EXPLORING ON REASONOF TONGGUAN ELEVATION'S INCREASE AND ITS STRATEGY

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ABSTRACT

The main effective factors of heightening and lowering of Tongguan elevation have been analyzed in this paper. It is pointed out that the main reason on heightening of Tongguan elevation in recent years is caused by the condition of reservoir water and sediment, and the harnessing measures of improving Tongguan elevation is put forward.

KEY WORDS Yellow River; Tongguan elevation; incoming water and sediment

1 BASIC CONDITION OF TONGGUAN ELEVATION'S EVOLUTION

Tongguan is located in the outlet with the confluence of Yellow River, Weihe River and Beiluohe River, 11.3km of Sanmenxia Dam. The valley of confluence above Tongguan is wide, the widest reach of Xiaobeiganliu (between Longmen and Tongguan) in the Yellow River can be up to 18km, but the valley of Tongguan is narrowed to 1km suddenly, forming a natural constriction. Before constructing Sanmenxia Reservoir and when meeting the major flood, the phenomenon of contracting flow and banked-up water level occurs, the confluence of three rivers above Sanmenxia is an area of natural flood and sediment retention. Because of special geographic position in Tongguan, Tongguan section is a local erosion datum between Xiaobeiganliu of Yellow River and Weihe River, the variation of bed elevation in Tongguan will directly effect the erosion and deposition of sediment, flood control and water-logging elimination in lower reaches of Xiaobeiganliu and Weihe-Luohe River, therefore they are paid close attention to by all circles from time immemorial. In order to reflect the characteristics of erosion and deposition in Tongguan section, Tongguan elevation is shown by the water level with discharge of 1000m^3/s in Tongguan section (6).

Before constructing Sanmenxia Reservoir, Tongguan Hydrologic Station began to observe from 1929, among which some year stopped observing, there were 19 years' observation data up to 1959. It is seen from the results of average water level difference for 19 years[1] that the water level raises 0.35m every year in non-flood season, the water level lowers 0.28m every year in flood season, with regard to the whole year, the raising tendency prevails in Tongguan elevation, its average annual elevation raises 0.07m.

After operating Sanmenxia Reservoir, during the operation of water storage, Tongguan elevation was deposited and raised by a big margin due to the influence of backwater. It was up to 328.70 m of maximum value in June, 1969, raising 5.30m more than one before constructing the reservoir; with the double reconstructions of Sanmenxia Project and its changes in operation mode, Tongguan elevation lowered gradually in 1970, it lowered 326.64m after flood in 1973; since the reservoir adopted "storing clear water and discharging muddy water" in 1974, the reservoir's section below Tongguan was deposited during the storing water of non-flood season and scoured for discharging sediment during the lowering water level of flood season, Tongguan elevation raised and lowered with them, prevailing in periodically changes[2].

After the flood in 1973 to 1985, though there was a fluctuation of heightening or lowering of Tongguan elevation yearly, the reservoir kept the equilibrium of erosion and deposition basically from 326.64m in 1973 to 326.64m in 1985. Since the operation of Longyangxia Reservoir in October, 1986, making the incoming water in a year during flood season and non-flood season taking place large changes, also adding the influence on water utilization.

2 REASON OF TONGGUAN ELEVATION WITH HIGH WATER LEVEL

2.1 Influence of variation on reservoir water-sediment condition

Since the operation of "storing clear water and discharging muddy water" in Sanmenxia Reservoir, the reservoir water-sediment condition can be divided into two time intervals, i.e. from November, 1973 to October, 1985 and from November, 1985 to October, 1996. The first, Tongguan elevation in flood season lowered 0.48m averagely, Tongguan elevation was up to equilibrium of erosion and deposition basically in the operation for 12 years, the average annual water volume and amounts of incoming sediment is close to the mean value for years, but the water volume in flood season is more than the mean value for years; the second, Tongguan elevation in flood season lowered only 0.19m averagely, with 60% of lowering margin less than the first , and Tongguan elevation raised 1.53m during this period also, the main reason of this phenomenon caused is that the water volume in flood season of the second reduced 9.2 billion m^3 than that of the first, especially the peak water volume of the second reduced 2/3 nearly than that of the first, the flood duration lessened 50% (Table 1). It can be shown that Tongguan elevation can scour to lower or realize the equilibrium of erosion and deposition under the beneficial condition of water and sediment; under the unfavorable condition of water and sediment, Tongguan elevation deposited and raised, it raised if meeting the year with low water continuously.

