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ANALYSIS ON THE HYDRODYNAMIC ENVIRONMENT AND ITS IMPROVEMENT MEASURES FOR LINGDING BAY

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Abstract: The estuaries in Lingding bay are not only the main flood way for the Pearl river, but also the main tide way for south sea . The navigation in LingDing bay is very important. The variation of the hydrodynamic environment is the direct reason for the evolution of Lingding bay and the evolution is correlative to the discharging capacity of the estuaries, the flood control, drainage, and so on. In recent years, the shallow areas have become bigger and bigger, and the channels deeper and deeper. The hydrodynamic condition has changed because of the reclaimed project, the optional dredging, the constructions of the docks and the bridges, and so on. These changes are disadvantageous to the capacity of absorbing tidal and its transportation in Lingding bay. According to the observed data, the changes of the hydrodynamic condition of the Lingding bay have been studied in this paper. The improvement measures for Lingding bay are put forward to keeping up its dynamic condition and reducing sedimentation by regulating river way.

Key words: Lingding bay, The hydrodynamic environment, Scour and aggradation, The improvement measure

1. INTRODUCTION IN LINGDING BAY

LingDing bay is a part of the Pearl river estuaries, It concentrates on water and sediment from East four gates under the eight gates of the Pear river. Its north boundary is tiger-gate, south boundary is inner LingDing bay, east and west boundary are alluvial plains or islands. Its water area is 1040 km^2 in middle tidal. Its sea bed in the west and north is higher than in the east and north.

Because of difference hydrodynamic conditions, two deep channels in the east and west are formed, and three bank in the east, middle and the west are formed. The tidal area in the east of bank is about 32km length and 1-2m width. In the east channel, its upper river is DaSha riverway, its below river is FanShi riverway. The middle bank is also FangShi bank, It is in the middle of east and west deep channel,

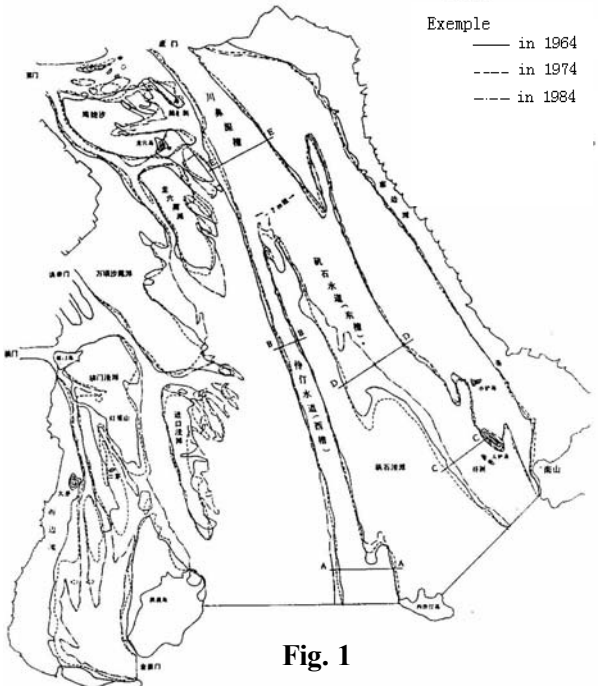

Fig. 1

its north 5m contour has 12km to inner island of LingDingYang, its south 5m contour has 9.5km to inner island of LingDing bay.

The west channel is also LingDing riverway, Its whole length is 73km, its mean depth is 11.5m in the sea-route channels. For the moment, it is only routeway in GuangZhou harbor to outside sea. The west island is west in the west channel which have three riverway as JiaoMen, HongQiLi and HengMen, commonly its water deep is 0.4−0.7m, sometimes it comes out water level in low tidal season.

