Research on Diversion of Flow Path at Yellow River Estuary to Beicha

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Abstract: It has been 30 years since diversion of Yellow River estuary to Qingshuigou in May 1976, and 10 years since diversion of Qingbacha before flood in 1996. To extend passing river years of Qingshuigou flow path, decrease affects on lower reach and be more beneficial to development of regional economics, analysis and research covers continuing using of Qingba or diversion to Beicha and the conclusion is: diversion to Beicha can shorten distance of the river flowing into the sea, maintain the lower water level in the estuary with the same flow rate in a longer time, and improve safety of flood control at the estuary; it can reduce potential threat of natural bank-breaching and adverse water-sediment conditions to the flow path; it will perform retrogressive erosion on the lower reach; diversion to Beicha will deposit 70 km^2 additionally and increase safety factor of Eastern Gudong Border Dike with rising of deposit of bottomland.

Key Words: Yellow River estuary, flow path into the sea, Qingbacha, Beicha

1 Basic Situation of Qingshuigou Flow Path

In May 1976, Xihekou cross-section at Yellow River estuary Yellow River diverts to Qingshuigou from Diaokou River to enter the sea, and initial length of Qingshuigou was 37km shorter than that prior to diversion. Before flood season of 1996, to achieve manual land reclamation and oil extraction, diversion to Qingbacha was carried out at 950m before Qingba cross-section and length down Xihekou was shortened to 49km from 65km, and at present Yellow River flows through Qingbacha. It has been 30years since 1976 and 10 years since diversion of Qingba, and length down Xihekou is nearly 60km.

In June 1986, to fill the sea to reclaim land and extract oil, Shengli Oilfield dug a bypass channel in the northeast (90^0 between it and the existing river course) on left bank at 500 down Qingqi cross-section, which is about one hundred meters in width and 5km in length, 9km shorter than the former river course. The slope of the bypass channel is 1/2200 and discharges water in ice flood period at the end of the year, but it can only split less than 10% of the flow. In February 1988, actually measured flow carrying by Beicha was 94% of the big river flow and in June Beicha was blocked up until now.

At present, Beicha is 110m in width, and 7km in length. River bed of the upper reach is low, with difference between the flood-plain and the river bed of about 0.8-1.0m, and flow area of the main channel under bank full discharge is about 150m^2; channel of the lower reach is wide and shallow, saucer-shaped, with difference between the flood-plain and the river bed decreasing along the river, only 0.3m in lower reach. In high tide, two bigger san hills can still be seen and the river is divided into three strands, with the middle one 1.2m in depth and 0.4m in low tide. Due to bed-making of the two diversions, vertical section of the river bed is out of level and river course of the several kilometers above the opening area has back slope. Sketch of Qingshuigou Beicha and Qingbacha is shown in Figure 1.