Table 1 Relationship of Tongguan elevation's raising and lowering to

flood duration and water-sediment amounts in flood season

item / interval	flood season		whole year		flood period			raising and lowering value of Tongguan elevation(m)
	water volume (10^9m^3)	sediment amounts (10^9t)	water volume (10^9m^3)	sediment amounts (10^9t)	water volume (10^9m^3)	sediment amounts (10^9t)	duration (d)	
1974~1985	236	8.4	401	10.5	155	7.0	58	–0.52
1986~1995	132	6.5	287	7.6	52	4.4	29	–0.19

1974~1995	189	7.6	349	9.4	108	5.8	46	–0.37

2.2 Effect of reservoir operation on Tongguan elevation

Sanmenxia Reservoir took the task of ice control, irrigation in spring and generation etc in non-flood season, Tongguan elevation during the storing water raised. When water level before dam was 315m, Dayudu section began to be effected on backwater. When water level was 320m, Guduo section began to be effected on backwater. After the section was affected on backwater before dam, the water depth near the section increased, the velocity reduced slowly, the sediment-laden of flow lowered and the sediment deposited, resulting in river bed raised. After water level before dam was over 323m, the reservoir sediment was mainly deposited between Tongguan and Guduo, resulting in Tongguan elevation raised. It can be seen from table 2 that the margin of raising and lowering of Tongguan elevation was in direct proportion to the days of water level before dam over 323m. If water level in the reservoir was not over 323m, Tongguan elevation was scoured and lowered during spring flood period.

Table 2 Days with water level over 323m and raising-lowering values of Tongguan elevation during the operation in non-flood season

interval (year. month)	water level before dam >days of 323m(d)	raising-lowering values of Tongguan elevation(m
1973.11~1979.10	51	0.75
1979.11~1985.10	40	0.35
1985.11~1992.10	28	0.37
1992.11~1995.10	0	0.29

Since Sanmenxia Reservoir was controlled and operated by storing clear water and discharging muddy water, because of reservoir operation with lower water level in flood season, Tongguan reach still kept natural channel pattern. Although Tongguan elevation was effected on the conditions of incoming water and sediment, sometimes scouring, sometimes depositing, the total tendency was scoured and lowered.

2.3 Analysis on development tendency of Tongguan elevation in present years

For 10 years, Tongguan was with low water continuously in flood season, the mean reservoir water volume was 13.2 billion m^3, 30% of mean value was less than that from 1974 to 1985. The water volume in flood season was 6.13 billion m^3 only in 1991, with 71% of lower water. In order to suit for the variation of incoming water and sediment condition, the erosion and deposition in reservoir region were regulated automatically (shown in Fig.1). It can be seen from Fig.1 that various incoming water volume and slope of Tongguan-Beichun reaches in flood season is good with on a curve. According to data analysis, the distance of retrogressive erosion in reservoir is near Dayudu commonly under the condition of operation with low water level in flood season. It can be known from them that the effect of reservoir operation on erosion-deposition of river bed above Dayudu was gradually weakened, but effect of incoming water-sediment condition on erosion-deposition of river bed was gradually strengthened. The erosion-deposition variation of river bed was mainly effected on incoming water-sediment condition, i.e. the development tendency of Tongguan elevation for 10 years was closely related to rapid reduction of incoming water in flood season.