2. THE VARIETY OF THE ENVIRONMENT IN LINGDING BAY

After the year of 1950, as engineering ware built continually, The water and soil in Pear middle and below river were severity lost. The sediments entering bay were continually aggraded in estuary bay under the action of flow and tide together, so LingDing bay became shallow gradually, its west bank was continually aggraded and its west channel became narrow, its middle bank was elongated in the northwest-southeast direction and slightly moved to the east, its east bank was slowly aggraded and its width was slightly reduced.

Since the year of 1970, 200 km^2 beaches are developed in LingDing bay, in which excess two-part placed in tree-gates outside for its west bank. In recent 20 years, the east and west bank lines in LingDing bay had trend to sea field, it was mainly because Jiao-gate, HongLi-gate and Heng-gate are improved, Chi-bay and DaSha-bay ware filled , JiaoYi-ray is reclaimed. From the year of 1978 to the year of 1999, the water surface area was reduced to 0.85% mean rate annually. See Table 1.

Table 1 The variety stat. of water surface area in LingDing bay.

	Surface area(A:km^2)	reduced area to compare in 1978 （Δ： km^2）	reduced rate(Δ /A:%）
1978	1133.41	——	——
1988	1043.80	89.61	7.91
1992	987.84	145.57	12.84
1995	960.75	172.66	15.23
1999	931.95	201.46	17.77

As the east and west bank lines bay had trend to sea field, the areas of beach channels were changed in LingDing bay. Table 2 is the comparison of mean area variety of the beach channels in the various times. Thus the result is: in upper 0m, total area is increased about 175.4km^2 in 1953−1998 , in which increasing area in 19891−998 is 55% of total area, so we can obtain below conclusions: the beach in LingDing bay is gently expanded, its water area is reduced gradually. Because the area under -5m deep channels was gradually reduced in 1953−1998, the deep channels became narrower and deeper, the ability of transporting water and silt in the deep channels became higher.

Table 2 Comparison on mean area of the beach channels in the various times （unit：$25\times10^4 m^2$）

	Upper 0m	-2−0m	-5−-2m	-10−-5m	below 10m
1953−1964	208.21	-179.23	186.22	-196.47	-18.71
1964−1974	42.86	174.17	-174.64	-35.25	-7.15
1974−1989	61.59	-69.90	62.58	-50.93	-3.34
1989−1998	388.68	-301.49	-62.97	-50.68	26.50
Total variation	701.34	-376.45	11.19	-333.33	

Inner Ling bay is a firth which can take up the runoff of east river and north river,the part flow of west river. Upper river network and lion bay are the field of accepting tidal in LingDing bay, its area variety directly influences the tide and flood in estuary, at the same time, it is connected with the stabilization of hydrodynamic boundary in the tide way of LingDing bay. In HuangPu harbor to tiger gate, because port wharfs are built and its alongshore is developed, 0 m highness area was 95.92km^2 in 1998, which was reduced 9.2% in 1997. In recent 20 years, a great deal port wharfs and bridges were built in main rivers and branch river ways, so the tide and flood were directly restricted.

In LingDing bay, the variety factors of rushing and silting beach channels were not only upper flow and sand, but also the reclamation and evolution of estuaries, the dredging in sea-route, the constructions of the docks and the bridges, randaom development, and so on. It also changed the hydrodynamic environment. The variation of hydrodynamic condition must conduce to the variation of rushing and silting in LingDing bay. So that we must analysis the variational rule of hydrodynamic condition to forecast evolvement trend and to discuss the Improvement Measure of regulating LingDing bay.

3. ANALYSIS ON HYDRODYNAMIC ENVIRONMENT AS THE VARIATION OF ABOUT LINGDING BAY

3.1 TO INFLUENCE OF FLOOD TIDE DYNAMIC IN TIGER GATE

Because of the reduction for tide accumulation area and hydraulic engineering in upper river network, and stone embankment in northeastern of below JiBaoSha bank, the flow section in ShaJiao electricity factory is narrowed, and flood tide dynamic in sea is restricted. After LingDing sea-routes are improved and dredged up, the food tide dynamic is enhanced. For the moment, the flood tide quantity is lesser than that in 70 years. Fig.2 is the relation of observational tide error and flood tide flow in 1978-1979 and 1999-2001. This shows that the tide flow is reduced obviously in middle and little tide, and the reduction of flood tide mean flow is bigger as tide error is lesser. When flood tide flow is bigger than 15,000m^3/s, two curves is basically superposition, which makes out less variation of dynamic condition in tide way.

