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Identification of Water Quality Monitoring Sites on the Kshipra River

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ABSTRACT

The location of a permanent sampling station is probably the most critical factor in a monitoring network which collects water quality data. If the samples collected are not representative of the water mass, the frequency of sampling as well as the mode of data interpretation and presentation becomes inconsequential.

Besides the economic considerations, there are three levels of design criteria of sampling station location. The macrolocation deals with river reaches in the river basin, the microlocation deals with the location of outfalls or other specific features within a river reach and the third level deals with the representative location points within a river's cross-section. In the present study only the macrolocations have been identified on Kshipra river. The Sharp's procedure which is widely used for selecting locations is used.

One year monthly water quality data monitored at existing nine sites was available. This data was used to analyse both the temporal and spatial trend in water quality. On the basis of trend analysis, the justification of existing monitoring sites is carried out. further, as monitoring is a costly affair, it is also studied whether monitoring at some of the sites could be discontinued or may be less frequent.

Further, macrolocation for water quality monitoring were identified using Sharp's procedure. Because, the flow data was not available, the pollution loading could not be calculated, the pollution indices were used in the Sharp's procedure. The comparison is made between the existing and proposed water quality monitoring sites. It is found that sampling should be done at site no.9, 3, 4, 5 and 7.and sampling can be discontinued at site no. 1, 2, 6 and 8.

1.0 INTRODUCTION :

Hydrological and ecological variables follow their own patterns of ebb and flow in space and time, and sampling design should reflect these differences. It might be of interest to measure populations of benthic invertebrates in a riffle, for example, yet a riffle may not be the best location for measuring average stream discharge. Similarly, measurements of discharge or bedload movement from a bridge may be feasible at high flows but drift driving for fish observation during floods would be unwise. Often, some variables can be measured to give information about how to sample others more efficiently. Gordon et al. (1992), for example, found that precision was increased when abundance of benthos was first correlated with hydrodynamic factors. The object of sampling is to estimate population parameters from information contained in a sample. A good sample survey design will maximize the amount of information for a given cost.

As complex as it is water quality monitoring is also highly significant because it is our only means of being informed about water quality. Thus monitoring constitutes the link between the actual process and our understanding, interpretation and assessment of the highly complex phenomena. Therefore water quality monitoring is the most crucial activity on man's side with respect to all management and control efforts. Adequately accomplished monitoring may serve to increase our knowledge on water quality processes and hence reduce the uncertainties whereas results of poor monitoring practices may lead to erroneous interpretations and decisions (Harmancioglu and Alpaslan, 1990).

For example, Harmancioglu et al. (1992) claims that 'we are not really sure of the cost-effectiveness of some of the program accomplished to date because of the lack of adequate monitoring of water quality in our streams, lakes, and estuaries'. According to Harmancioglu et al. (1992) our understanding of environmental processes and problems evolve quite rapidly, whereas monitoring systems develop at a slower pace, often becoming out of date with respect to recently emerging issues and purposes of water quality assessment. On the otherhand the decision making process in water quality management is highly sensitive to the reliability and accuracy of available data. Further unreliable data the misinterpretation of information they convey may lead to wrong decisions. This situation is apparently worse than taking no action at all. In such a case, 'the underlying data can be said to have a negative economic value' (Harmancioglu et al. 1992).

Water quality management may be defined as the effort by society to control the physical, chemical, and biological characteristics of water. The efforts are directed at controlling the impacts of society upon the quality of water. Water quality in the environment, however is the result of two primary casual mechanisms: (1) the activities of society; and (2) the natural hydrologic cycle. Therefore, water quality management must deal with both events though it attempts to control only one the activities of society. Both mechanisms may be described as stochastic processes in that each, to some degree, is governed by the laws of chance. Thus, water quality, from a broad management perspective, can be considered a random variable.

Only recently has the random nature of water quality been recognised as having a large influence on the methods used to manage water quality, in general, and on the methods used to monitor (measure) water quality, specifically. Much of this recognition has been developed as the state-of-the-art in water quality hydrology and evolved the need to treat water quality monitoring as a statistical sampling process has been recognised (Ward and Loftis, 1983).

The purpose of this report is to present basic principles of water quality monitoring network design. The design technique presented acknowledge the practical limitations and objectives of current monitoring efforts while stressing the need to be more quantitative in the design process.

Water quality monitoring is the effort to obtain quantitative information on the physical, chemical, and biological characteristics of water via statistical sampling. The type of information sought depends upon the objectives of the monitoring network. Objectives range from detecting stream standard violations to determining temporal water quality trends.

The word "monitoring" in the strictest sense, implies watching the ongoing of water in order to ensure no laws or rules are violated. This connotation, while relevant to some objectives, has, in general, been lost since "water quality monitoring" refers to most types of water quality sampling or measurement.

As the word "monitoring" has taken on a different meaning when used to refer to water quality measurement, so has the term "network" taken on a meaning beyond the strict definition of the word when referring to water quality monitoring. As used here "network design" means determining the placement of sampling points, the calculation of sampling frequencies, and the selection of water quality variables to measure in a hydrologically and statistically sound manner. Thus, network design relates more to the statistical and hydrological design of a water quality monitoring program than to the procedures used to collect samples, perform laboratory analyses, etc.