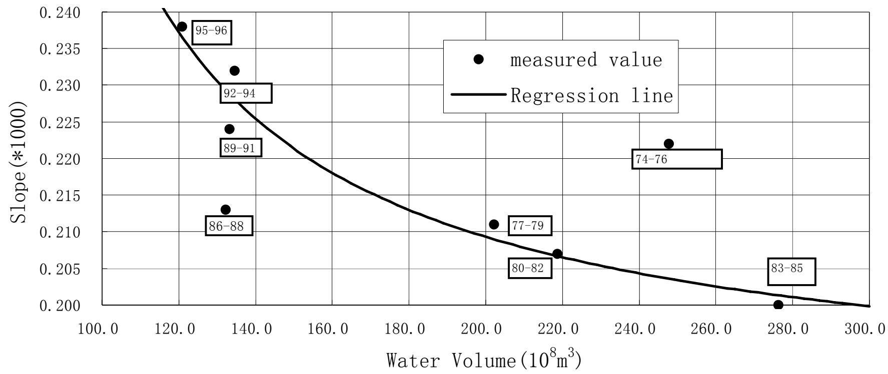

Fig.1 Relationship of slope after flood to water volume in flood season

between Tongguan and Beichun

3 EFFECT OF RIVER BED REGULATION ON TONGGUAN ELEVATION

Because the reservoir is built in rivers, reservoir deposition is automatically regulated, which makes water and sediment from the upper reaches crossing throughout to reach new balance. When the condition of incoming water and sediment takes place the variation, the channel's pattern in the reservoir region is also changing, the river bed is the same as alluvial river, the variation suited for incoming water and sediment condition is automatically regulated, the auto-regulated speed of river bed is faster on the rivers with heavy sediment load.

3.1 Variation of river length in the process of bed regulation

Table 3 is that the variation of river length is caused by various operation mode of reservoir and variation of incoming water-sediment condition during the process of bed auto-regulation after the founding of Sanmenxia Reservoir. It can be seen from Table 3 that the characteristics of river length's variation are: the measured results in 1971 reflects river bed auto-regulation caused by various operation mode in Sanmenxia Reservoir and reconstruction of outlet structure of the project etc, which forms river length with high floodplain and deep channel, the variation of incoming water-sediment condition is not large, comparing with the measured results in 1960, the distance of Tongguan from dam increases 12.4km; the measured results in 1993 reflects the improvement of reservoir operation, which makes Beichun's water level lower and incoming water volume in flood season reduce by a big margin, the distance of Tongguan from dam is 16.8km more than that in 1971, amounting for 13.4% of original river length, among them, the river length beween Tongguan-Guduo and Dayudu-Lingbao increases 1.3km and 13.5km respectively, accounting for 7.7% and 80.4% of increase in Tongguan from dam respectively, the river length of the rest two reaches increases unlargely.

Table 3 Variation of typical sections at a distance from dam

section number	center line with 340m elevation (km)		center line of main channel (km)					
	1960		1971		1984		1993	
	distance from dam	distance	distance from dam	distance	distance from dam	distance	distance from dam	distance
Beichun (2)	43.4		46.2		45.6		48.3	
Huangyu 27	55.2	11.8	62.0	15.8	60.6	15.0	63.5	15.2
Dayudu	68.4	13.2	76.1	14.1	81.4	20.8	91.1	27.6
Guduo	94.0	25.6	105.0	28.9	110.3	28.9	121.1	30.0
Tongguan (6)	113.2	19.2	125.6	20.6	129.0	18.7	142.4	21.3

3.2 Slope variation in the process of bed regulation

The slope is a very active factor in the process of bed regulation, the slope variation of various duration and reaches between Tongguan and Beichun is listed in Table 4, in which the interval division is same as Table 1. At the same time, the slope of various reaches before the flood season in 1960 and during the flood season (at the end of flood season in 1973) after reconstruction is listed, in order to make a comparison.

Table 4 Variation of water level difference, reach length and slope in various reaches

interval	Beichun's water level with 1000m^3/s (m)	Tongguan to Guduo			Guduo to Dayudu			Dayudu to Beichun		
		water level difference (m)	reach length (km)	slope (‰o)	water level difference (m)	reach length (km)	slope (‰o)	water level difference (m)	reach length (km)	slope (‰o)
before flood season in 1960	301.85	5.10	20.6	2.48	6.82	28.9	2.36	9.75	29.9	3.26
at the										

end of flood season in 1973	306.96	5.78	20.6	2.81	7.25	28.9	2.51	6.62	29.9	2.21
at the end of flood season in 1985	310.08	3.93	18.7	2.10	5.78	28.9	2.00	6.72	35.7	1.88
1994~1999	308.56	4.17	21.3	1.96	6.48	30.0	2.16	8.84	42.9	2.06