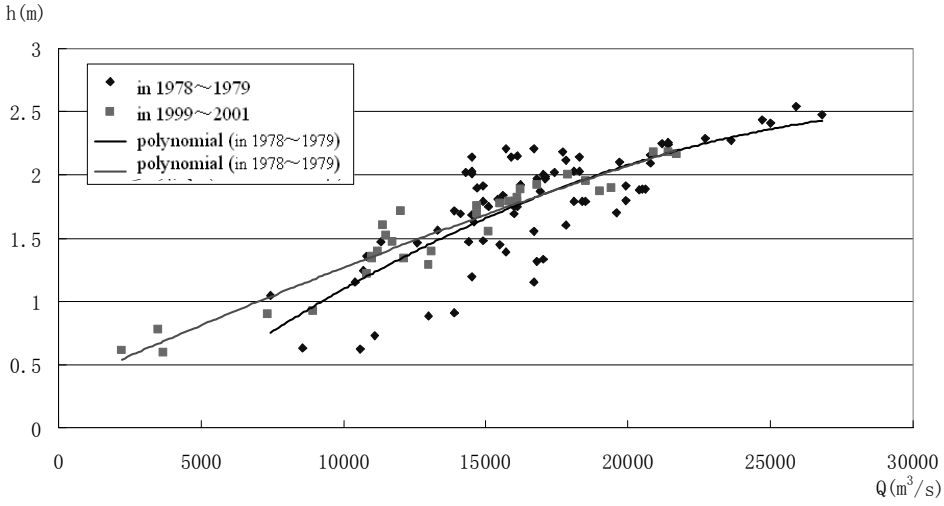

Fig. 2 The relation of observational tide error and flood tide flow in 1978-1979 and 1999−2001

3.2 TO INFLUENCE OF THE HYDRODYNAMIC CONDITION IN THE WEST BANK OF LINGDING BAY AS NON-LEGALITY STONE BANK IN THE NORTHEASTERN SEA FIELD OF JIBAOSHA

During 1997-1998, stones often wrer thrown to bank up in the northeastern sea field in JiBaoSha, the boundary of threw stones exceeded 700m-900m of plan control line, so the tide way in west ShanBan island was enveloped. According to three measure maps in 1998, February 2000, December 2001, Annual accumulation sediment was about 5 million m^3 in JiBaoSha east land line (see Table 3). After 1998, its thickness of Annual accumulation sediment was about 0.3m-1.0m. Because the tide way in west side of ShanBan island was enveloped, the hydrodynamic condition in east side of ShanBan island was strengthen and its riverbed was washed out. But the hydrodynamic condition in east side of JiBaoSha was reduced, and its riverbed was washed out. Specially below ShanBan island, slow flow field was formed, its riverbed was filled up, and it had the trend to backward position, it will exacerbate coastwise hydrodynamic environment in in east island line of JiBaoSha.

