (Ahmed, 1999).

The mangrove cover in Korangi Creek, Gharo Creek and Phitti Creek varies from sparse to dense. According to IUCN (1987) the dense mangrove forest was estimated to have primary production of 365 to 780 gc m^3/yr in dense forest. The mangrove ecosystem of Korangi, Gharo and Phitti Creeks are known to be inhabited by various invertebrate fauna as well as fish species. The forest also contributes to the stability of creeks in this locality.

4.5 Survey on Benthic Ecology of Port Qasim

4.5.1 Overview

The survey of benthic ecology was conducted in the Port Muhammad Bin Qasim (Port Qasim) area during the NE Monsoon period from 1 April to 7th April 2011. The overall objective of the study was to establish a baseline with reference to impacts of Benthic Marine Invertebrates, mangrove ecosystem, coastal habitats and fishery in response to dredging at the proposed site designated for construction and operation of a LNG import terminal by Pakistan Gas Port Limited (PGPL). The survey was carried out within an area of approximately 5 Km radius of the proposed site in the vicinity of PQA Figure 4.1.

The Gharo Phitti Creek System consists of three creeks: Gharo Creek, Kadiro Creek and Phitti Creek. All three are connected in a series starting from Gharo Creek at the north-eastern end to the Phitti Creek at the south-western end and located at 22.3 km from Karachi. This creek system is about 42 km long and its width ranges from 250 to 2,500 m. The Korangi Creek and Kadiro Creeks are connected with it at the north-eastern end while it acts as main waterway connected with the open sea at the south-western end. The main channel of Port Bin Qasim lies in this creek system, which has been dredged to maintain a navigable depth of 11.3 metres. There are 6 bends in its overall length. A seagoing port has been established at the head of the creek system at Gharo Creek. The port also caters for imported LPG vessels, and other raw materials such as iron ore carrying vessels to Pakistan Steel Mill which is also situated near the Bin Qasim Harbour

The baseline program was carried out in support of biological studies in the marine environment in the vicinity of the proposed port facility at Port Qasim. The projected results are part of the ESIA for the port facility. The environmental baseline programme focuses on mangrove ecosystem marine organisms, their habitats, water quality, productivity, bird fauna of the Korangi/Phitti creek system and the ecosystems in which they inhabit. The baseline also takes into consideration the probability of the ecosystem being affected by port development, and evaluates unique creek ecosystems, key linkages, habitat loss for any

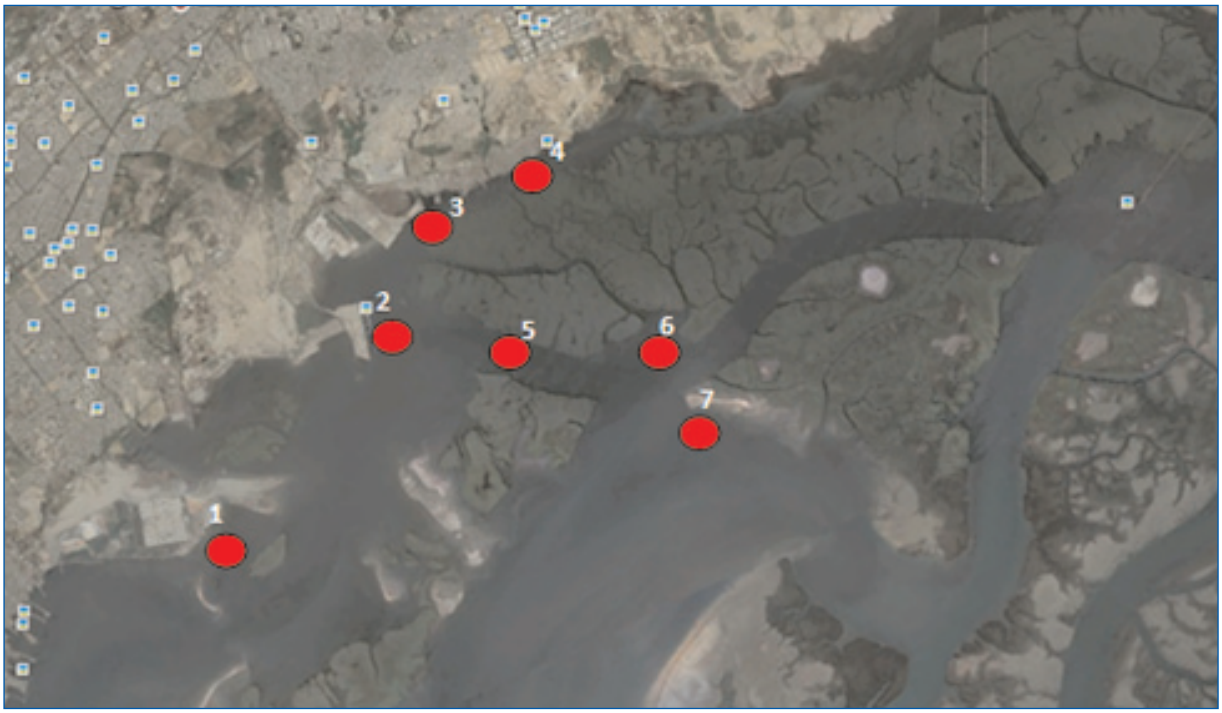

Fig 4.1 Map showing locations (red dots 1-7) marine benthic station and fish sampling stations (1, 2, 4 & 7) PQA

endangered organisms found in the Mangrove Ecosystem, marine flora and fauna of the Mudflats that may require special management during port development and operation.

4.5.2 Benthic Marine Habitats in PQA.

A. Study Components

Random stations for Benthic Invertebrates were identified by using a hand held Global Position System (Garmin GPS) along a transect at different locations to correspond to near zero tidal heights during the day light hours that would facilitate in survey of exposed mud flats, coastal habitats and the Mangrove community within a radius of 5 Km from the proposed site.

The components that were considered necessary for undertaking the survey in order to establish an environmental baseline survey in the proposed area included Marine fauna and the associated ecosystems. Documenting all the plants and animals living in the port area was not a viable option. Instead, the habitat components with the highest likelihood of being affected by the project were examined. These included:

- Mangrove habitat,
- Marine benthic invertebrates.
- Mudflats, surface and burrowing habitats.
- Interpretation of benthic marine biological data.
- Suspended matter
- Phytoplankton standing stock,
- Fish tissue metals concentration,
- Marine mammals, reptiles.
- Impacts of dredging

B. Spatial Boundaries.

The spatial boundaries associated with assessment of marine biological data and information both primary and secondary were based on preliminary interpretations of satellite imagery, admiralty charts and visiting and collection of samples from the location of the proposed study. The scope of the baseline biological assessment has been localised to marine environmental studies at Port Qasim.

The baseline assessment was focussed within a 5 km radius of the proposed port facility (Figure 4.1). To the west of the facility, the sampling area extends along the dredged waterway of Phitti Creek, while to the east; the proposed monitoring boundary extends to the major waterway boundaries. The sampling stations for the marine biological assessment of coastal benthic habitats, mangrove and associated fauna study are in close proximity to the proposed locations (Table 4.33).

4.5.3 Marine Flora

A. Mangroves

The Avicennia marina is the dominant species of the mangroves in the Indus Delta. In the PQA area under study the most dominant species was also Avicennia marina that grew on the northern and southern banks of the Phitti Creek. The Mangrove population of Avicennia marina was observed to be dense at stations locaion H1-H6. The density of mangrove trees was between 50-60/ 100 m^2. The height of the individual tree within the established Avicennia marina habitats were between 2-3 m.

B. Mangrove Population Density

PQA is part of the Indus Delta. The Indus Delta supports one of the largest single mangrove ecosystems in the tropical coastal environments. In the Indus Delta mangrove ecosystem, eight species of mangroves have been reported out of 53 species known to occur in the tropical forests of the world. Other mangrove species in the deltaic region such as the Ceriops tagal occur in localized patches and there are a few plants of Rhizophora mucronata. All other species are rare and have disappeared from most part of the Delta due to adverse environmental conditions.