It can be seen that the slope at the end of flood season in 1973 was one during the reservoir region’s scouring, the difference of water level and slope of various reaches above Dayudu was larger than the slope before flood season in 1960, besides the difference of water level and slope between Dayudu and Beichun less than the slope before flood season in 1960. The reason may be that the retrogressive erosion was still developing continuously upwards without reaching relative balance. After the reservoir was operated “storing clear water and discharging muddy water” in 1973, up to 1985 Tongguan elevation came back to the elevation in the initial period of reconstruction, i.e. 326.51m. The water level in Beichun maintained 310m or so during long term, it can be said that the relative balance in reservoir region was reached basically under this condition of water and sediment. After 1986, incoming water in Tongguan reduce by a big margin during flood season, the reach length of various reaches increases with different extent. The difference of water level and slope of two reaches below Guduo enlarge than before, this is accord to the characteristics of common alluvial rivers with the variation of water-sediment and auto-regulation. The characteristics of river bend’s plane pattern (bend radius, river bend span and range) are in the direct ratio to the discharge, the slope is in the inverse ratio to the discharge; but the difference of water level between Tongguan and Guduo increases as well, the slope doesn’t increase obviously due to the increase of reach length, the reason is that whether this reach is still in the process of regulation or Tongguan reach has been dredged. If the former, Tongguan elevation is possible to heighten continuously; the latter, now there is no such a big argument of research results about dredging if Tongguan elevation is stable in the present condition. As to the saying “ the channel is changed into the wide and shallow wandering, the river bed is smooth to be deposited”, it can not see from the measured data, which needs to be researched further; but it is seen from slope hydrograph that the slope between Tongguan and Guduo is still increasing, in general, it needs to be checked by practice further.

4 EXPLORING ON IMPROVEMENT MEASURES OF TONGGUAN ELEVATION

4.1 Improving river bend between Dayudu and Lingbao, shortening reach length and improving Tongguan elevation

After 1986, the length between Tongguan and Beichun reaches increases 10.7km, among which the length between Dayudu and Huangyu section 27 increases 6.8km amounting for 63.6%. It is mainly concentrated on bend crest located in two river bends between Huangyu section 29(Dongluwan) and Huangyu section 28. How to improve two river bends, to restrict free development of river bend and shorten reach length are beneficial to improving Tongguan elevation. It is primarily estimated that the length control between Tongguan and Beichun is close to the length in 1984 (this length is 5.9km longer than 1971), i.e. shortening 5~6km. So Tongguan elevation ca lower 0.5~0.7m, at the same time, the collapse of reservoir bank and its river condition downstream can also be improved. It must be pointed out that the reach length is changeable with the variation of water-sediment condition, therefore we can determine the reach length of regulation as long as we carry out scientific research in detail.

4.2 Strengthening research on reservoir operation and bringing the comprehensive effects in Sanmenxia Project into play continuously

The outlet works has been rebuilt over 10 years as well, the reservoir is regulated by the renewal and remake of gate starting equipment, shortening gate starting time and suiting to the variation of incoming water and sediment, there is an obvious effect on discharging sediment with reservoir, the generation experiments with muddy water and in flood season have been carried out simultaneously. Through the generation experiment with muddy water, the research on protective materials of turbine has made a great progress. Through the generation experiment in flood season, the operating mode “discharging sediment with flood, generating with mean water” is pointed out, which plays an obvious role in raising sediment discharge capacity of reservoir, improving erosion-deposition and its distribution in reservoir region, prolonging generation time and increasing generation benefits etc.

During flood season in this year, 11# and 12# bottom holes can also be into operation, according to existent outflow curve, it can be looked up that the water level lowers 1.5~2.0m with discharge of 3000m^3/s, there should be a lowering effect on Tongguan elevation. At present, how to fully utilize these two bottom holes after operation makes erosion datum formed by reservoir lower 1.5~2.0m in favorable condition to improve maximum effect of Tongguan elevation, this is an important problem to be researched as well.

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潼关高程升高原因及对策的探讨

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1 潼关高程演变基本情况

潼关位于黄河、渭河和北洛河三河汇流区的出口，距三门峡大坝 113.2km。潼关以上汇流区河谷宽阔，黄河小北干流河段（龙门至潼关河段）最宽可达 18km，而潼关处的河谷突然缩窄到 1km，形成天然卡口。在三门峡水库兴建前，遇到较大洪水时，有卡水壅高水位的现象，潼关以上三河汇流区是天然的滞洪滞沙区。由于潼关的特殊地理位置，潼关断面是黄河小北干流和渭河的局部侵蚀基准面，潼关河床高程的变化，将直接影响到小北干流和渭、洛河下游河道泥沙冲淤、防洪及除涝，因此历来为各方所关注。为了反映潼关断面的冲淤特性，潼关高程用潼关(六)断面 1000m^3/s流量时的水位表示。