Table 3 The accumulation sediment in about JIBaoSha east land line unit: ten thousand

Position	section	2000-1998	2001-2000	2001-1998
Backward river in JiBaoSha	L1−L15	246.2	150.2	396.4
Afterbody in JiBaoSha	L15−L20	8.0	64.2	72.2
Middle part in JiBaoSha	L20−L25	23.6	60.6	84.2
About ShanBan island	L25−L40		506.6	

3.3 TO INFLUENCE OF THE HYDRODYNAMIC CONDITION IN LINGDING BAY

In LingDing bay, because bank becomes land, west and east bank fills up in east or southeast direction, and west channel becomes deep, it is necessity that the hydrodynamic condition is changed. Fig.3 is the residual flow field("98.6" flood) calculated by mathematic model using landform condition of vary times in LingDing bay. Fig. 3 increases 10%−20% using landform condition of 80 times, This shows that the hydrodynamic condition in west channel is strengthen after LingDing sea-route is improved and dredged up. In about ShanBan island, because the tide way in west ShanBan island is enveloped, the hydrodynamic condition in east side of ShanBan island is strengthen , But the hydrodynamic condition in east side of JiBaoSha is reduced, Specially below ShanBan island, slow flow field is formed.

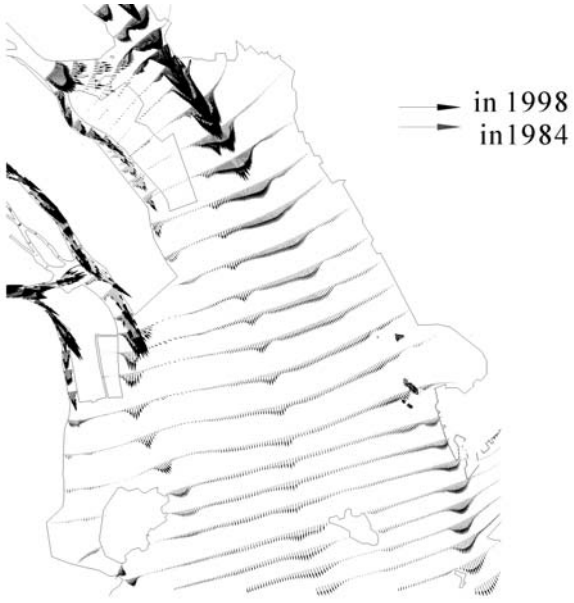

Fig. 3 The residual flow field calculated by mathematic model using landform condition of vary times in LingDing bay. (98.6 flood)

3.4 JUMP ANALYSIS

The change of all the hydrological viable has two basic form: continuous gradual change and uncontinuous jump. The characteristic of uncontinuous change is "sudden change", and it shows the phases of hydrological phenomena change.

Using the analysis method of A.F.S Lee, S.M.Heghinian and analysis method of order classification to calculate the runoff series, and the jump points can be found.

4. ANALYSIS ON THE VARIATION OF RUSHING AND SILTING IN LINGDING BAY

The evolvement of beaches and channels in estuary is made from hydrodynamic and sediment characteristic, but its change in sea field relates to people's development. Because of changing hydrodynamic condition, the beaches and channels happen new variation, which must bring about the evolvement of beaches and channels in seabed. In LingDing bay, basic characteristic of rushing and silting is: aggradations is main in flood season in shallow sea area, tide and sediment are main in dry season. These characteristics especially is obvious in west channel two-side (LingDing river way) and middle island.

Fig.4 is the distributed map of aggraded thickness in Nov.1991 to Apr.1992. Fig.5 is the distributed map of aggraded thickness in Apr.1992 to Jul.1992. Fig.6 is the distributed map of aggraded thickness in Jul.1991 to Nov.1992. Fig.7 is the distributed map of aggraded thickness in Nov.1991 to Nov.1992.

Upper maps can show: in flood season, middle beach usually is aggraded, its aggraded thickness commonly is 10cm to 30cm , that is 40cm to 50cm in local position. In dry season, middle beach usually is scoured(see Fig.5), its scouring thickness commonly is 20cm to 30cm , that is 40cm to 50cm in local position (see Fig.4, Fig.6) . the distributed map of aggraded thickness in 1992 (see Fig.7) is shows: the shallow sea fields are scoured as aggraded, as a whole scour is slightly main. In inner LingDing island, its north area is slightly scoured, its south area is slightly aggraded.