The mangrove trees growing 200-300 m away from the creek (seawater) in the land ward direction showed an overall decline in the height of the mangrove plantations. The density of mangrove vegetation was randomly

Table 4.33: Location of sampling station for Benthic Invertebrates, Coastal Habitats and, Mangroves Survey in the vicinity of PGL site at PQA

Sta No.	Date	Substrate Type	Position Lat. Long	Local Time	Tidal Height m	Type of Survey.
1.	1. 4. 2011	Muddy cum silty	N 24, 47,03.65 E 67,10, 56.68	1545 hrs	0.9 Ebb	Coastal Habitat, Mangroves, benthic survey
2.	1.4.2011	Muddy cum silty	N 24, 47,37.31 E 67,12,38.59	1630 hrs	0.7 Ebb	Coastal Habitat Mangroves, benthic survey.
3.	1.4.2011	Fine sand	N 24, 48,36.63 E 67,12, 38.21	1500 hrs	1.0 Low. receding	Coastal Habitat Mangroves & benthic survey.
4.	1.4.2011	Muddy cum silty	N 24, 48,44.26 E 67, 13,17.95	1320 hrs	0.9 Low receding	Coastal Habitat Mangroves, benthic survey.
5.	6.4.2011	Muddy to Clay	N 24, 47,22.75 E 67, 13,15.17	1435 hrs	0.6 Low receding	Coastal Habitat Mangroves & benthic survey.
6.	6.4.2011	Compact Silt	N 24, 47,19.79 E 67, 14,27.27	1530 hrs	0.7 Ebb	Coastal Habitat Mangroves & benthic survey.
7.	6.2.2011	Silty	N 24, 46,44.19 E 67, 14,18.56	1630 hrs	0.9 Flow	Coastal Habitat Mangroves, benthic survey.

Table 4.34. Density and tree heights of mangrove Avicennia marina in 100 m2 area at each of the stations surveyed.

Positions Lat/Long.	Mangrove Heights (%)	MangroveDensity/100m^2
N 24, 47, 367 E 067, 15, 67	High Medium Short Sapling	60 30 5 5
N 24, 46, 271 E 067,3, 547	High Medium Short Sapling	40 40 10 10
N 24, 46, 850 E 067,19, 955	High Medium Short Sapling	30 60 5 5
N 24, 43, 576 E 067,18, 607	High Medium Short Sapling	0 20 30 50
N 24, 47, 210 E 067,15, 982	High Medium Short Sapling	70 20 5 5
N 24, 46, 302 E 067,18, 032	High Medium Short Sapling	50 30 10 10
N 24, 45, 728 E 067,18, 934	High Medium Short Sapling	50 30 15 5

evaluated an area of 100 m^2 within the PQA sampling location. The trees were characterized (visual observations) according to the arbitrary height of the plants.

- The height of mangrove seedling were characterized as <0.5 m
- Mangrove sapling height 0.5 -1.0 m
- Short mangroves trees were characterized as having 1-2 m height.
- Medium height mangroves trees had were characterized as having 2-3 m height.
- High mangroves trees had were characterized as having 2-3 m height.
- Densities of high mangrove plantation were poor around station

Mangrove saplings/seedlings/propogules of A. marina were observed to be in greater numbers (100-150 m^2) at high water mark (figure 4.2b)

4.5.4 Marine & Fauna

A. Marine Benthic Invertebrates. (MBI)

The Marine Benthic Invertebrates (MBI) samples were collected from the predesignated station in close proximity to the proposed port site. A grab having a mouth opening of 0.1m^2 was operated from the survey vessel. The sediments along with the Marine Benthic Invertebrates were preserved in large mouth plastic bottles in 10% buffered formalin. The

Figure 4.2a. Mangroves in the flowering process in PQA.

Figure 4.2b Natural vegetation of Mangroves, young saplings & seedling of Avicennia marina in patches (100-150 m^2) at high water mark, substrate mud to clayey

benthic Invertebrates were preliminary washed and sorted using a 5 micron sieve in the laboratory, at the Marine Reference collection Centre University of Karachi .

B. Analysis Procedure for MBI

1) Generally the whole sediment sample was analyzed.

2) Predominantly, Muddy substrates were sieved using 120 µm mesh sieve.

3 Invertebrate taxa were identified to the lowest taxonomic level practical. Difficult taxa are identified to higher taxonomic level e.g. bryozoans

4 Only intact Polychaetes specimens were counted or when the head appendages were observed under Binocular microscope.

4.5.5 Result of Marine Benthic Survey

Taxonomic Groups

Crustaceans

Pinnotherid crabs

Xenophthalmus

Porcellanid crab

Porcellana

Amphipods

Erichthonius

Melita

Cheriphotis megachelas

Parasitic isopod

Alpheid shrimp (Juveniles)

Pasiphaeid shrimps

Leptochela

Tanaidaceans

Kalliapseudes omercoperi

Leptochelia savigny

Ostracods

Echinodermata

Family Amphiuridae

Worms

Polychaeta

Pheudopolyphora spp

Nemertea

Sipunculids

Nematopoda

Polyclada

Mollusc

Gastropods

Thais scrinifera

Scaphopods

A. Statistical Analysis

The statistical analysis was performed using statistical software package. Benthic invertebrates in the laboratory were washed sorted, enumerated and identified using standard identification keys. The overview of benthic organism abundance at different station locations is given in figure 4.3.

The mean statistical values and the distribution pattern of Benthic Marine Invertebrates are given in table 4.35.

B. Benthic Species Distribution Pattern

The Marine Benthic Invertebrates (MBI) plays an important role in mixing the organically enriched bottom sediments. The MBI are a key linkage in transferring the energy from lower trophic level to the next higher trophic level in the food chain. The species distribution pattern of benthic invertebrates in the PQA area of interest are randomly distributed, while a few species aggregate. (Table 4.36) The distribution of invertebrates is dependent on the surface current that redistributes the planktonic larval form to locations away from where they were spawned they are hence random in their population densities. Aggregation is also a function of reproduction, where the benthic organisms tend to colonies together. Nemetodes, Annelid Polychaete worms, bivalve mollusk, Pinnotherid crabs, and species of Tanaidacean were by far the most dominant benthic species in the benthic samples collected from the PQA region.