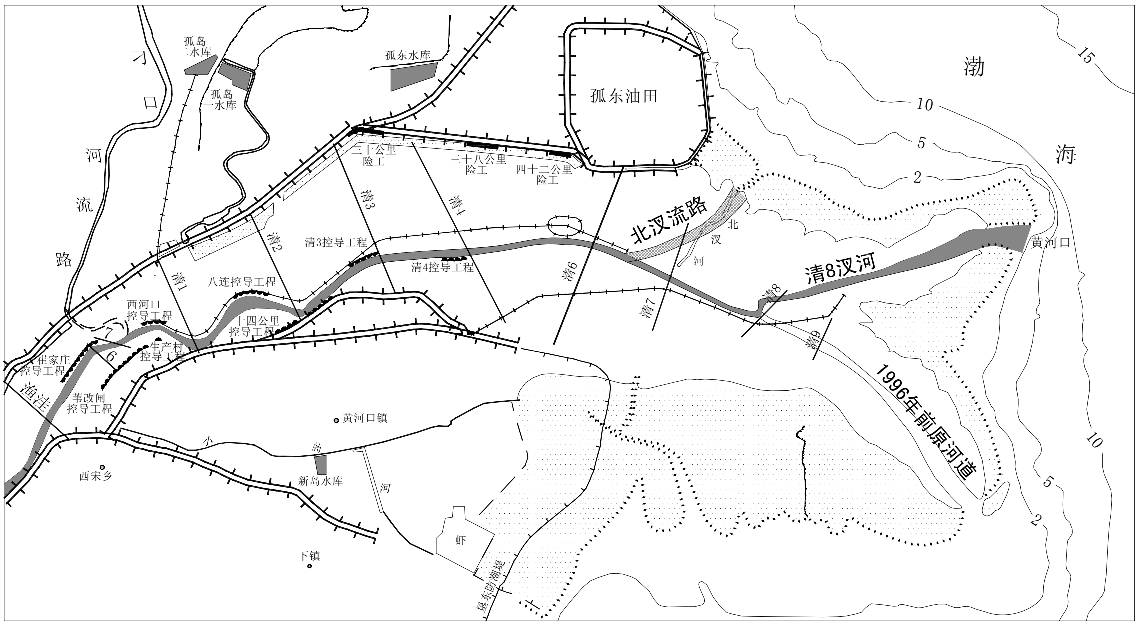

Figure 1 Sketch of Flow Path and Anabranches of Qingshuigou

2 Research of Diversion to Beicha of Qingshuigou

2.1 Arrangement and Investment Estimate of Diversion to Beicha

Incoming water and sediment and its forecast are in accordance with design water-sediment of *Comprehensive Management Planning of Yellow River Estuary*.

Based on experiences of the previous estuary diversion and Qingshuigou management in the past 30 years, trend of the former Beicha estuary id northeast, 90^0 angle with the existing river course, which forms an abrupt bend, unbeneficial to development of the flow path. The junction is move to the location between Qingqi and Qingliu cross-section, about 2700m away from Qingliu cross-section, 30^0 in the north of the mainstream axle of the former river course. Then the flow will run into the sea smoothly, beneficial to discharge and sediment deposit. The junction is 9km away from 0m line and 41km down Xihekou.

Based on estimate of diversion of Qingbacha project in 1996, the works measures include bypass channel digging and necessary flow diversion and closure works. At that time, the main projects included 5.88km bypass channel, 3.94km closure dam, 700m diversion dam at bypass channel mouth, 5.5km diversion dike on the left bank, and 600m from the former diversion dam to opening area. The work quantity is 1.5million m^3 earth work, with investment of 7.94 million Yuan. Investment in diversion to Beicha is about 20 million Yuan.

2.2 Analysis of Diversion to Beicha

For convenience of comparison and explanation, Qingbacha for passing river is taken as Scheme 1 and diversion to Beicha is taken as Scheme 2. Advantages and disadvantages of diversion to Beicha are as follows:

（1）Shortening River Length and Lowering Water Level

At present, Qingshuigou Qingba Anabranch is about 59km down Xihekou and it will be about 49km after diversion to Beicha, which will reduce the river length by 18km (Figure 2).

Retrogressive erosion will occur to river course above the junction, which will reduce the river bed and water level to some extent. Although the river course grows with siltation and extension of estuary and the retrogressive erosion does not lat long, retrogressive caused by diversion of anabranch will decelerate rising rate of siltation down Xihekou, which will be not unbeneficial to river regime and be beneficial to flood control of estuary and lower reach area.