2.0 DIFFERENT APPROACHES IN SAMPLING DESIGN :

The selection of measurement sites begins with decisions about the extent to which results are to be generalized (e.g. catchment or continent). Selected streams are normally divided into relatively homogeneous sections, based on topography, geology, slope, streamflow and/or biological characteristics (Bovee and Milhous, 1978). This type of division is called stratification which will be discussed further in the following section. Bovee(1982) provides a checklist for establishing study sites which considers a number of hydrological, geographical and ecological characteristics at several scales.

selection of the number and lengths of segments in a stream, reaches in a segment or transects or plots with in a reach is ultimately a problem in sampling design. this must take into account the variability of the stream, the precision required, and budget and time limitations. Some basic guidelines for partitioning a stream are as follows (Fig.1):

i) Identify and eliminate anomalous areas: Bridge or dam sites, road crossings, large waterfalls or other typical features should normally be eliminated from the study area unless they represent a large portion of the stream or are the object of the study. An example would be "critical reaches" defined by Bovee and Milhous(1978) as those which limit the success of a particular life stage of fish, such as a location which becomes a barrier at low flows. These areas would be set aside for separate study rather than included in statistics, which are used for making inferences the segment.

ii) Divide a stream into segments: A segment of a stream is a section where the flow and morphology are fairly uniform. Bovee(1982) recommends locating segment boundaries at locations where the average streamflow changes by more than 10% such as at major tributaries or diversions. He also recommends placing boundaries where abrupt changes occur in slope, sediment input, bank materials and channel morphology. Where changes are gradual, boundary locations become more subjective. Stream ordering is another method of segmenting a stream. Based on the study design,

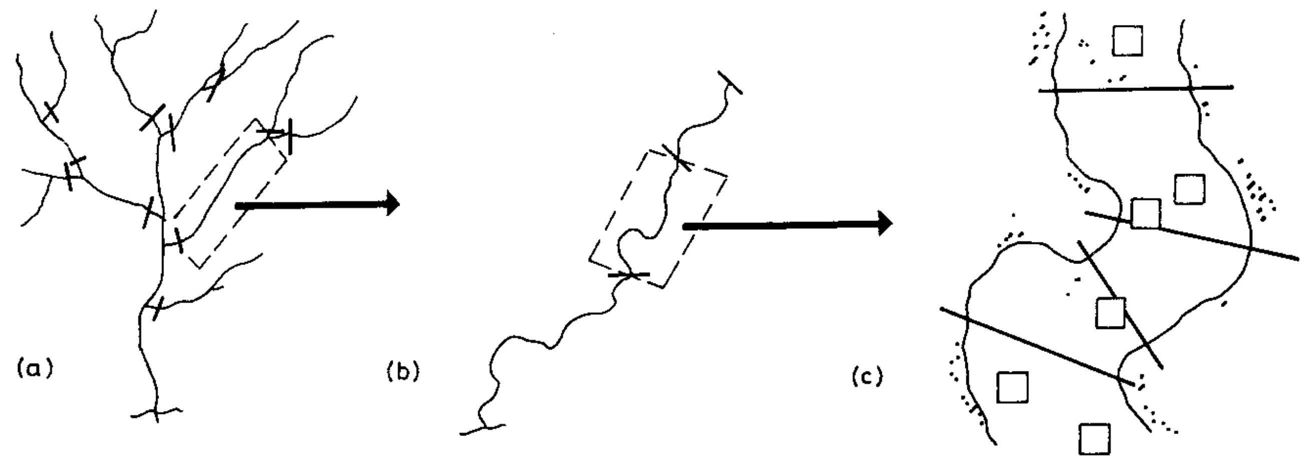

Figure 1: Location of sampling sites: (a) division of stream system into homogeneous segments, (b) division of a segment into reaches, and (c) location of transects (lines) and plots (boxes) within each reach

a certain number of segments are chosen from which inferences are made about the river system.

iii) Divide stream segments into reaches: A segment can be further subdivided into reaches, some of which are sampled to make inferences about the whole segment. Reach boundaries can be located on a uniform bias(all reaches are of equal length) if segment is homogeneous or changes smoothly from one end to other. Alternatively, as in locating segment boundaries, divisions can be based on more localised changes in channel structure. If the stream morphology is composed of meanders, pool and riffles, or other easily discernible changes in channel shape, reaches can be divided at the point of change. For example two cycles of riffles and pools or two meander loops constitute a workable reach length for hydraulic geometry surveys.

A common practice in stream surveys is to select "representative" reaches which are considered to be representative of the conditions in the segment. Selection is usually based on the ability of investigator to integrate knowledge about stream segment and choose a reach which contains the same features in the same relative proportions. To introduce randomness at this level, several candidate reaches can be located and one or a few chosen at random for further study.

iv) Select transect, plot or point measurement sites : A reach may be measured in its entirely(for example in counting fish populations or the number of debris dams) or sites might be located within a reach for measuring bed material sizes, cross-sectional profiles, aquatic insect numbers etc. A transect is typically a line along which measurements or samples are taken. The term plot is a throwback to agricultural terminology, and refers to an area within which samples are taken. Point measurements are made over an area determined by the size of the sampling instrument(e.g. rainfall gauge or substrate sampler).

Transects, plots or point measurement sites can be located at random, uniformly, at representative sites or within noticeable microhabitats. These may constitute subsamples at either the segment or reach level. For instance, cross-sections might be surveyed at uniformly spaced transects along an entire segment but crocodile populations sampled only within a few reaches.

Most of the steps in partitioning a stream can be done in the office if adequate streamflow records, topographical maps and recent aerial photographs are available. Critical areas, segment and reach boundaries and measurement sites should be marked on maps and/or aerial photographs. The precise location of reaches or measurement sites should be done in the field, perhaps in conjunction with pilot sampling. As much as possible, efforts should be made to avoid bias in selection of sampling sites by introducing randomization at some level.

Prior establishment of study sites is an essential part of planning. This eliminates confusion and time lost in the field, improves the validity of results and reduces the impact of the study itself on the study area.