C. Marine Benthic Invertebrates Cluster Analysis.

Bray and Curtis Bray and Curtis cluster analysis was

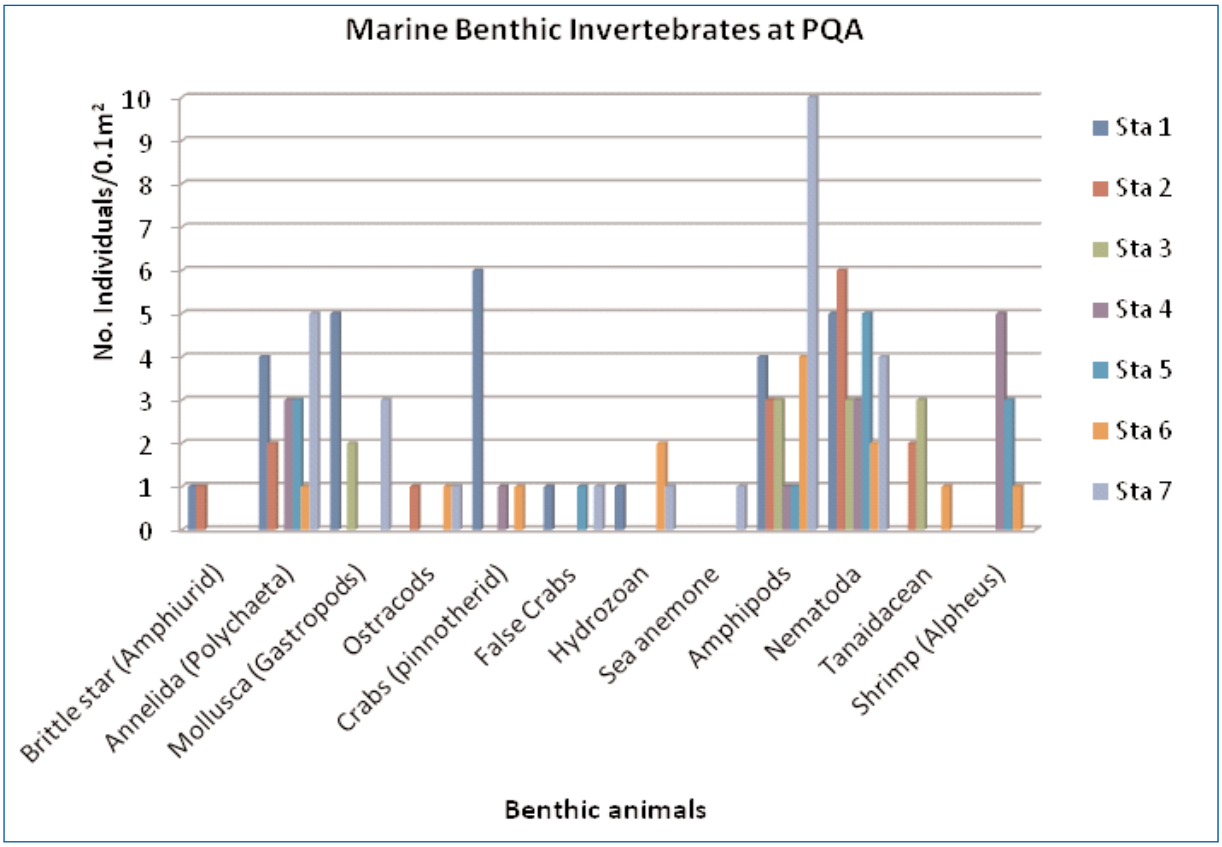

Figure 4.3. Histogram showing number of benthic organisms encountered at different location (Stations 1-7) in PQA

Table 4.35: The mean statistical values and the distribution pattern of Benthic Marine Invertebrates are given in table 3.

Station No.	Mean Individuals	Variance	Standard Deviation	Standard Error	Total Individuals	Total Species	Min indiv	Max indiv	Mean Confidence Interval
Sta 1	2.25	5.477	2.34	0.675	27	8	0	6	3.099
Sta 2	1.25	3.295	1.815	0.524	15	6	0	6	1.864
Sta 3	0.917	1.902	1.379	0.398	11	4	0	3	1.076
Sta 4	1.083	2.811	1.676	0.484	13	5	0	5	1.59
Sta 5	1.083	2.811	1.676	0.484	13	5	0	5	1.59
Sta 6	1.083	1.356	1.165	0.336	13	8	0	4	0.767
Sta 7	2.167	8.879	2.98	0.86	26	8	0	10	5.024

performed to evaluate the relationship between the number of species and groups of samples. This is given in the form of a dendrogram figure 4.4. That shows stepwise similarity were groups at locations observed (stations) are not clearly dissimilar from each other. (Sta. 4 & 5 show similarity) Stations 2 & 3 and 1 & 7 show similarities in benthic groupings.

D Benthic Invertebrate Species Diversity.

The Shannon Weiner species diversity index shows diversity values to range from a minimum of 0.596 at station location 3 to a maximum of 0.821 at station location 1 the species diversity values in PQA are generally low. Sediment grain size and compactness (Silt/clay) provides less interstitial space and less oxygenated water for the benthic animals to survive, which leads to higher Redox Potential Discontinuity Layer. (RPD)

4.5.6 Suspended Matter

The information on suspended matter has been collated from earlier studies in the Port Qasim Area. The strong ebb and flow of water currents especially during the south West Monsoons in the Indus deltaic

Table 4.36. Specie wise distribution of Marine Benthic Invertebrates and their distribution pattern in PQA benthic samples collected in close vicinity of the proposed jetty.

Species	Variance	Mean	Chi-sq	d.f.	Probability	Aggregation
Brittle star (Amphiurid)	0.2381	0.2857	5	6	0.545356	Random
Annelida (Polychaeta)	2.9524	2.5714	6.8889	6	0.330937	Random
Mollusca (Gastropods)	3.9524	1.4286	16.6	6	0.010985	Aggregated
Ostracods	0.2857	0.4286	4	6	0.678836	Random
Crabs (pinnotherid)	4.8095	1.1429	25.25	6	0.000355	Aggregated
False Crabs	0.2857	0.4286	4	6	0.678836	Random
Hydrozoan	0.619	0.5714	6.5	6	0.369585	Random
Sea anemone	0.1429	0.1429	6	6	0.423695	Random
Amphipods	9.2381	3.7143	14.9231	6	0.020851	Aggregated
Nematoda	2	4	3	6	0.810439	Random
Tanaidacean	1.4762	0.8571	10.3333	6	0.11034	Random
Shrimp (Alpheus)	3.9048	1.2857	18.2222	6	0.005848	Aggregated

Fig 4.4 Mudflats at PQA mud skipper co habitats with crabs Uca spp

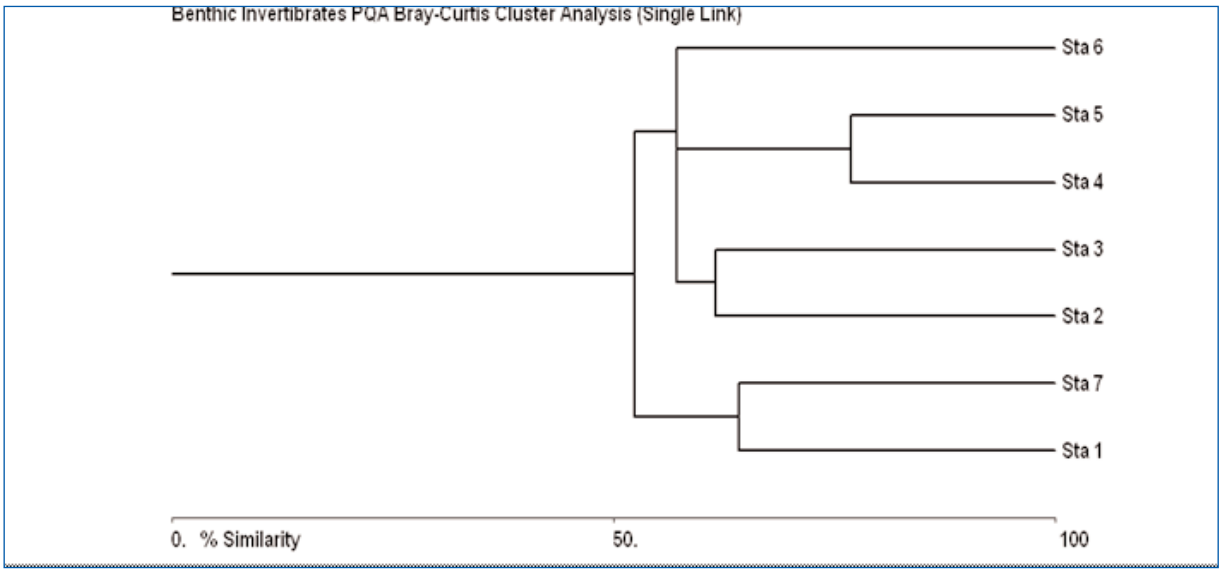

Figure 4.5. Bray-Curtis cluster analysis, Dendrogram showing stepwise structure where benthic invertebrate communities in the sampled stations at PQA area of interest are not dissimilar from each other.

Table 4.37 Shows percentage similarity amongst benthic groups sampled at different locations at PQA

Step	Clusters	Distance	Similarity	Joined 1	Joined 2		
1	6	23.07692	76.92308	4	5		
2	5	35.84906	64.15094	1	7		
3	4	38.46154	61.53846	2	3		
4	3	42.85714	57.14286	2	4		
5	2	42.85714	57.14286	2	6		
6	1	47.61905	52.38095	1	2		
Similarity Matrix							
	Sta 1	Sta 2	Sta 3	Sta 4	Sta 5	Sta 6	Sta 7
Sta 1	*	52.381	42.1053	40	50	45	64.1509
Sta 2	*	*	61.5385	42.8571	57.1429	57.1429	48.7805
Sta 3	*	*	*	33.3333	33.3333	50	43.2432
Sta 4	*	*	*	*	76.9231	46.1538	35.8974
Sta 5	*	*	*	*	*	38.4615	46.1538
Sta 6	*	*	*	*	*	*	46.1538
Sta 7	*	*	*	*	*	*	*

region can cause excessive erosion of sediments in the creeks and that can lead to smothering of intertidal fauna and impact some coastal communities.