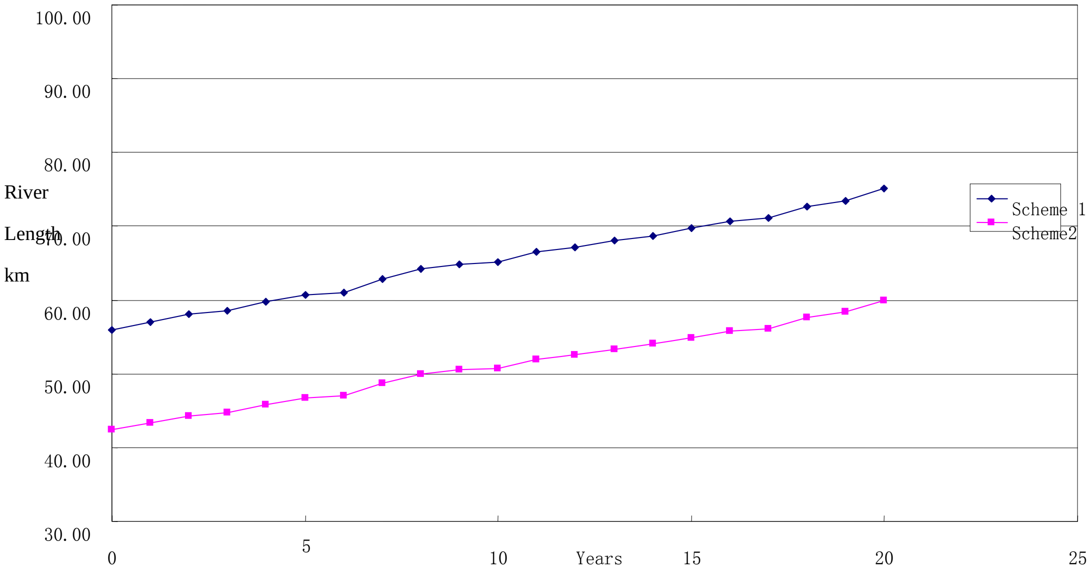

Figure 2 Comparison between River Lengths down Xihekou of the Two Schemes

Shortening of river length of flow path into the sea is also characterized by rising of flow slope into the sea, increase of bank full discharge and distinct decrease of water level with the same flow rate.

Based on the above water-sediment conditions, water level of Qingsan cross-section 3000m^3/s is taken as an example, in Figure 3. It shows that with the same flow rate, Scheme 2 will have a bigger much lower water level than Scheme 1; the average water level in Scheme 2 in the first ten years is about 0.34m lower than Scheme 1, about 0.5m in the 20 years; the highest water level in Scheme 2 in the first ten years is about 0.35m lower than Scheme 1, about 0.79m in the 20 years. The same conclusion is obtained for Xihekou cross-section and Qingliu cross-section.

（2）Safety Promotion of Lower Reach and Estuary Reach

At present, dike at Yellow River estuary is 77.466km, with dike on the left bank 49.731km, of which 26.8km (54% of the total length of dike on the left bank) is lack in height and width of dike on the left bank has not completely reached design standard. Although flood control dike on the left bank has not reached design standard, safety degree of flood control is different due to difference in river length and water level in the two schemes. First, when high water level, right-angled stream and tilted stream take place: because of long river course, probability of high water level, right-angled stream and tilted stream is big, which threatens the dike more greatly. Second, when medium flood carries flow through the whole section: because Weilü River of Yellow River has typical complex section, flow rate on the bottomland is slower than main channel, average section flow rate decreases distinctly, flood peak spreads in a longer period, the flood is close to the dike in a longer period and safety degree of the dike decreases accordingly. Therefore, due to short river course, low water level and big bank full discharge, and lighter threat of water-sediment conditions to dike, safety degree of the dike is higher.