三门峡水库建成以前，潼关水文站自 1929 年开始观测，期间有些年份停测，到 1959 年为止共有 19 年观测资料。从 19 年水位差的平均结果看[1]，非汛期每年上升 0.35m，汛期每年下降 0.28m，就全年来说，潼关高程呈上升趋势，年平均抬升 0.07m。

三门峡水库投入运用以后，在蓄水运用期，由于回水影响，潼关高程（流量为 1000m^3/s时的水位，下同）大幅度淤积抬高，1969 年 6 月达到最高值 328.70m，比建库前抬高 5.30m左右；随着三门峡枢纽工程的两次改建和运用方式的变更，1970 年潼关高程逐渐下降，1973 年汛后降至 326.64m；1974 年水库采用“蓄清排浑”运用以来，潼关以下库段非汛期蓄水淤积，汛期降低水位冲刷排沙，潼关高程也随之升高和下降，呈现周期性变化[2]。

1973 年汛后到 1985 年期间，潼关高程虽然在年际间有上升或下降的波动，但从 1973 年的 326.64m 到 1985 年的 326.64m，水库基本冲淤平衡。1986 年 10 月龙羊峡水库投入运用以来，使汛期和非汛期年内来水比例发生较大变化，再加上上游工农业用水增加的影响，因此除 1989 年天然来水较丰外，截止到 1995 年已连续 9 年汛期枯水枯沙。在此期间潼关高程累计上升 1.51m，到 1996 年汛后潼关高程达到 328.08m。

2 潼关高程居高不下的原因

2.1 入库水沙条件变化的影响

自三门峡水库“蓄清排浑”运用以来，入库水沙条件大致可以分为两个时段，即 1973 年 11 月至 1985 年 10 月和 1985 年 11 月至 1996 年 10 月。第一个时段汛期潼关高程平均下降 0.48m，在这 12 个运用年内潼关高程基本上达到冲淤平衡，年平均水量和来沙量与多年平均值比较接近，而汛期水量则比多年平均值偏多；第二个时段汛期潼关高程平均仅下降 0.19m，比第一个时段下降幅度偏少 60%，并且潼关高程在此期间还抬升了 1.53m，造成这一现象的主要原因是由于第二时段汛期水量比第一时段减少了 92 亿m^3，特别是第二时段洪峰水量比第一个时段减少了近三分之二，洪水历时减少了 50%(见表 1)。由此可以表明，在有利的水沙条件下，潼关高程可以冲刷下降或实现冲淤平衡；不利的水沙条件时，潼关高程淤积上升，若遇到连续枯水年则连续累计抬高。

2.2　水库运用对潼关高程的影响

三门峡水库在非汛期承担防凌、春灌、发电等任务，在蓄水期潼关高程是上升的，当坝前水位在 315m 时，大禹渡开始受到回水影响，水位在 320m 时，古夺开始受回水影响。断面受坝前回水影响之后，断面附近的水深增加，流速减缓，水流挟沙力降低，泥沙落淤，由此引起河床抬高。当坝前水位超过 323m 以后，进库泥沙主要淤积在潼关-古夺河段，引起潼关高程的上升。由表 2 可以看出，潼关高程升降幅度与坝前水位超过 323m 的天数成正比；若库水位不超过 323m 时，潼关高程在桃汛期间冲刷下降。

表 1　汛期潼关高程升降与洪水历时、水沙量关系

项目 时段	汛期		全年		洪水期			潼关高程升降值(m)
	水量(亿m³)	沙量(亿 t)	水量(亿m³)	沙量(亿 t)	水量(亿m³)	沙量(亿 t)	历时(天)	
1974～1985	236	8.4	401	10.5	155	7.0	58	-0.52
1986～1995	132	6.5	287	7.6	52	4.4	29	-0.19
1974～1995	189	7.6	349	9.4	108	5.8	46	-0.37

表 2 非汛期运用超过 323m 天数与潼关高程升降值

时段(年.月)	坝前水位>323m 天数(d)	潼关高程升降值（m）
1973.11～1979.10	51	0.70
1979.11～1985.10	40	0.35
1985.11～1992.10	28	0.37
1992.11～1995.10	0	0.29