3.0 STUDY AREA :

River Kshipra is one of the sacred Indian rivers. It is also known as "Avanti nadi". It originates from Kokri Bardi hills (747 metres high) about 11 km south east of Indore. After travelling a distance of 70 km through Indore district it enters Ujjain district. It receives its tributary river Khan near Ujjain and the Gambhir river near Mahidpur, before itself merging with the Chambal at the trijunction of Ratlam and Mandsaur districts of M.P. and Jhalawar district of Rajasthan. Most of its course lies over the broad rolling grassy plains of Malwa between low banks and from Mahidpur to Alot it is hemmed in by high rocky banks. Its total length is about 195 km (Fig.2).

Kshipra is not perennial and runs dry for a period of 5 to 6 months. During Summer it is transformed into a series of disconnected turbid ponds or pools of water and absence of any hydraulic connection between them renders from stagnant and filthy. During the first flush of rains these lagoons are again hydraulically connected. During rainy season the low lying areas along its banks, including Ramghat, Indoregate, Railway colony, Kartik Chowk, Port, Harsidhi areas of Ujjain etc. are frequently flooded and heavily inundated. The water of kshipra is used for drinking, Industrial and lift irrigation purposes (ENVIS,1987).

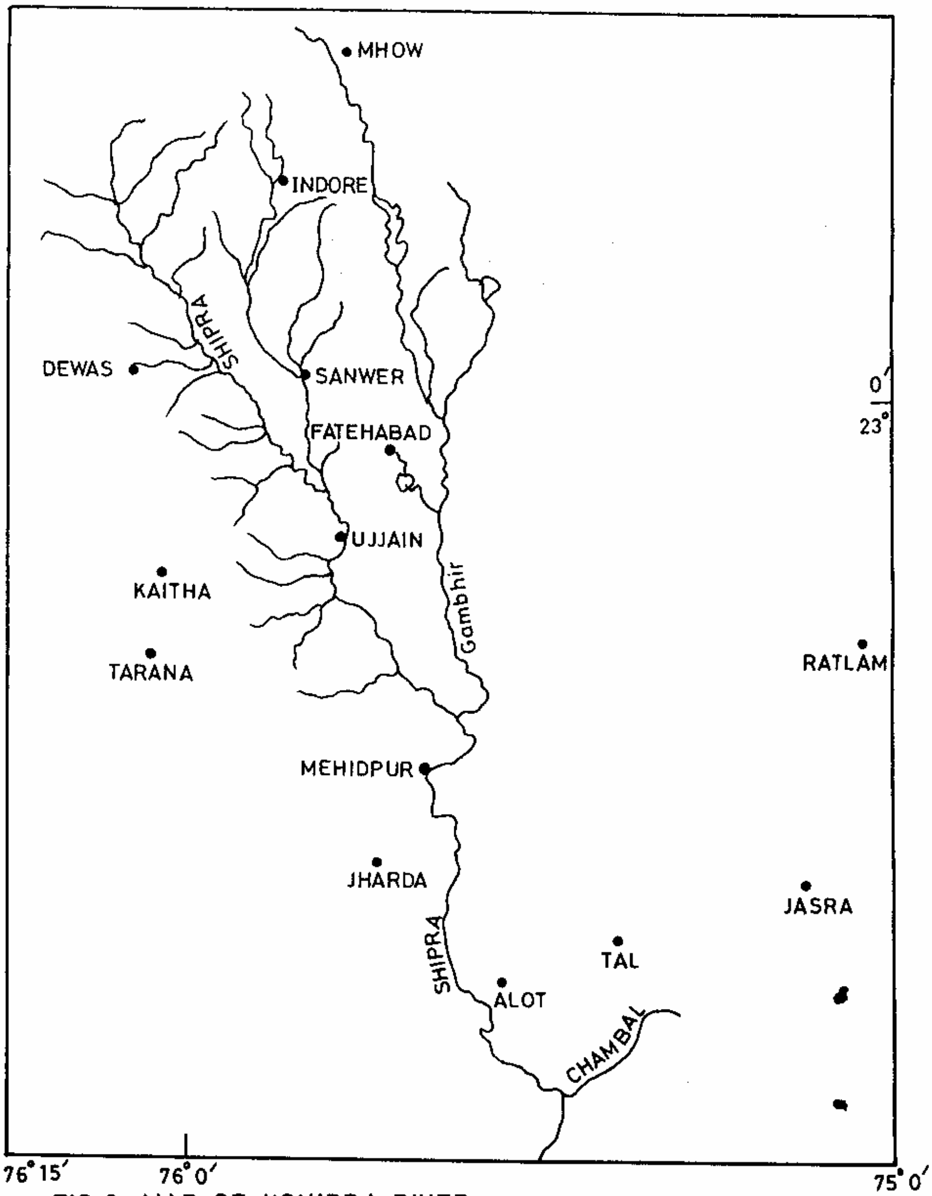

FIG. 2 : MAP OF KSHIPRA RIVER

4.0 WATER QUALITY AND POLLUTION STATUS OF KSHIPRA RIVER :

River Kshipra while flowing through the Indore, Ujjain and Dewas districts receives polluted water outfalls from different sources at different places. The pollution sources of Kshipra river is shown in Fig.3. Details are as follows (ENVIS,1987):

4.1 Domestic Sewage and Industrial Waste of Indore city :

Indore is an old centre of culture, education and industry. It is one of the important city of MP not only population-wise but also from considerations of industry and commerce. There are six major textile units and three industrial sectors in the city with several small scale industries. The water supply of the Indore city is from Yashwant Sagar lake and Narmada river which flows at about 60 kms. distance from Indore. But unfortunately the city is devoid of adequate underground sewage system as well as sewage treatment facility and consequently domestic waste water of the city and the industrial waste water is carried mostly through the open drains into the Khan river. River Khan originates from Nimboli tank along the Indore-Khandwa road approximately 9 km. from Indore city. The river passes through the heart of Indore. Excess water of Nimboli tank is released into river during monsoon. Initially in Indore, Khan river had water flow only during rainy season but now due to discharge of domestic and industrial effluents in it, it flows the year around. At present about 20 MGD water is supplied to Indore town. Indore city is having only partial sewerage system. The sewage is collected in a primary treatment plant constructed near Kabit Khedi, having only 3 MGD capacity. During its course Khan receives 1500 m^3 of water from textile mills. This water is coloured and contains high value of BOD and COD. In addition about 50 m^3 of waste water is added from vegetable oil industry which also contributes high values of BOD and COD together with oil and grease.