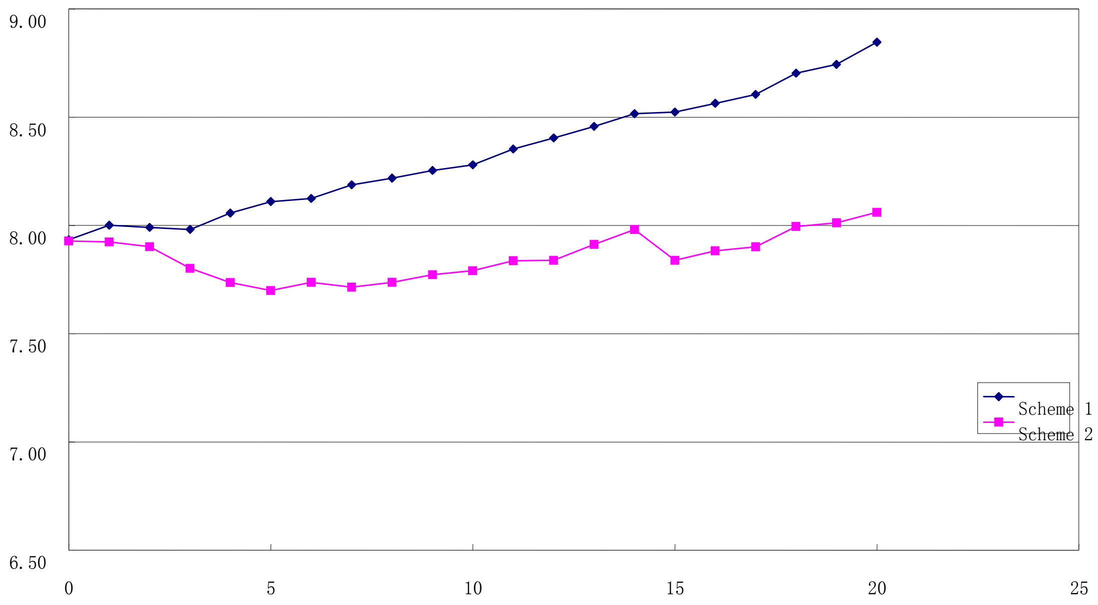

Figure 2 Water Level Variation of Qingsan Cross-section 3000m^3/s

（3）Safety Promotion of Gudong Border Dike

Crude oil yield of Gudong Oilfield is 3～5million ton, with great economic benefits. Its ground level is mostly 0～2m, with 35km border dike around it. The eastern border dike is about 5～6km long the sea, which is threatened by storm tide greatly. When storm tide occurs, this section is often in danger. Shengli Oilfield invests about 60 million to 100 million Yuan of maintenance fee in Gudong Border Dike along the sea (reinforcement fee 20 million Yuan/km) and the total investment is about 600 million Yuan in the past years. After diversion to Beicha flow path, with extension and rising of siltation of bottomland on the left bank of Beicha flow path, the shoreline will be apart from the border dike, which will avoid damage of ocean wave and storm tide to border dike, promote safety degree of the border dike and be beneficial to production and construction of Gudong Oilfield.

（4）Promotion of Land-making Area

Based on the above incoming water and sediment conditions, land-making areas in the years of continuing Qingba Anabranch and diversion of river course are shown in Table 1. diversion to Beicha River will make 70km^2 (105,000mu) more than before, which will increase territory area and also create conditions for petroleum exploration from offshore exploration to ashore exploration. Additionally, with development of shoreline, area of fresh-water wetland at estuary is increased, which makes great economic benefits.

Table 1 Comparison between Land-making Areas of Different River Passing Schemes

Year	Continuing Qingba Anabranch		Diversion to Beicha Anabranch	
	Annual siltaion area km^2	Accumulative siltaion area km^2	Annual siltaion area km^2	Accumulative siltaion area km^2
0				
1	12	12	19	19
2	10	22	16	35
3	5	27	8	43
4	21	47	32	76
5	15	63	25	101
6	8	70	13	114
7	3	74	6	120
8	16	90	28	147
9	7	96	12	159
10	11	107	19	178

（5）Saving of Investment of Flood Control Works

Based on *Feasibility Research of Flood Control Works of Recent Yellow River Estuary Harnessing* approved by Shui Zong Gui [2004]No. 129, total investment estimate of flood control works in recent Yellow River estuary harnessing is 400.9 million Yuan, including height and width increase of the dike 72.2131million Yuan, vulnerable spot rebuilding and reinforcement works 14.027 million Yuan, river improvement 85.7275 million Yuan, river dredging works 141.4843 million Yuan (including siltation protection and bank reinforcement), compensation for works occupation and resettlement 59.516 million Yuan, environmental protection fee 5.93 million Yuan, investment increase of water and soil conservation 1.9776 million Yuan, investment in estuary basic work and scientific tests 11.1054 million Yuan, flood control nonconstructional measures 7.6482 million Yuan and work management and construction 1.2709 million Yuan.

Ddiversion to Beicha Anabranch can lower water level greatly; dike and vulnerable spot works will not be necessary recently; shortening of river length will cause retrogressive erosion in reaches above the junction and river digging will not be necessary; compensation for works occupation and resettlement will be unnecessary. All those will decrease the fee by 250 million Yuan. Diversion to Beicha will only need investment of 20 million Yuan, so more than 200 million Yuan will be saved.