High sediment load and turbidity can also cause damage to intertidal plants such as mangroves, and to saltmarsh species.

The suspended matter in the creek areas has an annual range of 25-170 ppm. The higher values were observed during the southwest monsoon period (usually May-August). The average suspended load during June-July was between 80-115 ppm. However, higher values (115-170 ppm) were also recorded at some places in the Gharo/Korangi Creek system. Lower suspended matter (25-50 ppm) was recorded during

Table 4.38. Shannon Weiner diversity index calculated for benthic invertebrates at PQA

Index	Sta 1	Sta 2	Sta 3	Sta 4	Sta 5	Sta 6	Sta 7
Shannon H' Log Base 10.	0.821	0.689	0.596	0.625	0.625	0.836	0.748
Shannon Hmax Log Base 10.	0.903	0.778	0.602	0.699	0.699	0.903	0.903
Shannon J'	0.909	0.886	0.99	0.894	0.894	0.926	0.829

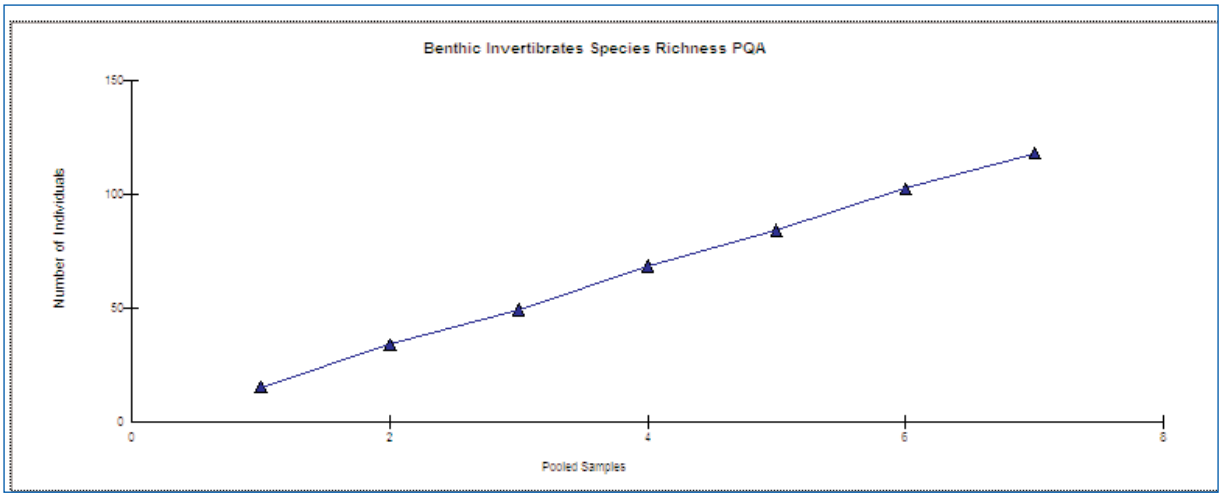

Fig 4.6. Species evenness (J') calculated for the benthic organisms at difference location of PQA

March and the September-November period. The suspended load in these creeks also exhibits variations with the degree of turbulence during a tidal cycle. During the flood season in the Indus River (September) the suspended load rises to about 4000 ppm in Khobar Creek and to about 1500 to 2000ppm in the adjacent creeks.

4.5.7 Coastal Mudflat Habitats.

Coastal areas and the intertidal region is a complex area where the division between land and sea is unclear. Coastal intertidal areas have a diverse range of communities including sandy shores, mudflats, and mangrove forests.

In the PQA, the Phitti Creek has faunal communities characteristic of very fine sediments from muddy to clayey. The communicaties included mud flats were dominated by faunal assembleges representing the soft sediments with high percentage of silt and clay. The sediment substrate were generally found to be high in organic content and with black mud just below the substrate (H_2S). Most of the area surveyed (figure 4.1 , table 4.33) constitutes of mangrove and the fauna associated with mangrove communities.

A. Methodology for Habitat Surveys

The sampling stations easily accessible by a road link were surveyed initially on the 1. 4. 2011. A shallow draft, fiber boat 4 m in length with an outboard motor (10 HP) was used for inaccessible locations along the coast to observe changes in coastal habitats. A hand held GPS (Garmin eTrek) was used to mark changes in the coastal configuration, and any significant sightings. The boat was navigated at slow speed between 3-5 Kts, along the coast at shallow depths of less than 2-4 m. The coastal area and the mangroves observation were made from were within 20-25 meters distance from boat. The main objective of a faunal survey was to identify the faunal habitats and the assemblage of species present. A hand held scoop net was also used to survey the larvae of shrimp and fish in shallow coastal area. The species were identified upto genus level in the field, using standard field guides for tropical seashells of India and Sri Lanka The unidentified specimens were preserved in the field in large mouth plastic containers containing10% formalin and bought back to the lab for identification using standard identification keys.

Estimates of relative species abundance at each station was accomplished by using a quadrat to represent 1x1 m^2 surface area (Figure 4.7) The small quadrat size are considered most suitable for a study of the dispersion of substrate faunal assemblages. The Habitat surveys were undertaken during low tides at daylight hours. Low tides facilitated in exposing submerged mud flat community. Appropriate statistical analyses were performed using statistical packages for data crunching and interpretation of results.

B. Results of Coastal Habitat Survey at PQA.

The PQA area of interest and the associated Creeks had faunal communities that are characteristic of mud flats. The substrate had very fine sediments (mud and clay). The faunal communities present were dominated by faunal assemblages representing the soft sediments. Table 4.39, provides information on the statistics of the total number of stations samples, mean individuals in each station along with variance, standard deviation and standard error of mean.

The result of spatial dispersion of a populaton describes the spatial distribution of the individuals in the population. Temporal changes in dispersion will usually occur, and different stages of the same species will often show different patterns of dispersion. The species distribution patterns observed in the mud flats at PQA sampling stations is given in table 4.40.

Crustacean Caridean Shrimp, were abundantly distributed and showed an aggregrate distribution pattern at station 6. The Carid shrimps were easily caught with the hand held scoop net. The scoop net measuring 10 x 10 cm caught 15-20 shrimp. The bivales Gafrarium spp, Marcinaria, and Gastropod Cerithium spp, Turritella spp were also found to aggregate in the mud flat habitat collected at the stations surveyed in the PQA area.

Statistically, the dispersion of a Population determines the relations between the variance and the arithmetic

Figure 4.7 A 1x1 m quadrate was used for random survey of substrate fauna. Data collected was analyzed using statistical package to determine population densities.

Table 4.39, statistical parameters of the total number of stations sampled, mean individuals in each station along with variance, standard deviation and standard error of mean.

Station/Sample	Mean Individuals	Variance	Std Dev	Std Error	TotalInd.	Total Spp	Min	Max	Mean Confidence Interval
Sample 1	0.235	0.316	0.562	0.136	4	3	0	2	0.15
Sample 2	0.235	0.316	0.562	0.136	4	3	0	2	0.15
Sample 3	0.353	0.493	0.702	0.17	6	4	0	2	0.234
Sample 4	0.941	2.059	1.435	0.348	16	8	0	5	0.979
Sample 5	0.412	0.382	0.618	0.15	7	6	0	2	0.182
Sample 6	2.353	19.993	4.471	1.084	40	8	0	12	9.504
Sample 7	0.294	0.346	0.588	0.143	5	4	0	2	0.164

mean. If the variance more or less equals mean than the Population is said to be randomly distributed. If the variance is less than the mean the Population is termed as regularly distributed. And if the variance is greater than the mean than the Population is considered to be an aggregate population that are known to be found in clumps. The highly aggregate populations of Caridean Shrimp Species. Cerithium spp, Turritella spp have been clumped together.