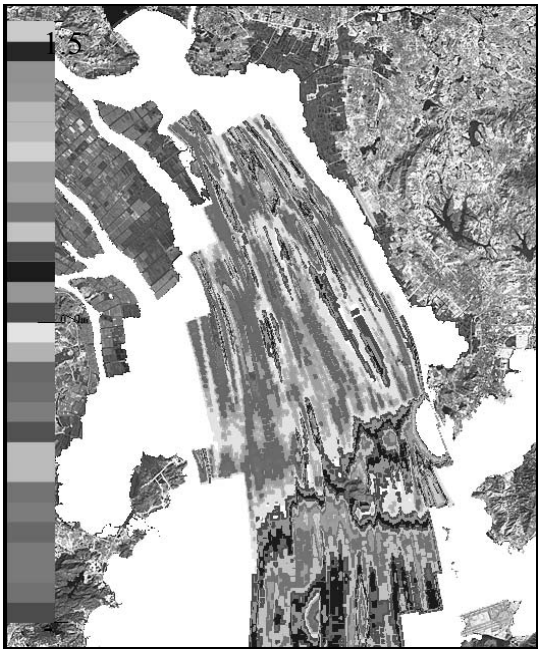

Fig. 4 The distributed map of aggraded thickness in Nov.1991 to Apr.1992

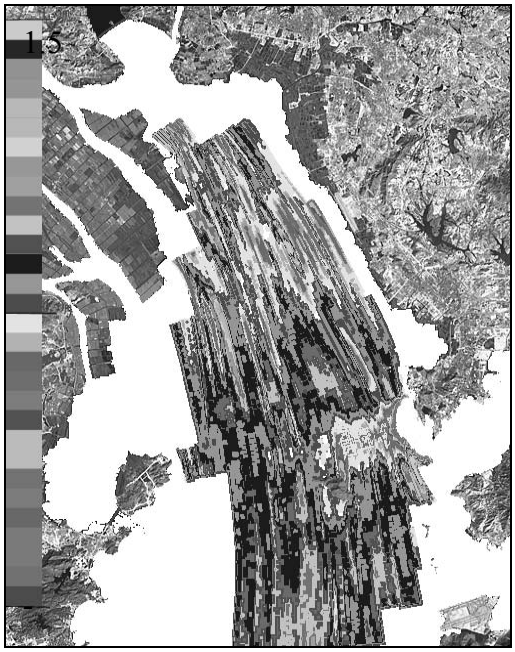

Fig. 5 The distributed map of aggraded thickness in Apr.1992 to July1992

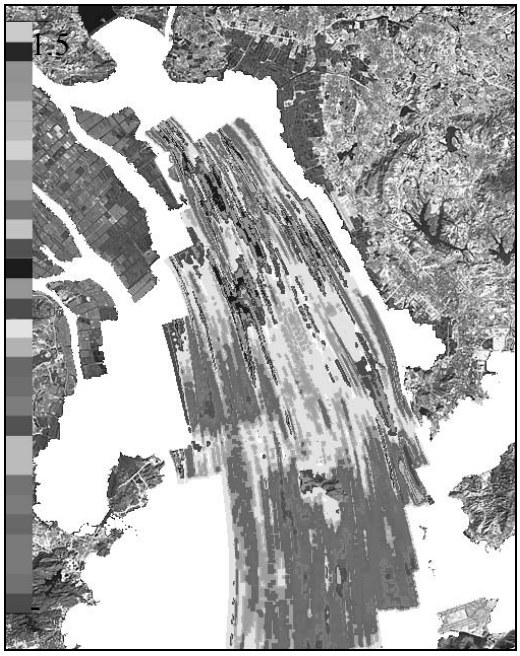

Fig. 6 The distributed map of aggraded thickness in July 1991 to Nov.1992

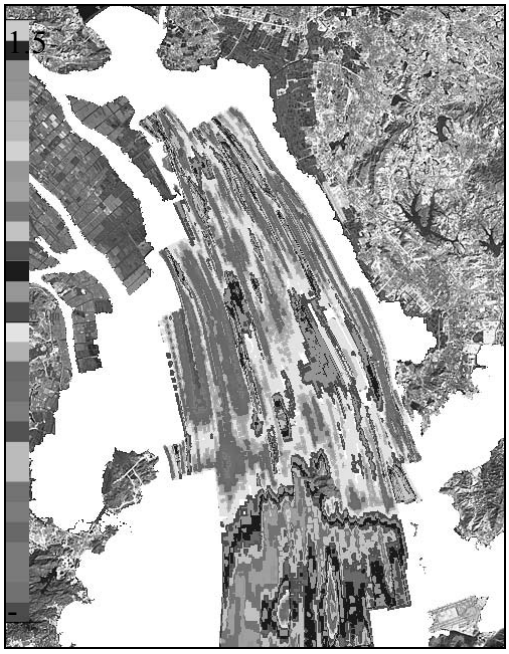

Fig. 7 The distributed map of aggraded thickness in Nov.1991 to Nov.1992

Table 4 is the annual mean variation of aggraded capacity and sediment rate in different depths of LingDing bay. According to Table 4 result, during 1953-1998, whole LingDing bay is aggraded, its annual sediment rate is about 1.57m, its annual mean aggraded rate of bottomland (upper -5m) is 1.9cm . During 1953-1974, the deep channel under -5m is aggraded, its annual mean aggraded rate is 2.74m. But whole LingDing bay is scoured , its annual scouring thickness is about 1.5m, the deep channel in LingDing bay becomes narrower and deeper.

Table 4 The annual mean variation of aggraded capacity and sediment rate in different depths of LingDing bay. (unit: aggraded capacity: ten thousand m^3/a； sediment rate：cm/a）

	under 0 m		0−-2m		-2−-5m		under -5m	
	Aggraded capacity	sediment rate	Aggraded capacity	sediment rate	aggraded capacity	sediment rate	aggraded capacity	sediment rate