In conclusion, compared with continuing passing Qingbacha, diversion to Beicha can shorten distance of the river flowing into the sea, maintain the lower water level in the estuary with the same flow rate in a longer time, and improve safety of flood control at the estuary; it can reduce water level, make opening area smooth, and reduce potential threat of natural bank-breaching and adverse water-sediment conditions to the flow path; Beicha passing river maintain lower water level recently, which will perform retrogressive erosion on the lower reach; diversion to Beicha will deposit 70 km^2 additionally and increase safety factor of Eastern Gudong Border Dike with rising of deposit of bottomland. All those will be beneficial to development and construction of the delta and Shengli Oilfield and regional economic development and national economic construction.

黄河入海流路改走北汊研究

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摘　要：黄河河口从 1976 年 5 月改走清水沟以来已行河 30 年，距 1996 年汛前改清 8 汊也亦 10 年，为延长清水沟流路的行河年限，降低对下游河道反馈影响，更有利于地区经济发展，本文针对目前继续走清 8 或改北汊河进行分析研究，认为：改走北汊可缩短河道入海距离，较长时间地保持河口段同流量下的较低水位，提高河口地区防洪安全程度高；减少了自然决溢以及不利水沙条件对流路的潜在威胁；将对下游产生一定的溯源冲刷；改走北汊可多淤出 $70km^2$土地，并随着滩地淤积抬升，孤东东围堤安全系数增大。

关键词：黄河河口　入海流路　清 8 汊　北汊

1　清水沟流路基本情况

1976 年 5 月黄河河口西河口断面由刁口河入海改道清水沟入海，清水沟初始河长比改道前缩短 37km。1996 年汛前，为达到人工造陆采油之目的，在清 8 断面以上 950m 年实施清 8 改汊，由原来的西河口以下河长 65km 缩短至 49km，缩短河长 16km,目前仍走清 8 汊河。从 1976 年至今已行河 30 年，改清 8 汊河已过 10 年，西河口以下河长已近 60km。

1986 年 6 月胜利油田为淤海造陆采油，在清 7 断面左岸以下约 500m处，沿东北方向（与现河道夹角约为 90^0）开挖一条宽约百米的引河，长 5km，比当时原河道短 9km，引河比降 1/2200，于年底凌汛期放水，但分流不足 10%，1988 年 2 月，实测北汊过流已占大河流量的 94%，6 月将北汊河堵复至今。

目前北汊河宽约 110m，河道长约 7km。上游河段床面较低，滩槽高差约 0.8-1.0m，平滩流量下主槽过水面积约 $150m^2$；下游段槽宽浅，呈浅碟状，滩槽高差沿程减少，至下游段仅为 0.3m。入海口门处，高潮时，仍显露出两处较大的沙岗，河分三股，中股水深 1.2m左右，低潮时 0.4m左右，由于两次分流的造床作用，河床纵剖面起伏不平，口门以上几公里内河道呈倒比降。清水沟北汊及清 8 汊河示意图见图 1。