After receiving untreated waste water from these industries, the polluted Khan river, [illegible] area in Indore, where about 400 [illegible] out from the river for waste water irrigated vegetable farming in an

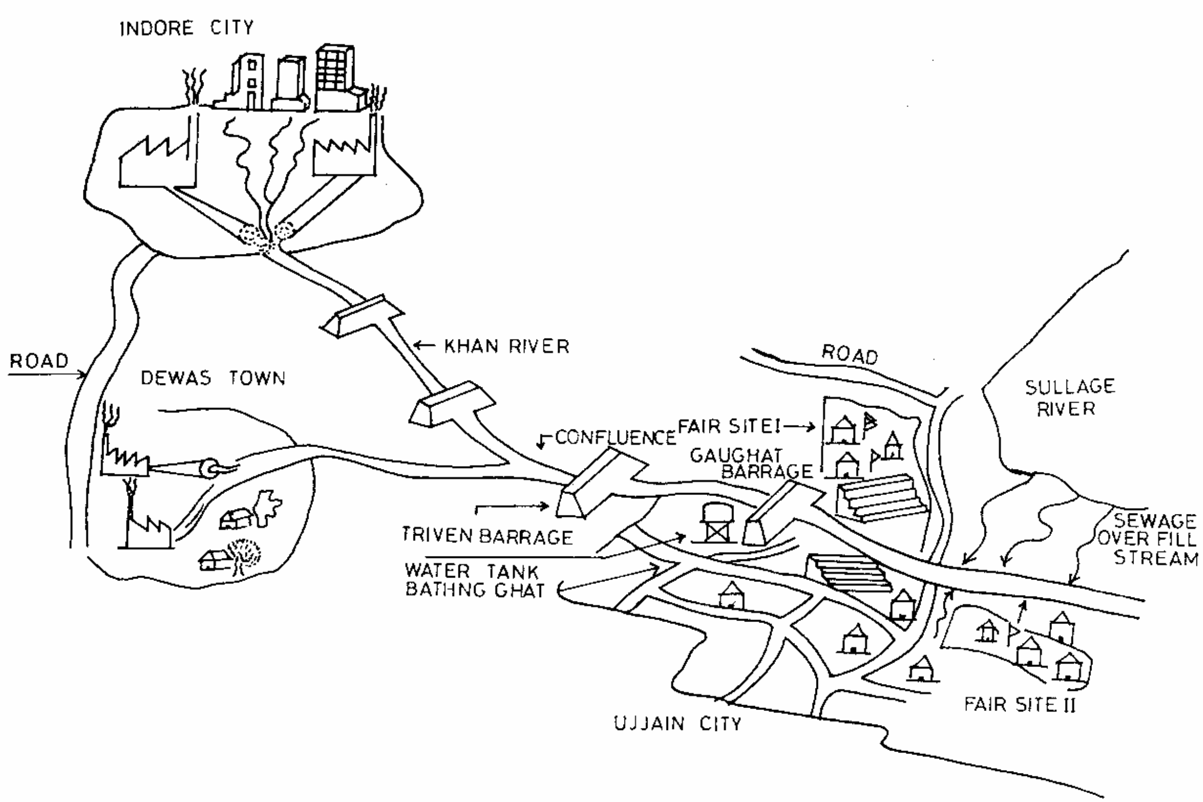

FIGURE 3. POLLUTION SOURCES OF KSHIPRA RIVER NEAR UJJAIN CITY.

area of about 600 acres. Likewise there are other pickup wiers along its course where water is utilised for irrigation. Thus by the time the river reaches Sanwer there is practically no water left in it. The river flows only during rainy season and upto the month of October/November.

After Sanwer, Khan river is fed by small rivulets, which contribute to the water flow of the river. This water is again stored in Ramwasa Tank by constructing a dam near Ramwasa village located just 6 km upstream of Triveni Sangam. The Ramwasa dam is maintained and operated by irrigation department. The water of the reservoir is utilised for irrigation purposes. Thus it is seen that Kshipra receives water only from release of Ramwasa Tank. Khan river after travelling through a total distance of approximately 64.5 km joins river Kshipra. The place of confluence is known as Triveni Sangam. Kshipra river is the source of water supply for Ujjain town. The intake point is located about 7 km. downstream of Triveni Sangam. A detailed study conducted by a Committee constituted by MPPNM during 1977-78 from Indore to Triveni Sangam Barrage and Gaughat stretch of Khan river also revealed that the Khan river is grossly polluted upto village Darjikariadia but shows start of regeneration 3 km. down stream of this station. At Sanwer it again receives sullage of the town and get polluted. The river is fully rejuvenated by self purification by the time it reaches Triveni Sangam. The details of water quality sampling sites are given in Table-1:

4.2 Water quality of Kshipra river in Dewas :

Dewas city is located about 40 km west of Indore city along the Agra-Bombay national highway. About 3 km due south of Dewas city along both sides of the National Highway No. 3 are located many small, medium and large industrial units. Another industrial sector is in the west of city on the Dewas-Ujjain road. Kshipra river flows through 10 km south of the city. A dam has been constructed on the river to meet the water supply demand of the city. The water demand of industrial sectors is however met by tubewells. The sewage from the city flows through open drains into the Nagdhawan nalla. The general slope of the industrial area is also towards Nagdhawan nalla hence practically all the

Details of Sampling sites

site no.	Place
1	Upstream of Bhandari Mill, Indore
2	Downstream of Bhandari Mill after mixing of Industrial waste
3	Near Ravishankar Bridge, Indore
4	After mixing of partially treated sewage near Kabitkhedi
5	Village Darjikariadia
6	Sanwer
7	Village Panth Piplai
8	Triveni Sangam near Ujjain
9	Gaughat Headworks, Ujjain

industrial waste water finds its way to the Nagdhawan nalla. There are in all 15 industries situated in Dewas in the catchment of Kshipra river and total waste effluent generated by these industries is about 0.28 cusecs. Out of these, some industries are utilising their entire effluents for land irrigation and as such 0.15 cusec of this total flow does not find its way into Kshipra at all. Remaining 0.13 cusec discharged into the Nagdhawan nalla ultimately finds its way into the Kshipra river. However, most of this water flowing through the nalla is utilized for cultivation purposes in lands situated between the point of discharge of effluent and the point of confluence. As a result the nalla remain dry for atleast 8 months of the year. The main problem of the industrial waste discharge arises in the rainy season.

Out of the 15 industries, only M/S Tata Export is reusing their entire waste for land irrigation after treatment and as such do not contribute to the pollution of river at all. The bank note press discharge its entire waste (industrial as well as domestic) into the river after treatment but they do contribute to the pollution in respect of dyes and dissolved solids, though the latter remain within the permissible limits. The HAP Chemical

Enterprises does not have treatment facility for their wastes and thus they add to pollution load with respect to total solids and dyes. These industries do not act as polluting agents for eight months of the year but during the monsoon the solid wastes which get deposited in the Nalla get flushed and add shock loads. Since, none of these industries is directly causing pollution of the river Kshipra they presently do not create any alarming situation. However, efforts are being made by MPPNM through persuation and legal action with the aim of discouraging them from causing any alarming situation at a later stage.

Any river flowing through habitation and industrial zone is bound to get polluted in its course the index of pollution being highest during the monsoon season when the rains wash off all pollutants into the river stream and this problem is going to increase with increased use of technology in respect of both industrialisation and agriculture. It will be necessary to create artificial means of absorbing and regularising the river flows wherever the rivers are used for drinking water purposes. It is more important in the case of river Kshipra which is not only used for water supply to Ujjain but since it is a sacred river, it is used for drinking and public bathing purposes by the populace living along its course and pilgrims congregating from different parts of the country.

4.3 Water Quality of Kshipra at Ujjain :

Ujjain city is located in the Malwa Plateau region of Madhya Pradesh and dates back to the puranic times as seen from the references in "Garud purana" and "Skandapurana". Kshipra river flows along 1 km. west of Mahakaleshwar temple. Kshipra is the main source of water supply for Ujjain city. In addition to drinking water, Kshipra water is also used for industrial and irrigation purposes. There are four anticut on the Kshipra river, viz; Piliya barrage, Triveni barrage, Gaughat barrage and Ramghat barrage. The city water supply intake point is between Triveni and Gaughat barrages. About 10 MGD water is tapped at this point. There is no source of pollution in this stretch of river. Previously sewage water used to get access into the river through nalla which has now been diverted. The river gets highly polluted due to bathing and washing clothes by pilgrims and Dhobies. Very often cattle bathing is also seen in this area which further adds to the water pollution. The river remains almost dry during summer season in this area.

The main water polluting industries in Ujjain are three textile mills and one distillery unit. The waste waters from these industries enter Kshipra river through Piliyakal nalla near Mnaglalnath Temple, which is about 1/2 km away from habitats of Ujjain.

Thus it is seen that the water of Kshipra gets polluted due to bathing and washing of clothes at bathing ghats, entry of industrial waste water through Pilyakhal Nalla and overflow of sewage in the down stream of the Ujjain water supply intake point.

The monthly data of these selected sites on Kshipra river from September, 1977 to July, 1978 published in the report of ENVIS (ENVIS, 1987) is used for the present study.

Table-1 : Water Quality datta of River Kshipra at Ujjain

S.NO.	Parameters	Triveni Barrage		Gaughat Barrage	
		Minimum	Maximum	Minimum	Maximum
1.	pH	7.9	8.7	8.0	8.9
2.	Dis. Solids	126	519	185	434
3.	Alkalinity	174	356	240	336
4.	Hardness	170	252	166	230
5.	Chloride	31	72	37	67
6.	DO	3.3	12.1	3.5	13.1
7.	BOD	2.0	24.0	0.9	6.6
8.	COD	15	40	7	38
9.	Nitrate	0.04	5.2	0.14	8.4
10.	Phosphate	0.0	2.5	0.03	0.88
11.	Ammonia	0.0	1.0	0.00	0.72
12.	Nitrite	0.00	0.18	0.00	0.13

5.0 METHODOLOGY :

The Sharp's procedure can be successfully applied to identify the water quality stations on the basis of Pollution loadings(Clarkson, 1978). In the present case, the flow data is not available and hence the pollution loading can not calculated. In this situation, it is proposed to use the water quality index as a measure of water quality of the stream. the procedure is as follows:

i) To see the water quality at each existing site, the water quality Index at each site is calculated. For this purpose, the following mathematical functions are used for subindex functions of selected water quality parameters as given in Table-2:

Table-2 : Subindex functions used for different parameters

S.No.	Parameter	Subindex Function	Source
1.	Dissolved Oxygen	(0.82DO+10.56)/100	Dinius(1987)
2.	BOD	$1.08(BOD)^{-0.3494}$	Dinius(1987)
3.	Alkalinity	$1.10(Alk)^{-0.1342}$	Dinius(1987)
4.	Hardness	$5.52(Hard)^{-0.4488}$	Dinius(1987)
5.	Chloride	$3.91(CL)^{-0.3480}$	Dinius(1987)
6.	E.Conductivity	$5.06(EC)^{-0.3315}$	Dinius(1987)
7.	Temperature	$[400-(T-20)^2]/400$ $0<T<40$	Walski and Parker(1974)
8.	Nitrate	Exp(-0.16Nitrate)	Walski and Parker(1974)
9.	Phosphate	Exp(-2.5Phosphate)	Walski and Parker(1974)
10.	pH	$[25-(pH-7)^2]/25$ $2<pH<12$	Walski and Parker(1974)

The 10 individual subindex functions were combined into one general function using a multiplicative aggregation suggested by Walski and Parker(1974). The final multiplicative aggregation

3function has the general form:

$$I = [\Pi f_i]^{1/n} \quad \text{------------------------} (1)$$

in which f_i = subindex function for i^{th} variable varied from 0 to 1.

n = number of variables considered

To see the effect of phosphate on overall Index, Phosphate parameter was dropped, again the overall Index was calculated in the similar manner. The calculated index values for different month at different existing sites are given Table-3. The Pollution Index at different sites on the Kshipra river are given in Table-4.

ii) Assign the number equal to the index multiplied by 100 (to convert the index scale from 0-1 to 1-100) to existing site on the river.

iii) Complete the numbering of the whole river using Sharp's procedure.

iv) After completing the numbering of the basin apply the Sharp's procedure to determine the sequential sampling stations using different hierarchies.

Using the four steps stated above 4 stations have been identified on the basis of two-hierarchies for each month for both the cases of including and excluding Phosphate. The identified links based on Pollution Index have been tabulated in Table-5. The networks of sequential monitoring water quality sites based on Pollution Index have been shown in Fig.24 to 33.

One can proceed further in the same manner to determine higher level of hierarchical (lower priority) stations, as long as economic considerations permit and information expectations require doing so. To isolate a source of pollution, Sharp proposed that samples be drawn at one hierarchy and analysed to select those portions of the river network which should be sampled at stations of the next hierarchy, and so on, until the pollutant source had been found by a process of elimination.

A modified Sharps procedure is proposed to designate sampling sites except that hierarchies will denote priorities for

Table-3 : Water Quality Index at different sites on Kshipra river for different months

Month	site no. 1		site no. 2		site no. 3		site no. 4		site no. 5	
	I	I_1	I	I_1	I	I_1	I	I_1	I	I_1
Sept.	0.312	0.607	0.162	0.616	0.018	0.604	0.208	0.595		
Oct.									0.501	0.490
Nov.	0.092	0.609	0.106	0.611	0.062	0.568	0.009	0.555	0.165	0.497
Dec.	0.088	0.582	0.115	0.572	0.105	0.550	0.059	0.535	0.109	0.506
Jan.	0.113	0.559	0.117	0.584	0.106	0.523	0.033	0.489	0.309	0.528
Feb.	0.018	0.473	0.032	0.475	0.029	0.423	0.030	0.433		
Mar.	0.116	0.579	0.094	0.547	0.070	0.537	0.096	0.532	0.415	0.525
Apr.	0.176	0.560	0.150	0.469	0.119	0.576	0.388	0.593	0.238	0.480
May	0.201	0.575	0.130	0.543	0.149	0.559	0.308	0.497	0.315	0.511
Jun.	0.223	0.569	0.313	0.506	0.151	0.570	0.269	0.547	0.245	0.455
Jul.	0.139	0.626	0.170	0.610	0.135	0.603	0.048	0.616		

I : With Phosphate

I_1 : Without Phosphate

Table-3 Continued.

Month	site no. 6		site no. 7		site no. 8		site no. 9	
	I	I_1	I	I_1	I	I_1	I	I_1
Sept.	0.373	0.551	0.454	0.555	0.599	0.615	0.654	0.653
Oct.	0.495	0.553	0.442	0.536	0.528	0.598	0.623	0.676
Nov.	0.273	0.544	0.426	0.560	0.626	0.611	0.513	0.609
Dec.	0.109	0.502	0.237	0.504	0.487	0.578	0.648	0.624
Jan.	0.484	0.557	0.551	0.577	0.667	0.656	0.590	0.582
Feb.	0.448	0.541	0.611	0.587	0.678	0.649	0.647	0.633
Mar.	0.548	0.526	0.600	0.577	0.618	0.589	0.602	0.576
Apr.	0.552	0.529	0.631	0.613	0.685	0.664	0.697	0.669
May	0.286	0.527	0.545	0.567	0.620	0.591	0.632	0.605
Jun.	0.369	0.515	0.509	0.554	0.342	0.607	0.642	0.621
Jul.	0.301	0.573	0.674	0.682	0.550	0.541	0.561	0.601

I : With Phosphate

I_1 : Without Phosphate

Table-4 : Pollution Index at different sites on Kshipra river for different months