Cerithium species are a large group characterized by an upturned canal in their shell that protects the siphon and allows them to live just beneath the substrate. Cerithium spp are algae and detritus feeders and are common prey for predatory mollusks.

Turritella are by far the largest family group and also one of the oldest, being represented in the fossil record as long as 135 million years, during the Cretaceous Period. During this presence on Earth, they have occupied every geographical locality and are ubiquitous.

Table.4.40. Statistical parameters and dispersion pattern of species observed in the mudflats in the Coastal Habitat Survey conducted at each of the sampled stations at PQA

Invertebrate sp	Variance	Mean	Chi-sq	d.f.	Probability	Aggregation
Metaplex disctincta	0.2857	0.4286	4	6	0.6788355	Random
Volutidae	0.2381	0.2857	5	6	0.5453557	Random
Caridean Shrimp	19.2381	2.2857	50.5	6	0	Aggregated
Eurycarcinus orientalis	0.2857	0.4286	4	6	0.6788355	Random
Marcinaria sp	0.619	0.4286	8.66	6	0.192137	Random
Cerithidae	0.2381	0.2857	5	6	0.5453557	Random
Bullia spp	0.2381	0.2857	5	6	0.5453557	Random
Barbatia spp	0.2857	0.4286	4	6	0.6788355	Random
Gafrarium spp	1.2857	0.4286	18	6	0.0063792	Aggregated
Telescopium spp	1.4762	0.8571	10.33	6	0.1103398	Random
Marcinaria sp	3.5714	0.7143	30	6	5.19E-05	Aggregated
Tellina (Tellinidae)	0.2381	0.2857	5	6	0.5453557	Random
Codakia(Lucinidae)	0.2381	0.2857	5	6	0.5453557	Random
Cerithium (Cerithidae)	17.2857	1.5714	66	6	0	Aggregated
Turritella(Turritellidae)	20.5714	1.7143	72	6	0	Aggregated
Nerita spp	0.1429	0.1429	6	6	0.4236949	Random
Polycheate (worms)	0.8095	0.8571	5.66	6	0.5375987	Random

4.5.8 Fishery in the PQA.

Fish and Cetacean survey was undertaken in randomly selected station in the PQA Creeks at designated station 1, 2, 4 and 7. The station locations were in the Korangi and Phitti Creeks table 4.41. A shallow wooden boat with 10 hp out board engine was used. The wooden boat was approximately 4 m in length owned by the local fisherman of the area. The boat has a small trawl net having a mesh size of 5 cms at the cod end. The net could easily be operated by two people from the boat. The net was deployed at each of the fish station and towed for 10-15 minutes. The number of fish was counted and identified to the genus level.

A. Pelagic Fish Community:

Pelagic community includes powerful swimmers, which are exclusively carnivore in nature like predaceous fishes, croakers, sharks, carangids breams, perches, and sea snakes. Dolphin and seagulls are some important forms, which readily pick up fishes, shrimps, and cephalopods for food. In the mangrove ecosystem the predaceous forms are often small in size and easily wander among the mangroves at high tide. A 15-20 minutes fish trawl was conducted at selected station in the major creeks of PQA viz -a- viz Korangi, Kadrio, Phitti creeks. The fish species caught are given in figures 4.9 and4.10

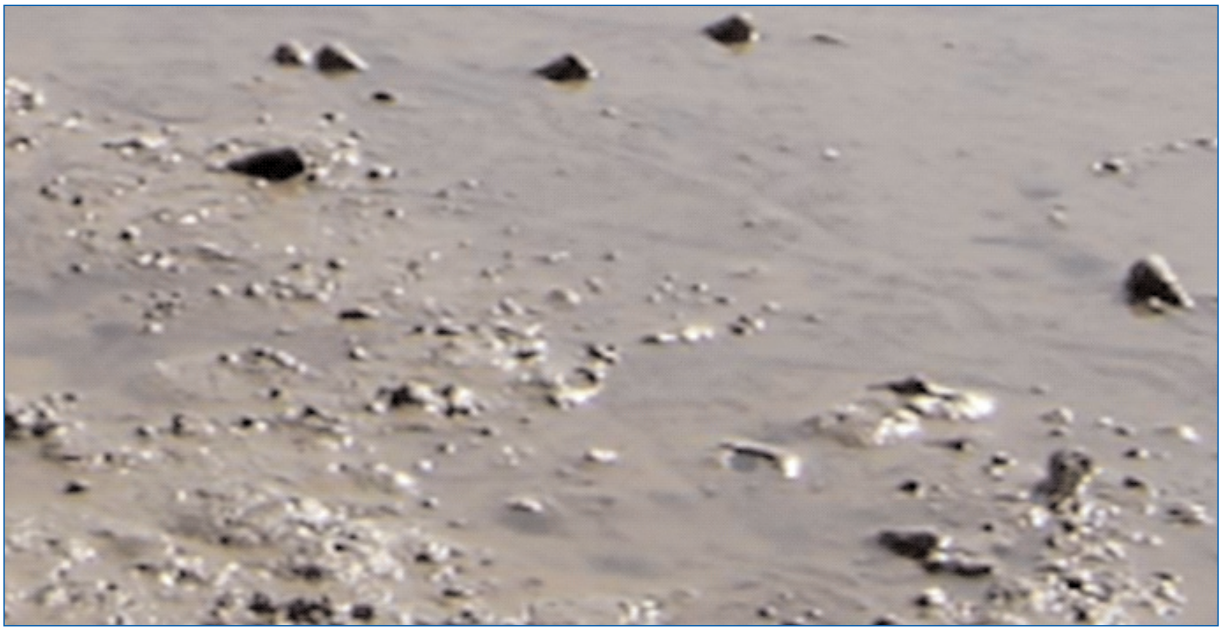

Fig 4.8. A Bivalves and Gastropod spp in muddy substrate at low tide in PQA during the survey.

Table 4.41. Fish and Cetacean Survey at randomly selected station PQA

Sta No.	Date	Substrate Type	Position Lat. Long	Local Time	Tidal Height m	Type of Survey.
1.	7. 4. 2011	Muddy cum silty	N 24, 47,03.65 E 67,10, 56.68	1025 hrs	1.9 high to low	Fishery and Cetacean Survey
2.	7.4.2011	Muddy cum silty	N 24, 47,37.31 E 67,12,38.59	1130 hrs	1.7 Ebb	Fishery and Cetacean Survey
4.	7.4.2011	Muddy cum silty	N 24, 48,44.26 E 67, 13,17.95	1320 hrs	1.0 Low receding	Fishery and Cetacean Survey.
7.	7.4.2011	Silty	N 24, 46,44.19 E 67, 14,18.56	1630 hrs	0.9 Flow	Fishery Cetacean Survey.

B Distribution of Fish Species in PQA creek

The distribution and aggregation of fish in PQA is given in table 4.43.The fish aggregation generally show a random behavior. With the exception of shrimps with showed to aggregate at station 7.

C Cluster Analysis Fish Groupings.

Bray and Curtis cluster analysis was performed to evaluate fish group similarity at different fish trawl station in the major creeks of PQA. The results are shown in figure 4.11. Station 2 and 4 show greater similarity while fish at station show affinity with fish station 1 and 7.

