Proceedings of Republic of China - South Africa Bilateral Symposium on Water Resources, Taipei, Taiwan, R.O.C., 1994

A Study on Modification of River Pollution Index (RPI)

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ABSTRACT :

The purpose of this study is trying to modify the current River Water Quality Index (RPI). The current RPI uses step change function to show the four categories of river pollution status. Since the implementation of the amended Water Pollution Control Act in 1974, the organic pollutant loading reduction rate of Taiwan's 21 major rivers reached 47% in 1993. However, the current RPI is not able to show the improvement. The reasons for the incompetence are: (1) Step change function is a single constant method, and the single constant value is not able to adequately present the true variations of pollution status. (2) The improvement of the river quality is not by steps. The study will evaluate the insensitivity of the current RPI and make recommendations for modification.

INTRODUCTION:

The current River Water Quality Index used to evaluate river water pollution status in Taiwan area is dividing the pollution status of river segments into four categories. As shown in table 1, the four categories are named "unpolluted", "polluted", "moderately polluted", and "heavily polluted". Four parameters (DO, BOD5, SS, NH3-N) are used to appraise the pollution status. Take DO as an example, DO concentration over 6.5 mg/l will get one (1) point, between 4.6 mg/l and 6.5 mg/l will get three (3) points, between 2.0 mg/l and 4.5 mg/l will get six (6) points and less than 2.0 mg/l will get 10 points. Average of the total points of the four parameters will determine the status of the river segment. The average less than 2.0 is in the category of "unpolluted", between 2.0 and 3.0 is "slightly polluted", between 3.1 and 6.0 is "moderately polluted" and over 6.0 is "heavily polluted" .

Summaries of representing river segment lengths of each water quality monitoring station of Taiwan's major rivers are provided in Table 2.

The amended Water Pollution Control Act have been implementing since 1974, and the organic pollutant loading removal rate of wastewater reached 47% in 1993. However, the pollution status of the major rivers represented by the lengths of river segments of the four categories didn't show much improvements accordingly.

As shown in Table 2, the length of "heavily polluted" segment are increased from 267.7 Km in 1986 to 379.4 Km in 1993. The percentage increase from 10.4% to 12.9%. These numbers do not reflect the pollution loading removal and the efforts of pollution control in that period.

It has been recognizing that there are two factors which caused the RPI does not reflect the actual changes of the river pollution status. The two factors are described as follows:

(1) The current RPI applies step change function to show the four categories of pollution status. A single constant value of that step is not able to represent the wide range of pollution variation in that pollution category.

(2) Often times, great improvements have been achieved in the "heavily polluted" segment of the river, but, it is not to a level that the pollution status can be up-graded to "moderately polluted". Therefore, the improvements of the heavily polluted segment are not able to reflect in the change of the river length.

Take the Nankang River as an example, the BOD level had been reduced from 400 mg/l to 50 mg/l between 1983 and 1993, but the river remains in the heavily polluted category. The reduction of 88% in BOD is not able to show it anywhere.

Because the insensitivities of the current RPI, different approaches are taken in this study trying to overcome the problem. The scale of points will be extended in order to cover the entire variation of pollution changes. The modification steps taken are listed as follows:

(1) Continuous straight line method will be used to replace the step function change.

(2) Two sampling stations will be selected as representing stations. One will be the <u>Reference Station</u> (heavily polluted station), and the other will be the <u>Alert Station</u> (station closest to the un-polluted zone). The length variation between the two stations will be used to present the real situation of river pollution changes.

(3) BOD5 and NH3-N, the two man-made pollutants are the main contributors of Taiwan's river pollution. Taiwan river's high concentration of SS are the results of short distances and deep

slopes which are the natural characteristics of the rivers. The D.O. is not a pollutant itself as BOD5 and NH3-N. Therefore, for the purpose of able to show the improvements in pollution control, which is mainly in the category of man-made pollutants, the point scale of BOD5 and NH3-N are going to be extended to 90 respectively. The point scale of D.O. and SS will remain at 10. This design will give the "heavily polluted" status a total maximum point of 200 from the four parameters, and the average will be 50 points.

STUDY:

The modifications of the four parameters of current RPI using continuous straight line method are presented as follows:

(1) D.O.

The step function method of D.O. vs Point is shown on Figure 1. The first interval between point (6.5, 1) and point (10,1) is status A (unpolluted). The second interval between point (4.5,3) and point (6.5,3) is status B (slightly polluted). The third interval between point (2,6) and point (4.5,6) is status C (moderately polluted) and fourth interval between point (0,10) and (2,10) is status D (heavily polluted).