Month	site no. 1		site no. 2		site no. 3		site no. 4		site no. 5	
	I	I_1	I	I_1	I	I_1	I	I_1	I	I_1
Sept.	0.688	0.393	0.838	0.384	0.982	0.396	0.792	0.405		
Oct.									0.499	0.510
Nov.	0.908	0.391	0.894	0.389	0.938	0.432	0.991	0.445	0.835	0.503
Dec.	0.912	0.418	0.885	0.428	0.895	0.450	0.941	0.465	0.891	0.494
Jan.	0.887	0.441	0.883	0.416	0.894	0.477	0.967	0.511	0.691	0.472
Feb.	0.982	0.527	0.968	0.525	0.971	0.577	0.970	0.567		
Mar.	0.884	0.421	0.906	0.453	0.930	0.463	0.904	0.468	0.585	0.475
Apr.	0.824	0.440	0.850	0.531	0.881	0.424	0.612	0.407	0.762	0.520
May	0.799	0.425	0.870	0.457	0.851	0.441	0.692	0.503	0.685	0.489
Jun.	0.777	0.431	0.687	0.494	0.849	0.430	0.731	0.453	0.755	0.545
Jul.	0.861	0.374	0.830	0.390	0.865	0.397	0.952	0.384		

I : With Phosphate

I_1 : Without Phosphate

3Table-4 Continued.

Month	site no. 6		site no. 7		site no. 8		site no. 9	
	I	I_1	I	I_1	I	I_1	I	I_1
Sept.	0.627	0.449	0.546	0.445	0.401	0.385	0.346	0.347
Oct.	0.505	0.447	0.558	0.464	0.472	0.402	0.377	0.324
Nov.	0.727	0.456	0.574	0.440	0.374	0.389	0.487	0.391
Dec.	0.891	0.502	0.763	0.496	0.513	0.422	0.352	0.376
Jan.	0.516	0.443	0.449	0.423	0.333	0.344	0.410	0.418
Feb.	0.552	0.459	0.389	0.413	0.322	0.351	0.353	0.367
Mar.	0.452	0.474	0.400	0.423	0.382	0.411	0.398	0.424
Apr.	0.448	0.471	0.369	0.387	0.315	0.336	0.303	0.331
May	0.714	0.473	0.455	0.433	0.380	0.409	0.368	0.395
Jun.	0.631	0.485	0.491	0.446	0.658	0.393	0.358	0.379
Jul.	0.699	0.427	0.326	0.318	0.450	0.459	0.439	0.399

I : With Phosphate.

I_1 : Without Phosphate

Table-5 : Location of proposed sites based on Pollution Index

Month	Location					
	Hierarchy 0		Hierarchy 1		Hierarchy 2	
	With P	Without P	With P	Without P	With P	Without P
Sept.	522.0	320.4	250.8	157.8	152.6, 392.7	77.7, 247.2
Nov.	672.8	383.6	373.1	216.0	180.2, 529.3	121.2, 305.6
Dec.	704.3	404.7	363.3	225.5	179.7, 541.5	129.6, 324.9
Jan.	603.0	394.5	266.4	184.5	177.0, 432.2	85.7, 276.0
Feb.	550.7	378.6	292.1	162.9	98.2, 444.3	150.2, 265.5
Mar.	584.1	401.2	272.0	180.5	179.0, 420.9	87.4, 275.4
Apr.	536.4	384.7	255.5	180.2	167.4, 392.9	97.1, 279.3
May	581.4	402.5	321.2	182.6	166.9, 461.1	88.2, 278.8
Jun.	593.7	405.6	304.4	180.8	146.4, 443.0	92.5, 283.8
Jul.	542.2	314.8	255.6	154.5	169.1, 420.7	76.4, 229.0

sampling rather than a sequence in which to sample. If the budget permit, one could sample simultaneously at all first and second hierarchy sites, then third hierarchy sites would be added, and so on, where sampling at additional hierarchies in effect steadily improves the resolutions of the picture obtained of the whole river network. Increasing levels of hierarchy correspond to decreasing levels of sampling priority when trying to isolate a pollutant source.

It must be emphasized that the locations of sampling stations determined above are not to be strictly applied. Engineering judgement may require that they may be moved some distance upstream or downstream in the vicinity of the computed order numbers. As pointed out earlier the method used here in specifying locations provides only guidelines instead of strict rules in pin-pointing the appropriate sampling sites.

It must also be noted that different designers may end up with different networks even if they apply the same procedure mentioned above . The reasons may be several. For example, the selection of the first exterior tributaries may significantly affect the stream orders. However this subjective aspect of method may be minimized by judging on the basis of mean minimum flow, minimum area of recharge basin or other similar quantitative criteria. Another reason may be the scale of map used, which also affects the choice of tributaries and hence location of the sampling sites.

6.0 RESULT AND DISCUSSION :

6.1 Temporal Water Quality Variation :

Monthly water quality variations for each site is plotted in Fig.4 to Fig.12. Water quality index for both the situations including and excluding phosphate in the index parameters is plotted. Following observations are made on studying the various plots:

i) At sites no.1 to 7, Phosphate is a major cause of water quality deterioration. This fact is clearly shown from Fig.4 to Fig.10 that overall water quality index containing phosphate is significantly below the overall water quality index excluding phosphate indicating phosphate is quite high at those sites which is responsible for the impairment in the water quality. It can be inferred that site no.1 to site no.7 are more susceptible to eutrophic conditions which may cause a serious water quality problem like depletion of dissolved oxygen and consequently impair water for both human and aquatic use.