1953−1964	2985.7	2.98	998.4	3.38	981.5	2.36	1005.9	3.38
1964−1974	1532.0	1.51	423.4	1.44	425.5	1.02	683.1	2.57
1974−1989	524.5	0.54	39.9	0.14	701.1	1.69	-216.5	-0.85
1989−1998	1278.6	1.41	1070.9	4.31	760.7	1.83	-553.0	-2.27
Total mean	1487.5	1.57	552.3	2.14	720.3	1.78	214.9	0.76

Fig.8 is the shape map of scouring and aggrading LingDing bay in 1984-1998. From Fig.8 can see: after improving Jiao, HongQi, Heng, JingXin estuary,and excavating LingDing sea-route, flow goes back to channel, two-sides in west channel are scoured, west beach is filled up continually, below east beach is aggraded speedily in west direction. Middle beach is as scouring as aggrading, which have trend of scouring westside and aggraded eastside.

As a whole, in shallow sea of LingDing bay, the thickness of scouring and aggrading in shallow sea of LingDing bay relates to flow and sediment, aggradation is main in great water and plentiful sand, tide and transported sand are main in dry season and little sand.

In recent time, because LingDing sea-route have be excavated to -11.5m and its hydrodynamic condition have be strengthened, the two-side of LingDing bay were scoured and middle beach were moved in east direction. It is further discussed problem that east beach

is aggraded greatly which is related to cosmically filling sea engineering (new HongKong airdrome).