The modification is to connect the mid-point of line (6.5,1) and (10,1) and mid-point of line (4.5,3) and (6.5,3), and a first order formula $\underline{8x+11y-77=0}$ is developed for the line which will be able to cover the area with D.O. concentration above 5.5.

A second first order formula $\underline{4x+3y-31=0}$ is also developed for the connecting line between the mid-point of (4.5,3), (6.5,3) and the mid-point of (2,6), (4.5,6). This line is extended to the Y-axis and it will be able to cover the area with D.O. concentration below 5.5.

(2) BOD5:

The step function method of BOD5 vs Point is shown in Fig 2. The first formula $\underline{2x-3y=0}$ is developed for the line connecting the original point (0,0) and (1.5,1) which is the mid-point of status A and it will be able to cover the area with BOD5 concentration under 1.5. The second formula $\underline{4x-5y-1=o}$ developed is for the line connecting (1.5,1) and (4,3) which is the mid-point of status B and it will be able to cover the area with BOD5 concentration between 1.5 and 4. The third formula $\underline{x-2y+1=0}$ developed is for the line connecting (4,3) and (182, 90). 90 is the maximum point designed to BOD5. For BOD5 concentration above 182, the points will remain at 90.

(3) SS:

The SS vs Point is shown in Fig. 3.

The first formula $\underline{10x-y=0}$ is developed for the line connecting the origin (0,0) and (10,1) which is the mid-point of status A and it will be able to cover the area with SS concentration under 10. The second formula 2x-25y+5=0 developed is for the connecting (10,1) and (35,3) which is the mid-point of status B and it will be able to cover the area with SS concentration between 10 and 35. The third formula 3x-40y+15=0 developed is for the line connecting (35,3) and (128.3,10). 10 is the maximum point designed to SS. For SS concentration above 128.3, the point will remain at 10.

(4) NH3-N

The NH3-N vs Point is shown in Fig 4.
The first formula 4x-y=0 developed is for the line connecting the origin (0,0) and (0.25,1) which is the mid-point of status A and it will be able to cover the area with NH3-N concentration under 0.25. The second formula 4x-2y+1=0 developed is for the line connecting (0,25,1) and (0.75,2) which is the mid-point of status B and it will be able to cover the area with NH3-N concentration between 0.25 and 0.75. The third formula 16x-5y-2=0 developed is for the line connecting (0.75,2) and (28.25,90). 90 is the maximum point designed to NH3-N. For NH3-N concentration above 28.25, the point will remain at 90.

APPLICATION:

The application of the modified RPI is focused on Chungkang (中港) and Kaoping (高屏) River. Both rivers are suffered by heavy pollution. The Chungkang River is located in the northern part of the island and it is on the first priority list for river restoration. The Kaoping River is the largest river of southern Taiwan. It is the major water supply source for the area.

The pollution status of a Reference Station (heavily polluted) of Chungkang River is presented in Figure 5. Using the current RPI point scale to assess the pollution condition of the river between 1980 and 1993, the line is almost flat and with not much variation. It is a totally different situation when using the modified RPI. The point scale vary dramatically between 1990 and 1993 and it is able to present a picture closer to the real situation. In 1992, when the river flow rate increased, the pollution situation got better. In 1992, when the flow rate decreased, the pollution points continued to decrease. This is contributed by the pollution control efforts. The detail calculation by using the developed first order formulas are presented in Table 3.

The pollution status point data from an Alert Station (station closest to the un-polluted zone) of ChungKang River is presented in Figure 6. The finding is the same as the Reference Station. The distance between the Reference Station and the Alert Station decreased between 1992 and 1993, it demonstrated the reduction of pollutants. Between 1991 and 1992, the finding is the opposite.

More studies are needed in order to understand this discrepancy. The detail calculation data are presented in Table 4.

Same procedures for both the Reference Station and Alert Station were repeated on Kaoping River. The results were not as significant as on Chungkang River. The high flow rate of Kaoping River is the main reason. And The findings are presented in Figure 7 and 8, Table 5 and 6.

CONCLUSION AND FURTHER STUDY:

(1) The modified RPI demonstrated that it is more sensitive to the improvement in the category of heavily polluted segment, but not in the category of moderately polluted segment. This is due to the designed of this study, the higher the concentrations of BOD5 and NH3-N, the clearer the changes.