Figure 4.9 Small fishs,(Carangoids) shrimps (Metapenaeus sp) and swimming crab (Portunids) are found in he open creek system of PQA

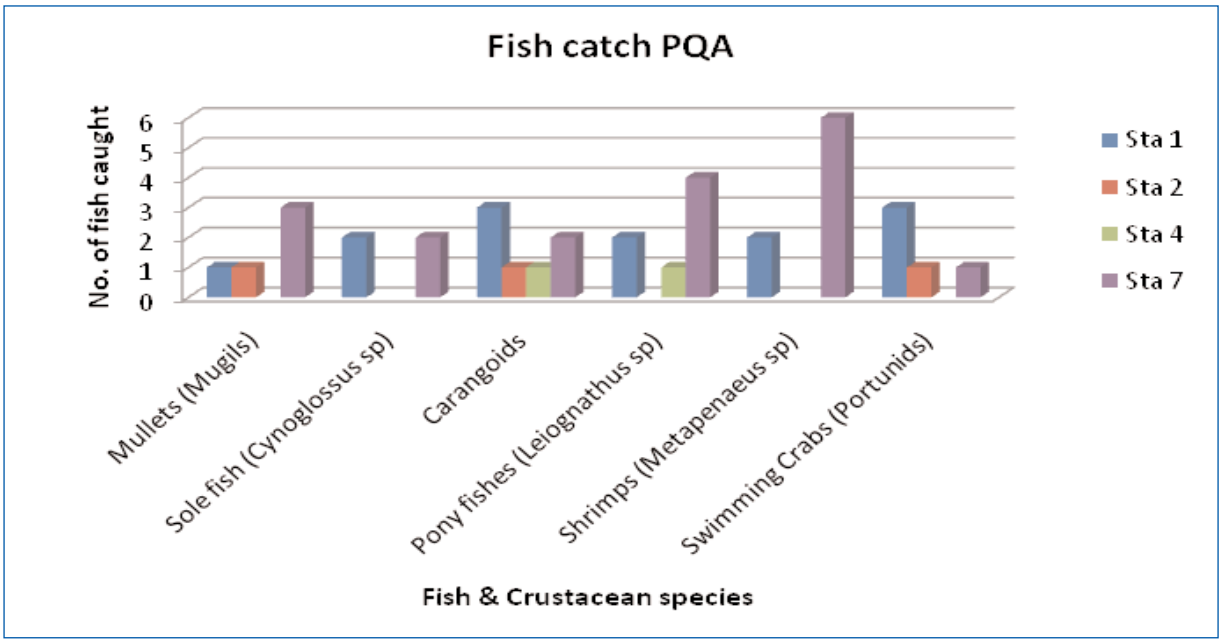

Figure 4.10. Fish caught using a small trawl net for 10-15 minutes in PQA at selected station (1, 2, 4, and 7)

Table 4.42. Descriptive statistics of Fish catch at selected station in PQA

Sample	Mean Individuals	Variance	Standard Deviation	Standard Error	Total Individuals	Total Species	Min	Max	Mean Confidence Interval
Sta 1	2.167	0.567	0.753	0.307	13	6	1	3	0.454
Sta 2	0.5	0.3	0.548	0.224	3	3	0	1	0.24
Sta 4	0.333	0.267	0.516	0.211	2	2	0	1	0.214
Sta 7	3	3.2	1.789	0.73	18	6	1	6	2.561

D Fish Diversity in Major Creeks of PQA

Fish diversity and evenness (J') was calculated using Shannon Weiner diversity Index. The biodiversity values are generally low in major PQA creeks (range from 0.301 – 0.778 Stations 1 & 7 comparatively have index values higher than stations 2 and 4.

Ahmed (1983) reported 98 species of fish from mangrove swamps of Korangi-Phitti creek system and backwaters of sandspit. Out of these 98 species 46 species were fingerling or young stages while 52 species were either sub-adult or adult. Mudskippers have adopted themselves to live in this particular environment. Pleuronectiformes which represent bottom living fish move towards this area for their

food. Many detritus feeders like clupeids, grey mullets etc. and small carnivorous fish like silver biddies and pony fish find this environment suitable for their living.

In Korangi Creek and the adjoining creeks areas Ahmed (1988) has described in detail four types of fish groups; the permanent dwellers which are few; partial residents; tidal; and seasonal visitors in the mangrove habitat where over 180 species of fish have been reported. As many as 148 species of fingerlings or young stages and juveniles have been reported from the mangrove of Indus Delta (UNESCAP, 1996). More common larvae of fishes described for Korangi Creek and adjoining creeks in Indus Delta belong to the

Table 4.43. Distribution behavior of fish in major creeks of PQA

Species	Variance	Mean	Chi-sq	d.f.	Probability	Aggregation
Mullets (Mugils)	1.5833	1.25	3.8	3	0.283189	Random
Sole fish (Cynoglossus sp)	1.3333	1	4	3	0.260453	Random
Carangoids	0.9167	1.75	1.5714	3	0.670141	Random
Pony fishes (Leiognathus sp)	2.9167	1.75	5	3	0.169987	Random
Shrimps (Metapenaeus sp)	8	2	12	3	0.007541	Aggregated
Swimming Crabs (Portunids)	1.5833	1.25	3.8	3	0.283189	Random

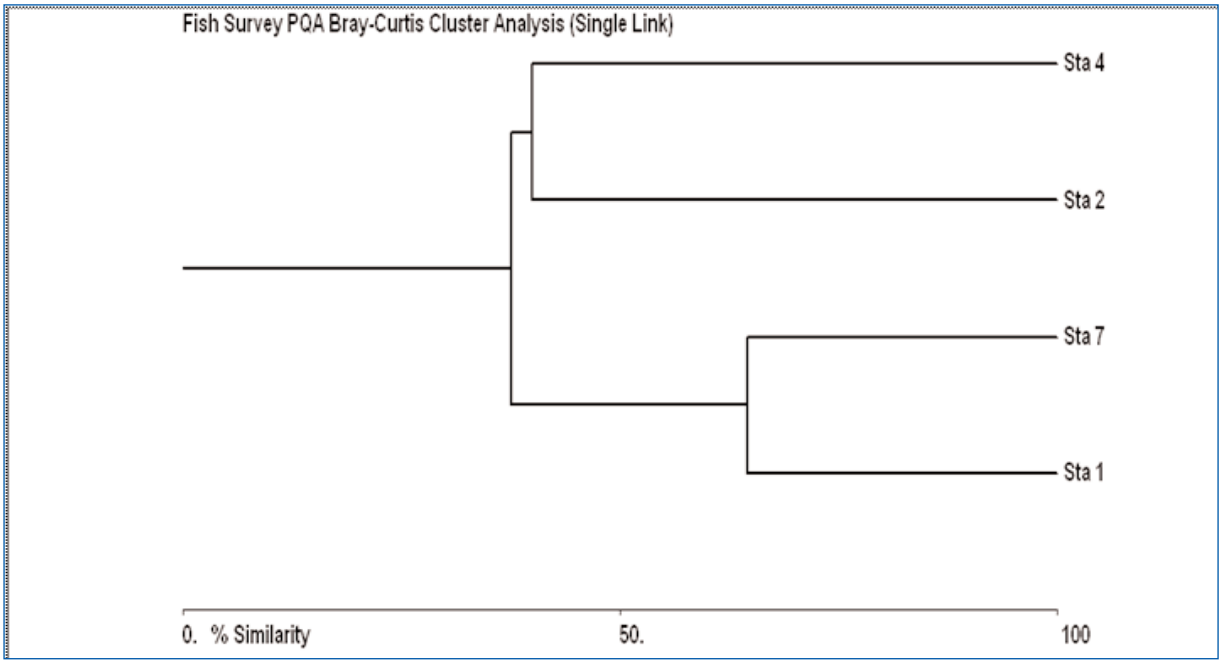

Figure 4.11. Fishery survey in major creek PQA .Bray-Curtis cluster analysis showing fish group similarity at selected station

Table 4.44. Bray-Curtis similarity values.

Step	Clusters	Distance	Similarity	Joined 1	Joined 2
1	3	35.48387	64.51613	1	4
2	2	60	40	2	3
3	1	62.5	37.5	1	2
Similarity Matrix					
	Sta 1	Sta 2	Sta 4	Sta 7	
Sta 1	*	37.5	26.6667	64.5161	
Sta 2	*	*	40	28.5714	
Sta 4	*	*	*	20	
Sta 7	*	*	*	*	

Table 4.45 Fish diversity and evenness (J') calculated using Shannon Weiner diversity Index.