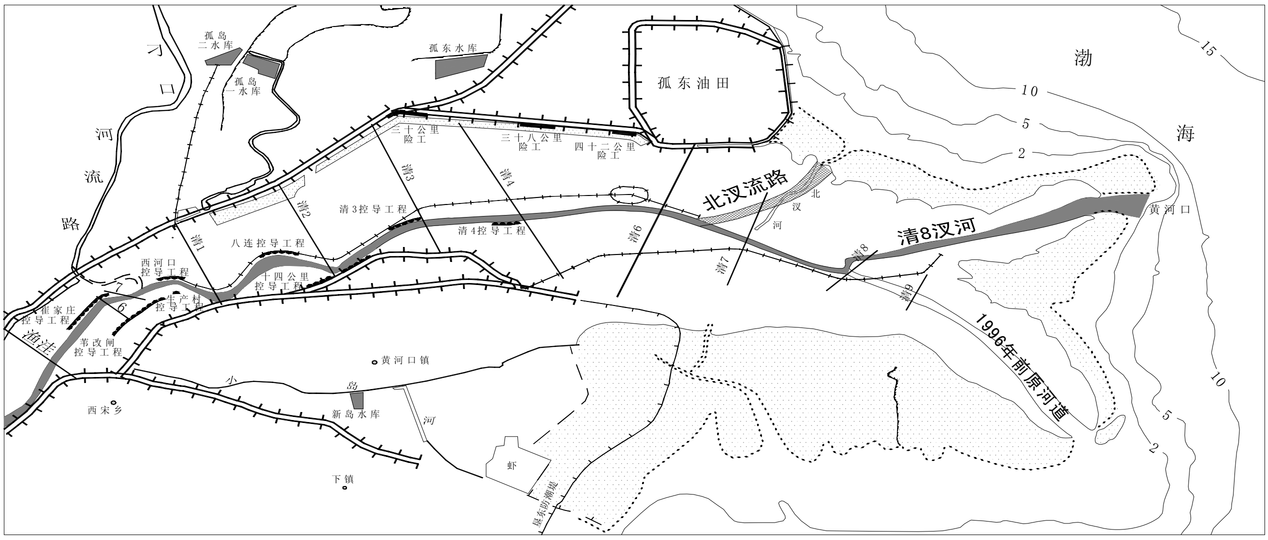

图 1　清水沟流路汊河示意图

2　清水沟改北汊方案研究

2.1 改走北汊工程布置及投资估算

来水来沙及其预测与目前正在工作的《黄河河口综合治理规》的设计水沙系列保持一致。

根据以往河口改道和清水沟近 30 年的河口治理经验，由于原北汊河口走向东北，与现行河道成近 90^0夹角，形成急弯，不利于流路发展，改汊点上移至清 7~清 6 断面之间，距清 6 断面约 2700m，与原河道主流轴线夹角偏北 30 度左右，届时改河水流将较平顺入海，有利于泄流排沙，改道点距 0m线长约 9km，西河口以下长约 41km。

按 1996 年改清 8 汊河工程估计，需要改道的工程措施包括引河开挖、必要的导、截流工程。当时主要项目包括引河 5.88km，截流坝工程长 3.94km，引河口导流坝长 700m，左岸导流堤长 5.5km。原导流堤破至口门 600m。工程量为土方 150 万m^3，投资 794 万元。改走北汊投资按 2000 万元估计。

2.2　改走北汊的分析

为便于比较说明，以目前行河的清 8 汊河作为方案 1，以改走北汊流路作为方案 2。改走北汊的利弊分析如下：

（1）可以缩短河长，降低水位

目前清水沟清 8 汊河西河口以下长约 59km，改走北汊后西河口以下河长约 41km，缩短河长 18km（图 2）。河道长度缩短，改汊点以上的河道将发生溯源冲刷，使一定范围内的河床及水位降低。虽然随着河口淤积延伸，河道又逐步延长，溯源冲刷历时不长，但总的看来，改汊引起的溯源冲刷，对延缓西河口以下河道的淤积抬升速率有一定作用，对河势没有明显的不利影响，对河口及下游地