(2) The modified RPI demonstrated its ability to show the improvement of pollution control in the heavily polluted segment of Chungkang River, however, it did not work as good at Kaoping River. This is the result of the high flow rate of Kaoping River diluting the concentration of the pollutants. Other factors might be involved, further studies are needed to understand more about this phenomenon.

(3) The length variations between the Reference Station and the Alert Station were not work as well as first thought it would. More studies are also needed to make this work better.

(4) The modified RPI will apply to other rivers as well. A correlation might be developed to demonstrate the effectiveness of this new system.

Table 1: Current River Pollution Index

pollution status parameter	A unpolluted	B slighlyt polluted	C moderately polluted	D heavily polluted
DO (mg/l)	>6.5	4.6−6.5	2.0−4.5	<2.0
BOD (")	<3.0	3.0−4.9	5.0−15	>15
SS (")	<20	20−49	50−100	>100
NH_3 −N (")	<0.50	0.50−0.99	1.0−3.0	>3.0
point	1	3	6	10
average point	<2.0	2.0−3.0	3.1−6.0	>6.0

Remark: average point are the average of the points of DO, BOD, SS and NH_3-N.

Table 2. Segment Variation of 21 Taiwan Major Rivers

length / year	unpolluted		slightly		moderately		heavily	
	KM	%	KM	%	KM	%	KM	%
1986	2086.3	73.1	145.9	5.2	320.5	11.3	267.7	10.4
1987	1998.9	70.9	180.9	6.4	319.7	11.3	321.1	11.4
1988	1965.2	67.5	287.7	9.9	336.7	11.6	321.0	11.0
1989	1966.2	68.0	205.7	7.0	371.0	13.0	346.4	12.0
1990	1936.3	66.9	230.5	8.0	428.0	14.8	297.1	10.3
1991	1983.5	67.5	239.4	8.1	342.6	11.7	373.4	12.7
1992	1803.9	61.4	368.8	12.5	461.0	15.7	305.2	10.4
1993	1796.4	61.1	408.6	13.9	354.6	12.1	379.4	12.9

Table 3 RPI at Reference Station of Chungkang River

Current RPI						Modified RPI				
Year	BOD	DO	NH3-N	SS	Point	BOD	DO	NH3-N	SS	Point
1990	10	10	10	10	10	20.65	8.8	16	10	13.9
1991	10	10	10	10	10	90	9.7	71.6	10	45.3
1992	10	6	10	6	8	25.25	7.6	46	7.1	21.5
1993	10	6	10	6	8	16.4	5.3	13	6.5	10.3

Table 4 RPI at Alert Station of Chungkang River

Current RPI						Modified RPI				
Year	BOD	DO	NH3-N	SS	Point	BOD	DO	NH3-N	SS	Point
1980	10	3	10	3	6.5	30.74	2.6	40	3.2	31.6
1981	6	3	10	3	5.5	7.25	2.5	90	2.2	25.5
1982	6	3	2	3	3.5	6.96	2.3	1.8	3.1	3.5
1991	10	6	6	3	6.25	11.45	6.1	5.3	3.25	6.5

Table 5 RPI at Reference Station of Kaoping River

Current RPI						Modified RPI				
Year	BOD	DO	NH3-N	SS	Point	BOD	DO	NH3-N	SS	Point
1987	6	3	2	3	3.5	3.6	4.1	2.7	3.97	3.6
1988	6	6	6	6	6	4.62	5.2	3.2	6	4.8
1989	6	3	6	10	6.25	3.69	3.6	3.9	10	5.3
1990	6	3	6	10	6.25	4.12	4.0	2.9	10	5.3
1991	6	6	6	10	7	5.24	5	6.3	10	6.6
1992	3	3	6	10	5.5	3.38	2.8	3.1	9.4	4.7
1993	6	3	6	10	6.25	4.31	2.9	6.9	9.6	5.9

Table 6 RPI at Alert Station of Kaoping River

Current RPI						Modified RPI				
Year	BOD	DO	NH3-N	SS	Point	BOD	DO	NH3-N	SS	Point
1987	3	3	2	3	2.75	2.5	2.5	1.5	2.7	2.2
1991	6	3	2	3	3.5	2.6	2.8	1.6	1.9	2.3
1992	3	3	2	6	3.5	2.8	2.7	1.7	4.2	2.9
1993	3	3	2	3	2.75	3.67	2.8	1.7	4.1	3.1