Index	Sta 1	Sta 2	Sta 4	Sta 7
Shannon H' Log Base 10.	0.755	0.477	0.301	0.716
Shannon Hmax Log Base 10.	0.778	0.477	0.301	0.778
Shannon J'	0.97	1	1	0.92

families Mugilidae, Gerreidae, Clupeidae, Nemipteridae, Gobiidae, Sciaenidae, Engraulidae, Sillaginidae and Lutjanidae. Their abundance from season to season varies. There are a number of settlements of fishermen along the creeks of Indus Delta which depend on the fisheries resources of these creeks.

E Benthic Fish Community.

Benthic fish community includes detritus feeders, small and large herbivores, and small and large carnivores. In the mangrove ecosystem, the benthic community of the adjacent shallow water is a subject of interest. Here, the microbes decompose the plant litter into organic detritus- a fundamental commodity of system energy. This detritus matter is picked up by the detritus feeders over the bottom, such as fishes, shrimps and shellfish, and then carried to the littoral zone by wave action, shared by the intertidal fauna such as crabs, shrimps, mudskippers, and other invertebrates. Grey mullets, gizzard shads, flat fishes, many skates and rays are some of the fish which prefer to live on soft bottom and feed on bottom detritus. At low tide, when a large part of muddy bottom is exposed, crabs, mudskippers and waders are seen in large numbers picking up their food which includes worms and different animals left behind by the receding tide.

F Artisanal Crab Fishery.

Local fishing community members from near by village fish for mud crabs Scylla serrata during low tide. The mud crab burrows in mudflats in close proximity to the mangrove plantation. The locals excavate the soft mud with bare hands during low tide. The crabs are caught from their habitats and kept alive in moist gunny bags (Figure 4.14). The gunny bag containing crabs are towed by a small wooden boat to be sold in the village for further processing and possibly for exports to foreign countries by the crab processing factory. The local earn their livelihood through the capture and sale of mud crabs.

Fig4.12. Mud skipper (Balanus spp) emerging from its borrowing habitat located at high water mark

Figure4.13 Juvenile mud crab, star fish, sole fish (Cynoglossus sp) and flat heads (Platycephalids) fish in PQA creek system

Fig.4.14 Local crab fisherman, excavating exposed mud flat at low tide to locate mud crabs and transporting them in live in wet gunny bags in PQA.

G Cetaceans.

Dolphins have been sighted in the PQA area of interest and in the In the Indus deltaic region. The survey team did not see any dolphins in the area during the recent boat survey undertaken.

Similarly, the team did not find any feeding turtles in the area nor any turtle tracks were found on the muddy shores. No turtle nest was observed. It is unlikely that the turtles would nest in muddy substrate, they prefer sandy substrates instead.

4.6- AMBIENT AIR AND NOISE QUALITY

Records with respect to air quality and noise emission level are not available for the project location. Field data were generated to establish the baseline of ambient air quality at Korangi Fish Harbour, which represents the project area. There is not much development activity in the area. The only source of air contamination is the few fishing boats and trawlers emitting a limited amount of air pollutants which get dispersed immediately by the wind on the coastal area.

A- Methodology and Equipment

Air and noise monitoring was conducted by SUPARCO mobile laboratory and personnel. The Mobile laboratory is equipped with online US EPA designated ambient air analyzers for specific criteria pollutants. The international protocols were followed during the acquisition of ambient air pollutants data such as, monitoring site selection, distance of analyser/sampler above the ground and type of monitoring technique etc. Concentration of TSP/PM_{10}, SO_2, CO, CO_2, and NO_x was recorded along with meteorological parameters at each study site. The sampling interval of measurement was 15 minutes and monitoring was carried out continuously for 24 hrs at the site. One-hour means were calculated from 15 minutes data. The peak value in hourly mean has been recorded graphically.

B- Ambient Air and Noise Quality Levels

The average observed levels of Total Suspended Particulate (TSP) and PM_{10} were 173.6 µg/m^3 and

Table 4.46: Air Emission Standards and Guidelines

	USEPA		WHO		World Bank		NEQS (Proposed 1999)	
Pollutants	Averaging Time	Standard	Averaging Time	Standard	Averaging Time	Standard	Averaging Time	Standard
SO_2	24 HRS	365ug/m^3 (140 ppb)	24 HRS 1 HR	90 ug/m^3 (34 ppb) 350 ug/m^3	ANNUAL MEAN 24 HRS	100 ug/m^3 (38 ppb) 500 ug/m^3	ANNUAL MEAN 24 HRS	100 ug/m^3 (38 ppb) 400 ug/m^3
CO	8 HRS 1 HR	10 mg/m^3 (9 ppm) 40 mg/m^3	8 - HRS	10 mg/m^3 (8.7 ppm)	-	-	-	-
NOx	ANNUAL MEAN	100 ug/m^3 (53 ppb)	1 HR	190-320 ug/m^3	ANNUAL MEAN	100 ug/m^3 (50 ppb)	ANNUAL MEAN	100 ug/m^3 (53 ppb)
O_3	1 HRS	235ug/m^3	8 HRS1 1 HR	120 ug/m^3	-	-	-	-
TSP	24 HRS	260 ug/m^3	24 HRS	200 ug/m^3	ANNUAL MEAN 24 HRS	100 ug/m^3 500 ug/m^3	-	-
PM_{10}	24 HRS	150 ug/m^3\	-	150-230 ug/m^3	-	-	-	-

Table 4.47: Ambient Levels of Gaseous Pollutants and Noise Levels (for 24 hours)

	SO_2 (ppb)	NO_x (ppb)	CO_2 (ppm)	CO (ppm)	Noise (dB)	Wind Speed (m/s)	Humidity (%)
Min.	5	9	282	0.71	51	4.3	50
Max.	11	17	317	1.8	61	6.8	95
Avg.	8.1	11.9	300.8	0.9	54	5.8	74

93.3 µg/m³, respectively. These concentrations were well with in the prescribed limits for TSP (260 µg/m³ for 24 hrs) & PM_{10} (150 µg/m³ for 24 hrs) of USEPA. The measured mean concentrations of gaseous pollutants were, 0.9 ppm for CO, 8.1 ppb for SO_2, 11.9 ppb for NO_x and 300.8 ppm CO_2. All these levels of gaseous pollutants were well within limits of USEPA, WHO and World Bank (Table 4.46). The major source contributing to the observed level of pollution were long distance transport of urban air pollution and from population centers as the monitoring site was downwind of these sites. The mean noise level at the site was 54 dB(A), which also shows the absence of any source of emission close to the proposed site. Furthermore the substantially strong winds have diluting and dispersive effect on the pervading pollution levels.

A detailed ambient air quality report is attached as Annexure-VI for reference.

Table 4.48: Ambient Levels of Particulate Matter (Total Suspended Particulate) TSP

Date	Filter Paper No.	Time Duration	Time		Air Volume	Weight(g)			Conc.
			Start	Stop	(m³)	Before	After	Net	(µg/m³)
12-09-07	S-003	24 hrs	11:00	11:00	1008	3.941	4.116	0.175	173.6

Table 4.49: Ambient Levels of Particulate Matter (PM_{10})

Date	Filter Paper No.	Time Duration	Time		Air Volume	Weight(g)			Conc.
			Start	Stop	(m^3)	Before	After	Net	($\mu g/m^3$)
12-09-07	S-002	24 hrs	11:00	11:00	1008	4.018	4.112	0.094	93.3