区防洪是有利的。

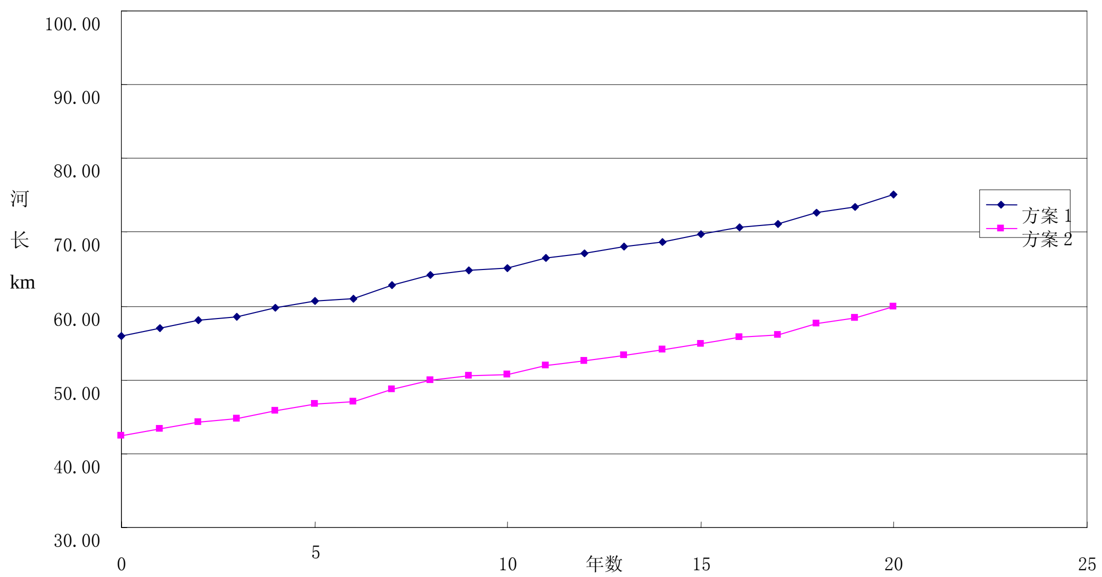

图 2　两方案西河口以下河长对比图

入海流路河长缩短的另一个表现为增加了水流入海比降，平滩流量增大，同流量水位显著降低。

根据以上所述水沙条件，以清 3 断面 3000m^3/s对应的水位为例，见图 3，从图中可以看出，同流量下，方案 2 要比方案 1 水位有较大的下降，平均水位，前 10 年中方案 2 比方案 1 低 0.34m左右，20 年低 0.5m左右。最高水位，前 10 年中方案 2 比方案 1 低 0.35m，20 年中要低 0.79m，西河口断面和清 6 断面也得出同样的结论。

（2）增加下游河段及河口河段的安全程度

目前，黄河河口设防堤防长 77.466km，其中左岸堤防长 49.731km，尚有 26.8km（占左岸堤防总长 54%）高度不足，且左岸堤防宽度全部未达到设计标准。在左岸防洪堤建设未达到设计标准条件下，由于两个方案的河长、水位的差异,其防洪安全程度也是有差别的。一是当高水位及横河、斜河发生时：方案 1 由于近期河道长，出现高水位及横河、斜河几率大，对堤防的威胁较大。二是中常洪水漫滩全断面过流时：由于黄河尾闾河段呈典型的复式断面特征，中常洪水漫滩全断面过流时，滩地流速小于主槽，断面平均流速明显降低，洪峰传播时间也相对延长，洪水偎堤时间也相应增加，堤防安全程度相应降低。从这个角度来讲，改走北汊由于河道短、水位低，平滩流量大，同样水沙条件则对堤防威胁相对较小，堤防安全程度相对较高。