Fig.1 DO vs Point

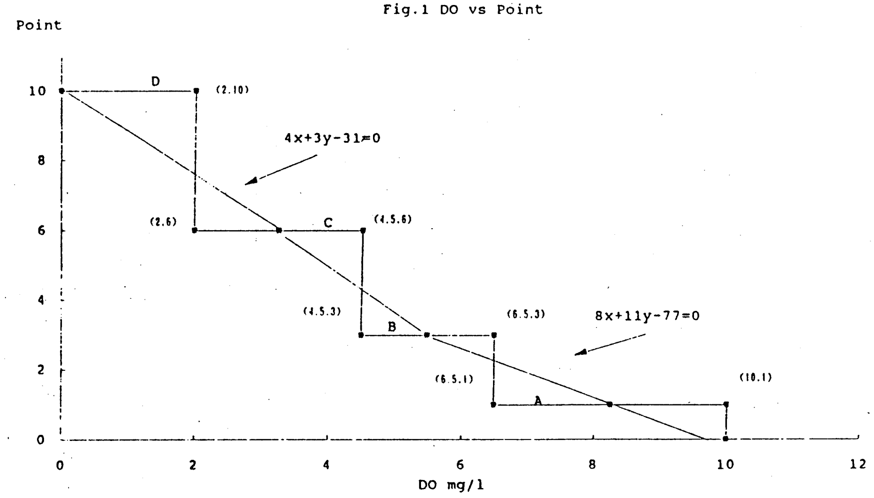


FIG.2 BOD5 VS. Piont

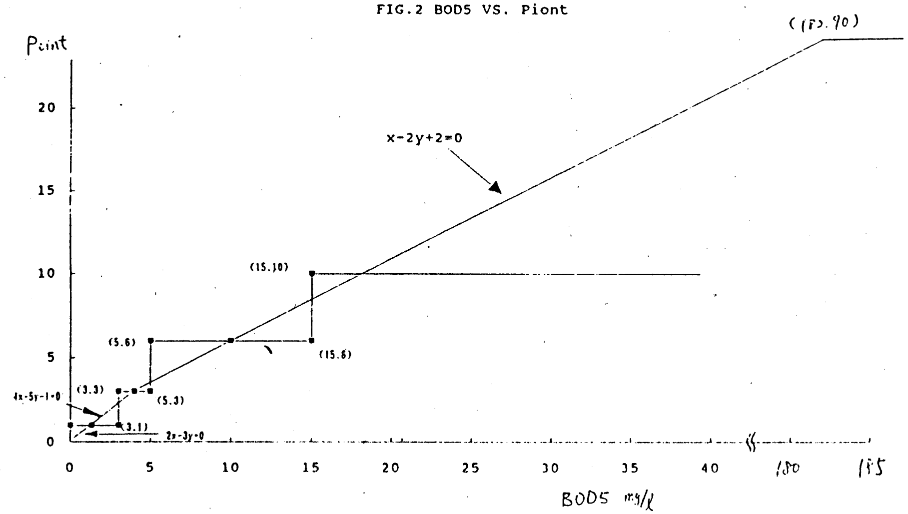


Fig.3 SS vs. Point

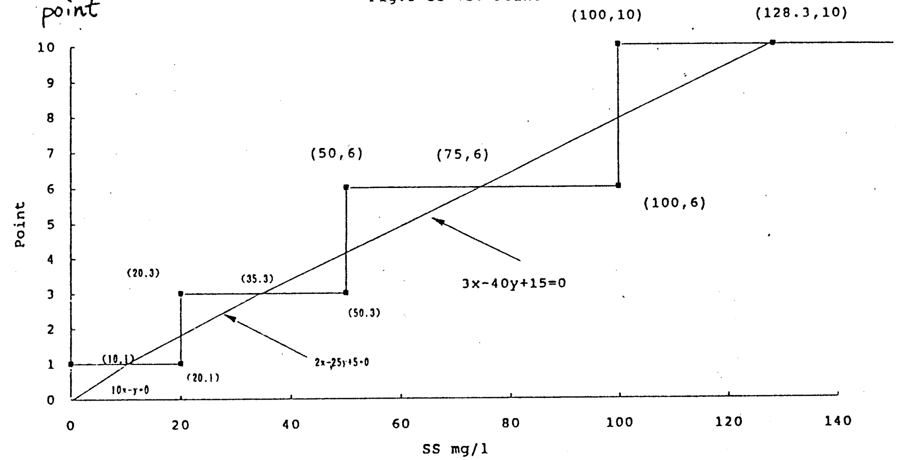