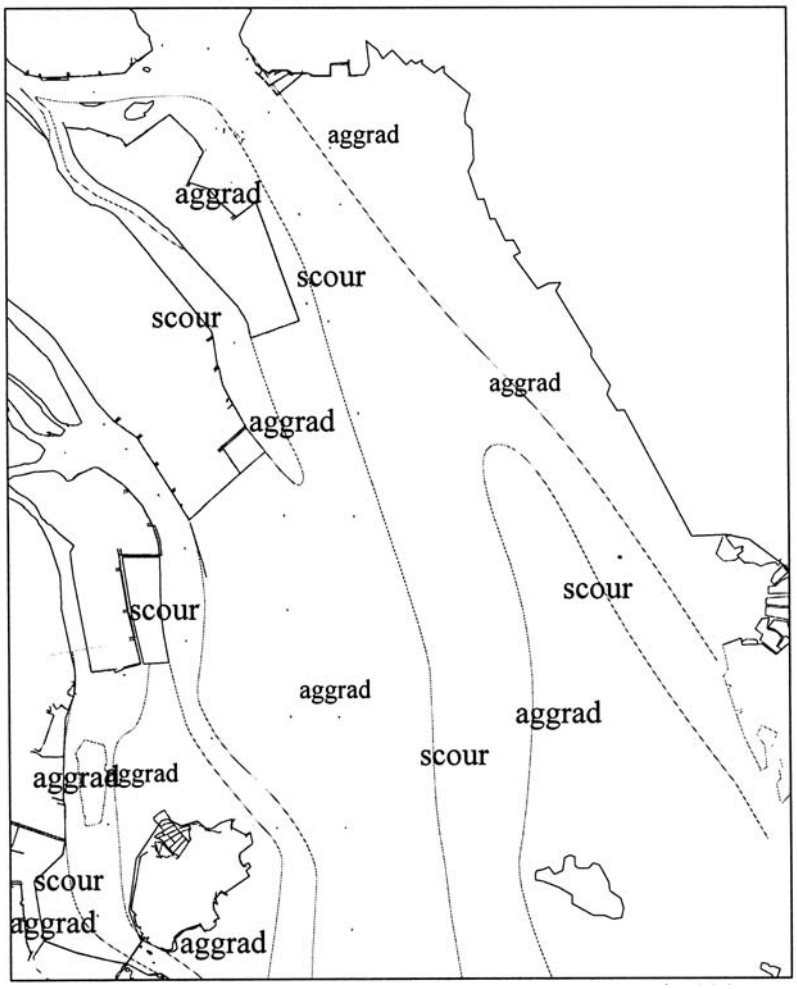

Fig. 8 The scoured and aggraded map in 1984 and 1998

5. TO DISCUSS ON IMPROVED MEASURE IN LINGDING BAY

LingDing bay in Pearl river estuary is the firth which is belong to both delta estuary of many junction river and bell mouth estuary, it is very typical estuary in the world. To understand the typical and complicated estuary is very important to regulate Peal rive , develop LingDing bay and NanSha island in GuangZhou city, build NanSha's harbor and west harbor in ShenZHen city. So we must keep the stabilization of east and west channels in LingDing bay, improve tide dynamic condition.

The evolvement of estuary beach and channel is due to its dynamic condition and sediment, so developing estuary must be according to the rule of its evolvement in differ character. In LingDing bay, west bank of most activated part in firth evolvement is a key part of developing and regulating LingDing bay.

So below projects is very necessary: to dredge up and expand Jiao-gate's south channel to reduce water and sand into ChuanBi river in LingDing bay, to reserve Jiao-gate's nouth channel to navigate and transport sand or flood, to reduce the Jiao-gate's flow collected from upper and below HengLi, to dredge up and regulate HongQi-gate's riverway to gradually renew its flood discharge, to increase flood discharge of south branch river in Heng-gate, to reduce aggradation and backwater in the junction of Heng-gate's north flow and HongQiLi's flow, to open tide channels in ShanBanZhou's west side, to increase tide dynamic condition in

JiBaoSha's east bank to remove near slow flow and reduce its aggradation. Basic on keeping the ability of accepting tide in tiger bay by increasing tide dynamic, we can keep the tide dynamic condition in LingDing bay.

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