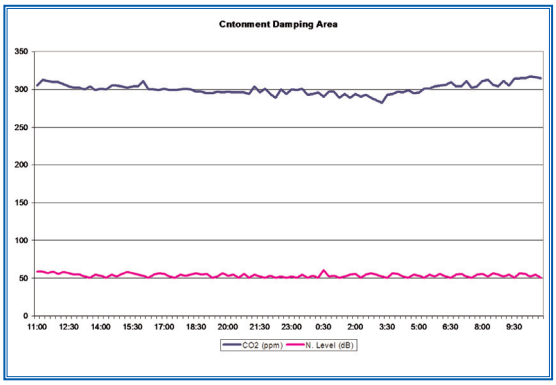

Figure 4.15 Ambient Levels of Carbon dioxide and Noise at LNG Terminal site

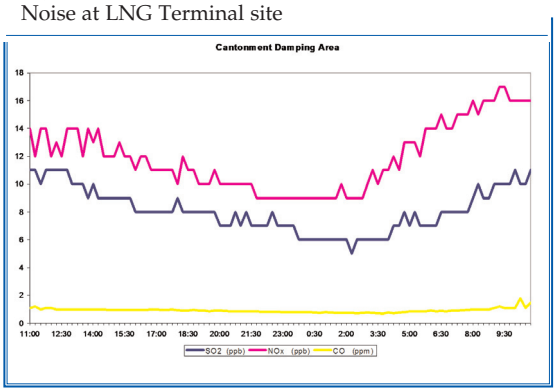

Figure 4.16 Ambient Levels of Gaseous Pollutants at LNG Terminal site

4.7- ARCHAEOLOGICAL AND HISTORICAL SITES

A review of investigations in the Port Qasim area and a visit to the site, did not indicate existence of any feature or structure of cultural significance or of archaeological interest within the area of the proposed activity. There is a grave of a certain saint Baba Kamal Shah about 4 km on the northeast, said to be attracting some devotees. A shallow sweet water well near the shrine is an attraction for the devotees. These features, however, do not suggest that the place has any historical or cultural significance. The nearest archaeological sites of ancient Port of Debal and the town of Bhambore are about 18 kms NW of the site.

4.8- LAND USE AND DEVELOPMENTS IN THE AREA

The proposed LNG Jetty and Storage Area will be located in the designated areas of Port Qasim under

the administrative control of Port Qasim Authority. The authority is developing the Port and its industrial areas generally in accordance with a land use Master Plan.

The development of inland adjacent areas is the responsibility of Malir Development Authority.

4.8.1- Port Qasim Authority

Port Qasim Authority (PQA) was established in 1973 with the following objectives:

- Provision of alternative and stand by Port facilities to Karachi Port Trust to remove congestion and to cater for the expanding economy of Pakistan
- Provision of specialized Port facilities for the exclusive use of Pakistan Steel for bulk handling of its iron ore, coal and manganese at its doorstep
- Environmental relief to the city of Karachi from congestion on road and atmospheric pollution caused by Port traffic.
- Provision of land for location of such industries and commercial establishments whose imports/exports pass through the Port, thus generating cargo for the Port
- A Master Plan was developed by the Authority for the phased development of the Port and its industrial areas. Following facilities have since been developed:
- A specialized berth designed to cater for vessels of 75,000 tonnes has been constructed for bulk constructed for bulk handling of iron ore and coal for Pakistan Steel but it is presently handling 50,000 tonnes vessels due to constrains of channel depth,
- Multipurpose Marginal Wharf area divided into seven berths which can take vessels of up to 25,000 tonnes, but berths 5, 6 and 7 can accommodate up to 35,000 tonnes,
- 45 km of navigable channel for vessels of up to 50,000 tonnes.

Development opportunities, identified for subsequent phases of the Port expansion included both private and public sector projects and establishment of bulk liquid/chemical terminals in the private sector. An oil handling facility has been established by FOTCO in private sector. Space for 4 more terminals is reserved in the vicinity, one of these is now proposed for the LPG Terminal.

PQA has, for the purpose of location of industries and commercial establishments, earmarked 4,900 hectare (ha) of land, (1080 ha in the north-western zone, 400 ha in the south-western and 3,520 ha in the eastern zone). Approximately 1,200 ha of the land has been allotted to national and international enterprises such as KESC, Toyota, Schon Refinery, FOTCO, BRR-Fertilizer, WakGas, RECP, and Daewoo. The utility agencies (KESC, Sui Southern Gas Company and Pakistan Telecommunication Co. Limited) have provided the corresponding infrastructure facilities in the area.

4.8.2- Coastal Area Development Plan

Karachi Development Authority had, in 1990 approved the Karachi Coastal Recreation Development Plan 1990-2000, wherein a number of environmental planning zones were proposed, to ensure the development of recreational facilities and to minimize the adverse impact of development on the natural environment. The zones were designated essentially according to the recommended level of development activity and were aimed at facilitating environmental control and protection.

Western Port Qasim where the proposed facility will be sited is located in Environmental Planning Zone 3a. According to KDA, it was essentially a "Utilization Area" which by their definition is an Area considered suitable for development, and is either environmentally stable or has already been degraded to a certain extent. Zone 3a was according to the KDA Master Plan, a sensitive area within which development may impinge on other uses. As such its natural character is required to be

maintained if not improved and development activities have to take account of repercussion in other areas. No action on this plan was however taken and its fate is uncertain. Now Malir Development Authority has taken over the responsibilities of KDA in the Eastern part of Karachi.

4.8.3- Land Use in Adjoining Area

PQA has administrative control over the 4,900 ha of land above the high water line and 64,000 ha of mangrove forests, mud flats and creeks. The major land use of the area adjoining the site includes industrial zones and port areas. The wastewater from the Steel Mills is discharged into a tributary of Bakran Creek on the north east of the site. The conveyor belt made specially for moving iron ore and coal from the respective berths to Steel Mills is to the east of the site.

Installations of Fauji Oil Terminal and Distribution Company (FOTCO) are located adjacent to the proposed LPG Jetty on the Kadiro Creek. FOTCO installations include its offices, an oil terminal berth, oil pipelines to the Buffer Oil Tank Farm and ancillary facilities including a fire-protection system. Several companies concerned with the import and storage of molasses operate on a 70 ha land area about 5 km to the east of the site. Other major establishments in the area include the PQA administration and operation buildings, some railway installations, and the potential residential areas as shown in the Master Plan.

4.9- SOCIO-ECONOMIC CONDITIONS

4.9.1- Human Settlements

Within the limits of Port Qasim, above the high water line, there are no residential areas. However, adjacent to these limits some urban settlements of significance are located. Further, there are several coastal villages along the creeks. Significant among these are located along Korangi Creek to the west of the site. A survey of these by IUCN in 1987 estimated the population as follows:

Further, there are several coastal villages along the creeks. Significant among these are located along Korangi Creek to the west of the site. A survey of these by IUCN in 1987 estimated the population as follows:

Ibrahim Hyderi	53,000
Rehri	18,500
Chashma	6,300
Irkamabad	3,900
Ittehad Colony	3,300
Lad Basti	2,500
Ali Akbar Shah	2,500

Major human settlements in the macro-environment are the several large and small rural villages and urban townships.The closest to the proposed site is a small coastal village Goth Lai Jat at a distance of about 3 km west of the land terminal.

4.9.2- Employment and Living Conditions

The Settlements in the Korangi Creek area are fisherman's villages but the dwellers are engaged in other low level occupations as well. The employment and therefore earnings for a large section of population in the area is variable, heavily dependent on fisheries and seasonal variations. Prawn and shrimp fishing from inshore waters is the main source of income of the majority. However, quite a substantial number are employed on deep-sea fishing boats. The relatively low level of income in this rural setting is reflected in the poor conditions of housing, with water supply and sanitation being too inadequate. Some of these villages are now provided with electricity,

connected by paved road and served by Public Transport.

The nearby urban areas are better served with civic amenities, schools, colleges and hospitals. Most people are employed in the nearby port and industries and the services sector. Income levels are higher than rural area.

4.9.3- Dependence on Mangroves

Mangroves are a valuable resource for many of the coastal villages. They are primarily used as a source of fuel and fodder and provide the feeding grounds for prawn and shrimp, besides protecting the land from erosion. The people have been overexploiting this resource over recent years. Camel herds comprising hundred of camels are fed from these denuding the trees of the leaves and cutting the tree trunks for wood. IUCN, in association with Sindh Forestry Department, has initiated a program of mangrove conservation, replanting and sustainable management in the Indus Delta and the creeks with some success as a result of awareness that has been created in the resident population.

A detailed socio-economic assessment has been conducted by EMC to evaluate the impacts of LNG project on the nearby communities. Chapter-5 of this report contains the details of socio-economic assessment.