FIG.4 NH3-N VS. Point

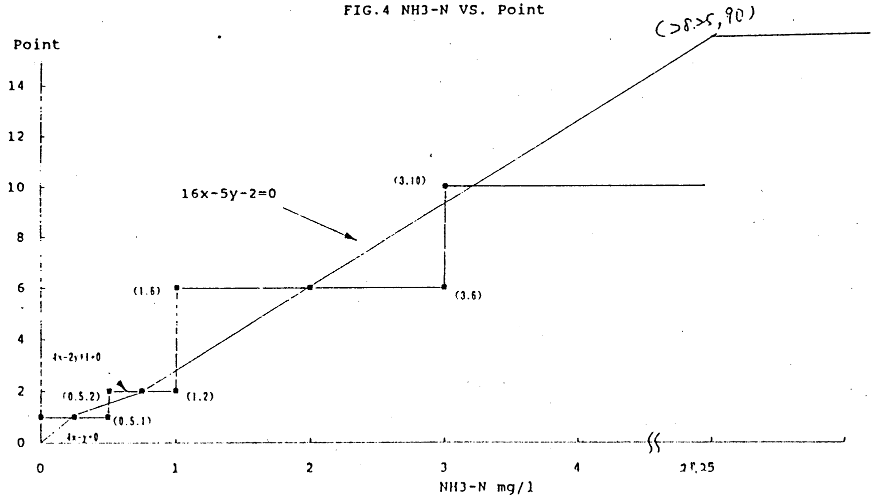
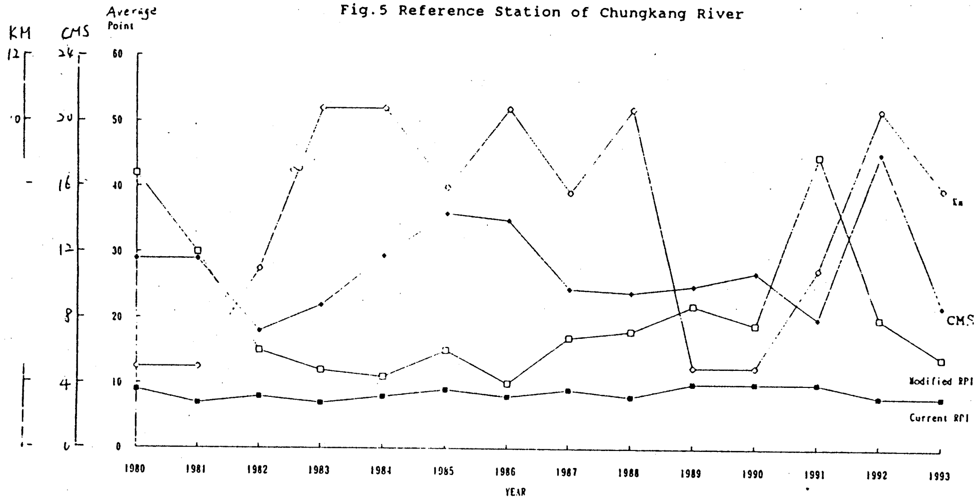
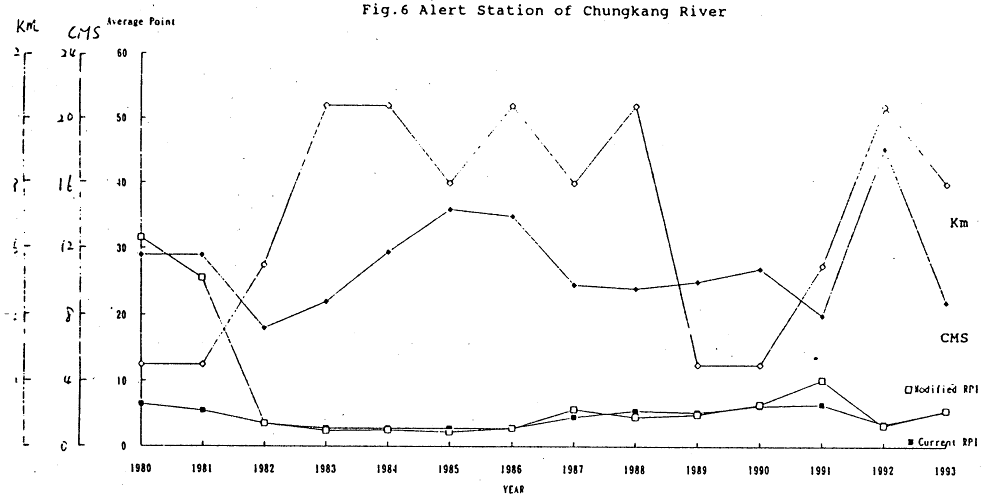