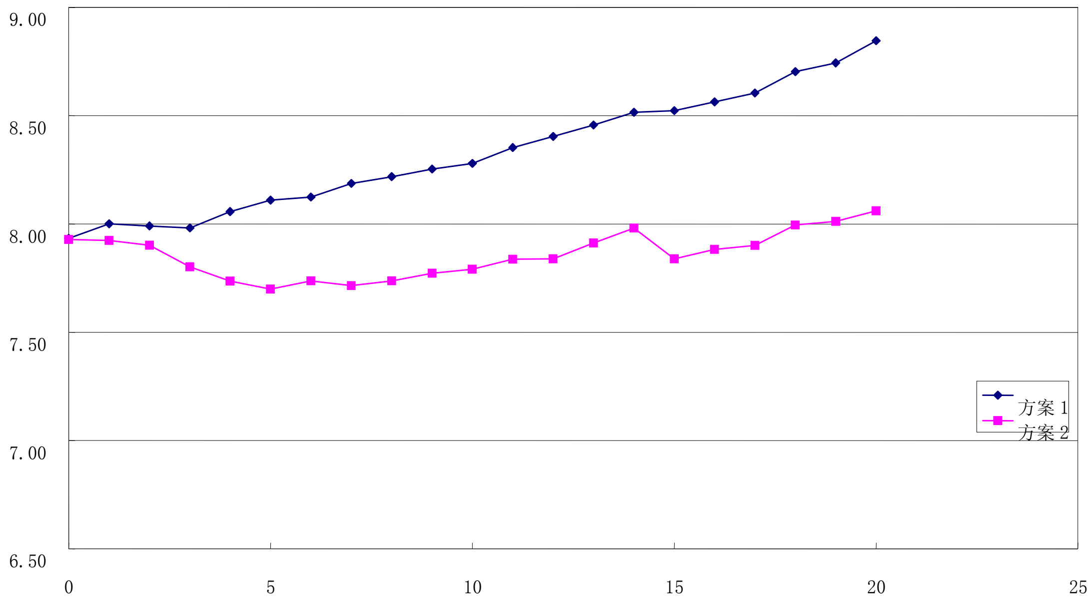

图 3　　清 3 断面 3000㎥/s水位逐年变化过程

（3）增加孤东围堤的安全

孤东油田年产原油 300～500 万 t，经济效益巨大。该油田地面高程多在 0～2m，四周约有 35km 围堤保护。现东围堤临海长度约 5～6km，风暴潮对该段围堤安全威胁极大。风暴潮发生时该段围堤常常出险，胜利油田每年对孤东临海堤投入维护费约为 6000 万元至 1 亿元（加固费用为 2000 万元/km），近年来油田共投资约 6 亿元。改走北汊流路后，随着北汊流路左岸滩地的淤积延伸抬升，能使海岸线渐远离围堤，能避免海浪及风暴潮对围堤的破坏作用，提高了围堤的安全程度，有利于孤东油田生产建设。

（4）增加造陆面积

按照上述来水来沙条件，计算继续走清 8 汊河和改走原河道两方案在 10 年内的造陆面积，见表 1，改走北汊可多造陆 $70km^2$（10.5 万亩），这些陆地在一方面增加了国土面积，另一方面为油田海上开采变陆上开采创造条件，另外，随着海岸线的推进增加了河口地区淡水湿地面积，经济效益巨大。

表 1　　不同行河方案造陆面积比较

	继续走清 8 汊		改北汊	
年份	年淤积面积 km^2	累计淤积面积 km^2	年淤积面积 km^2	累计淤积面积 km^2
0				
1	12	12	19	19
2	10	22	16	35
3	5	27	8	43
4	21	47	32	76
5	15	63	25	101
6	8	70	13	114

7	3	74	6	120
8	16	90	28	147
9	7	96	12	159
10	11	107	19	178

（5）节省防洪工程投资

以水总规[2004]129 号文批复的《黄河河口近期治理防洪工程可行性研究》，黄河河口近期治理期间防洪工程估算总投资为 40090.00 万元，其中堤防加高帮宽工程为 7221.31 万元，险工改建加固工程为 1402.70 万元，河道整治工程为 8572.75 万元，挖河疏浚工程为 14148.43 万元（含淤背固堤），工程占压及移民安置补偿费为 5951.60 万元，环境保护费为 593.0 万元，水土保持措施新增投资为 197.76 万元，河口基础工作及科学试验投资为 1110.54 万元，防洪非工程措施为 764.82 万元，工程管理建设为 127.09 万元。

改走北汊可使水位大幅降低，堤防、险工工程在近期将不再需要，河长缩短将引起改道点以上河段的溯源冲刷，挖河工程也不需要，再加上工程的占压及移民安置补偿费用，至少可减少 2.5 亿元。而改北汊工程只需投资 2000 万元，所以，可节省投资约 2 亿元以上。

总之，立即改走北汊与继续行河清 8 汊河相比，可缩短河道入海距离，较长时间地保持河口段同流量下的较低水位，提高河口地区防洪安全程度高；同时，立即改走北汊，可降低水位，使得入海口门通畅，减少了漫滩机率，减少了自然决溢以及不利水沙条件对流路的潜在威胁；北汊行河在近期保持较低水位，将对下游产生一定的溯源冲刷反馈影响；立即改走北汊可多淤出 70km^2土地，并随着滩地淤积抬升，孤东东围堤安全系数增大。这些都有利于三角洲及胜利油田的开发建设，对促进地区经济发展、促进国家经济建设大有好处。