三门峡水库蓄清排浑控制运用以来，由于汛期水库运用水位较低，潼关河段一直保持自然河道状态，潼关高程虽受来水来沙条件的影响时冲时淤，但总的趋势是冲刷下降。

2.3　潼关高程近年发展趋势分析

近十年来汛期连续枯水，平均入库水量 132 亿m³，比 1974 年～1985 年均值减少 30%，1991 年汛期水量只有 61.3 亿m³，偏枯 71%。为了适应来水来沙条件的变化，库区冲淤进行自动调整(见图 1)。由图 1 中可以看出，汛期不同来水量与潼关-北村河段比降很好地落在一条曲线上。根据资料分析表明，在汛期低水位运用的情况下，水库朔源冲刷的距离一般在大禹渡附近，由此可知，水库运用对大禹渡以上河床冲淤的影响逐渐减弱，而来水来沙条件对河床冲淤的作用逐渐加强，大禹渡以上河床冲淤变化主要受来水来沙条件的影响，也就是说近十年来潼关高程发展趋势与汛期来水量急剧减少有密切关系。

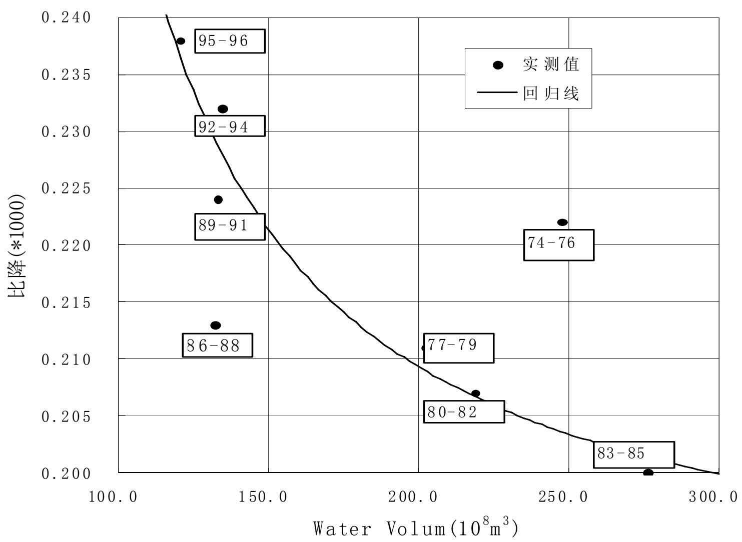

图 1　潼关至北村汛后比降与汛期水量的关系

3　河床调整对潼关高程的影响

在河流上修建水库，水库淤积自动调整，使上游来的水、沙全部通过水库，达到新的平衡。当来水来沙条件发生变化，库区河道平面形态也在演变，河床与冲积河流一样，适应来水来沙条件的变化进行自动调整，河床自动调整的速度在多沙河流上是比较快的。

3.1　河床调整过程中河长的变化

表 3 为三门峡水库建成后，水库不同运用方式和来水来沙条件变化等因素引起河床自动调整过程中河道长度的变化情况。

表 3　典型断面距坝里程的变化情况

断面号	340m 高程中心线(km)		主河槽中心线(km)					
	1960 年		1971 年		1984 年		1993 年	
	距坝里程	间距	距坝里程	间距	距坝里程	间距	距坝里程	间距
北村(二)	43.4		46.2		45.6		48.3	
黄淤 27	55.2	11.8	62.0	15.8	60.6	15.0	63.5	15.2
大禹渡	68.4	13.2	76.1	14.1	81.4	20.8	91.1	27.6
古夺	94.0	25.6	105.0	28.9	110.3	28.9	121.1	30.0
潼关(六)	113.2	19.2	125.6	20.6	129.0	18.7	142.4	21.3

由表 3 可以看出河长变化的特点：1971 年的测量成果反映了三门峡水库不同运用方式和枢纽泄水建筑物改建等引起的河床自动调整，形成高滩深槽时的河长，来水来沙条件变化不大，与 1960 年测量成果对比，潼关距坝里程增长 12.4km；1984 年的测量成果，反映水库蓄清排浑运用后河床调整引起河长的变化；1993 年的测量成果，反映水库运用改善，使北村水位下降，汛期来水量大幅度减少，潼关距坝里程比 1971 年增加 16.8km，占原来河长的 13.4%，其中潼关至古夺和大禹渡至灵宝河段的河长分别增加 1.3 和 13.5km，分别占潼关距大坝里程增加量的 7.7%和 80.4%,其余两个河段的河长增加不多。