Fig.5 Reference Station of Chungkang River



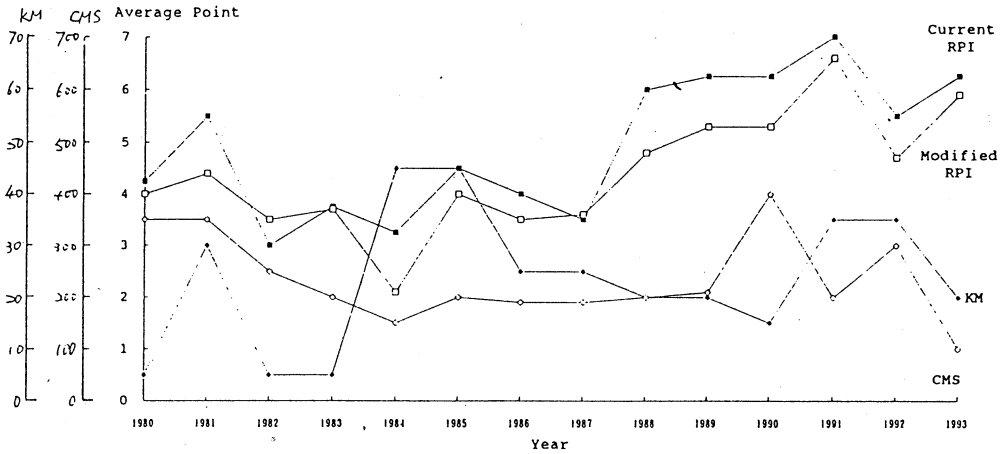
KM: Length Variation between Reference and Alert Stations, kilo meter
CMS: Yearly Average Flow Rate, cubic meter per second

Fig.6 Alert Station of Chungkang River



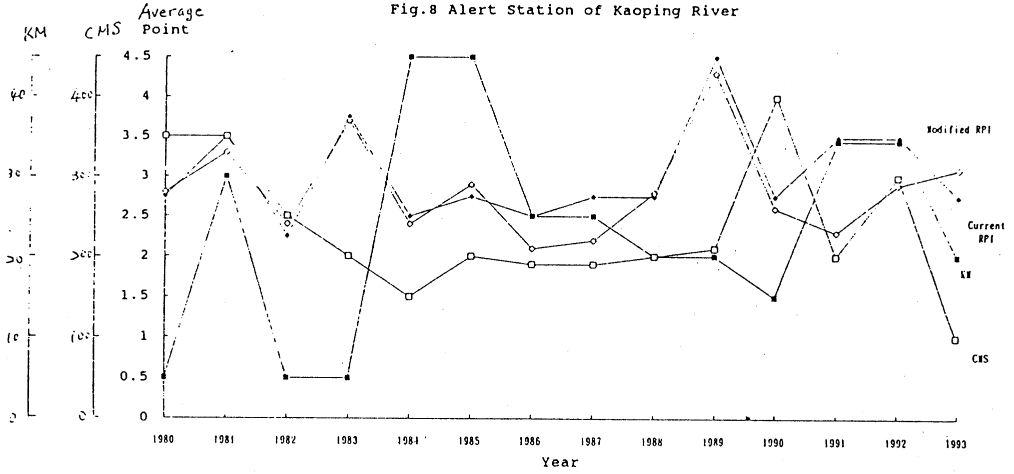
KM: Length Variation between Reference and Alert Stations, kilo meter
CMS: Yearly Average Flow Rate, cubic meter per second

Fig.7 Reference Station of Kaoping River



KM: Length Variation between Reference and Alert Stations, kilo meter
CMS: Yearly Average Flow Rate, cubic meter per second

Fig.8 Alert Station of Kaoping River



KM: Length Variation between Reference and Alert Stations, kilo meter
CMS: Yearly Average Flow Rate, cubic meter per second