3.2　河床调整过程中的比降变化

比降是河床调整过程中的一个非常活跃的因素，现将潼关至北村之间不同河段不同时段的比降变化列于表 4，表中时段划分与表 1 相同。同时列出 1960 年汛前和改建后汛期畅泄时(1973 年汛末)各河段的比降，便于进行比较。

表 4　各河段的水位差、河长、比降变化

时段	北村	潼关～古夺			古夺～大禹渡			大禹渡～北村		
	$1000m^3/s$	水位差	河长	比降	水位差	河长	比降	水位差	河长	比降
	水位(m)	(m)	(km)	(‰0)	(m)	(km)	(‰0)	(m)	(km)	(‰0)
1960 年汛前	301.85	5.10	20.6	2.48	6.82	28.9	2.36	9.75	29.9	3.26
1973 年汛末	306.96	5.78	20.6	2.81	7.25	28.9	2.51	6.62	29.9	2.21
1985 年汛末	310.08	3.93	18.7	2.10	5.78	28.9	2.00	6.72	35.7	1.88
1994～99	308.56	4.17	21.3	1.96	6.48	30.0	2.16	8.84	42.9	2.06

可以看出：1973 年汛末的比降为库区冲刷时的比降，除大禹渡至北村河段的水位差和

比降小于1960年汛前的比降外，大禹渡以上各河段的水位差和比降均大于1960年汛前的比降，原因可能是溯源冲刷仍继续向上发展，没有达到相对平衡。1973 年水库蓄清排浑运用后，至1985年潼关高程回落到改建初期的水平，即326.51m，北村水位长期维持在310m左右，可以说库区在这种水沙条件下，基本达到相对平衡。1986 年以后，潼关汛期来水量大幅度减少，各河段的河长均有不同程度的增加，古夺以下二个河段的水位差和比降较前均有增大，这是符合一般冲积河流随着水、沙变化而自动调整特点的，河弯平面形态特征(弯曲半径，河弯跨度和幅度等)与流量成正比，比降与流量成反比；但是，潼关至古夺河段的水位差也增加了，由于河长的增加，比降还没有发生明显的增加，其原因是否是该河段仍正在调整过程中或者是潼关河段清淤的作用[3]，如果是前者，潼关高程还可能要持续升高；如果是后者，欲使潼关高程稳定在目前的状态，现在清淤研究成果尚未有这样大的论据；至于“河道向宽浅游荡演变，河床坦化淤积”之说，从实测资料还看不出来，有待进一步研究；不过从比降过程线来看，潼关至古夺的比降还处在上升的趋势，总之，还有待实践进一步检验。

3.3　改善潼关高程措施的探讨

改善大禹渡至灵宝河段的河弯，缩短河长，改善潼关高程 1986 年以后，潼关至北村河段的河长增加 10.7km，其中大禹渡至黄淤 27 断面河段的河长增加 6.8km，占 63.6%，主要集中在弯顶位于黄淤 29 断面(东垆湾)和黄淤 28 断面上的两个河弯，这样如何改善这两个河弯，限制河弯自由发展，缩短河长，对改善潼关高程是有益的，初步估算，潼关至北村河段的河长控制接近 1984 年的河长(这个河长已经较 1971 年增长 5.9km)，即缩短 5～6km，则潼关高程可下降 0.5～0.7m，同时还可以改善库岸坍塌和其下游的河势。必须指出：河长是随水沙条件变化而变的，因此，只有进行详细的科学研究，才能较好地确定整治河道的河长。

3.4　加强水库运用的研究，继续发挥三门峡枢纽的综合效益

近十几年泄流工程又进行了改建，闸门起闭设备的更新和改造，缩短闸门起闭时间，适应来水来沙的变化进行水库调整，对水库排沙具有显著效果；同时进行了浑水发电试验和汛期发电试验。通过浑水发电试验，对水轮机的防护材料的研究，取得了很大进展；通过汛期发电试验，提出“洪水排沙，平水发电”的运用方式，在提高水库排沙能力、改善库区冲淤与分布、延长发电时间、增加发电效益等方面取得了明显的作用。

今年汛期 11 和 12 号底孔又可以投入运用，根据现有的泄流曲线查出，流量 $3000m^3/s$ 时的水位下降 1.5～2.0m，应该对潼关高程具有降低作用，当前如何充分利用这二个底孔投入运用后，使水库形成的侵蚀基准面下降 1.5～2.0m的有利条件，达到改善潼关高程的最大效果，这也是应该研究的重要课题。

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