Furthermore, there is a seasonal trend in the water quality deterioration due to phosphate. Phosphate related impairment is more pronounced from 3rd month (i.e. November) to 7th month (March) which suggest that intensive monitoring is needed to monitor water quality from site no.3 to 7 in this particular season so that preventive measure could be taken when needed. Site 6 is found to be more sensitive to the phosphate pollution as water quality is significantly low at this site.

ii) At site no. 8 to 9 (Fig.11 & 12), the overall water quality is not so bad as of site no. 1 to 7. At site no. 7 also water quality is good after 5th month (i.e. January). As both the indices i.e. including and excluding phosphate are more or less same which indicate that there is no problem related to phosphate and hence these sites are not eutrophic susceptible sites. The water quality index with or without phosphate is about 0.6 which is quite ok for aquatic life and ecosystem of the river. However, it should be treated if one wants to use it for human consumption.

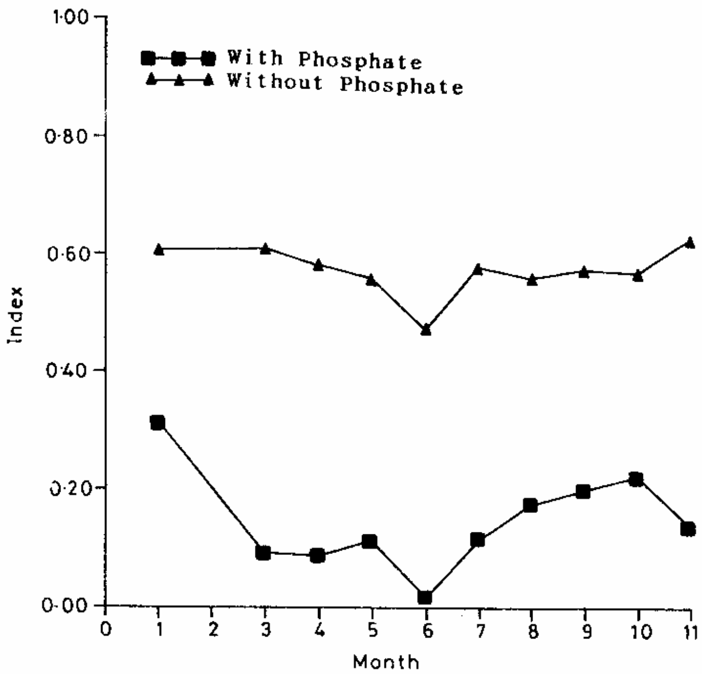

FIG.4 : MONTHLY VARIATION IN WATER QUALITY AT EXISTING SITE NO.1

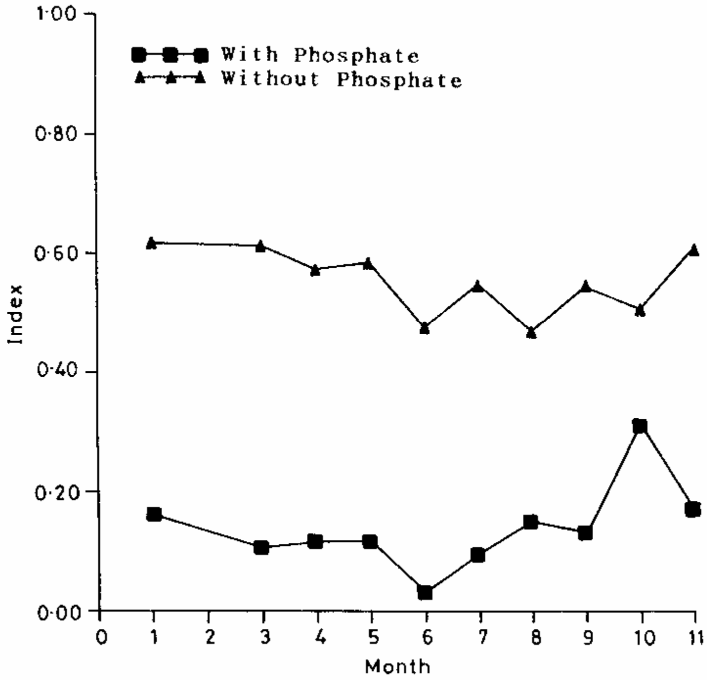

FIG.5 : MONTHLY VARIATION IN WATER QUALITY AT EXISTING SITE NO.2

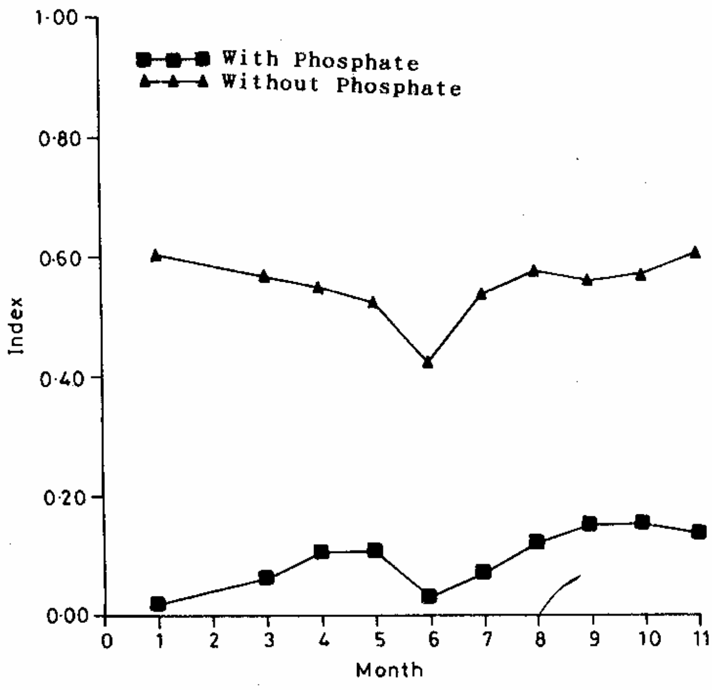

FIG.6 : MONTHLY VARIATION IN WATER QUALITY AT EXISTING SITE NO.3

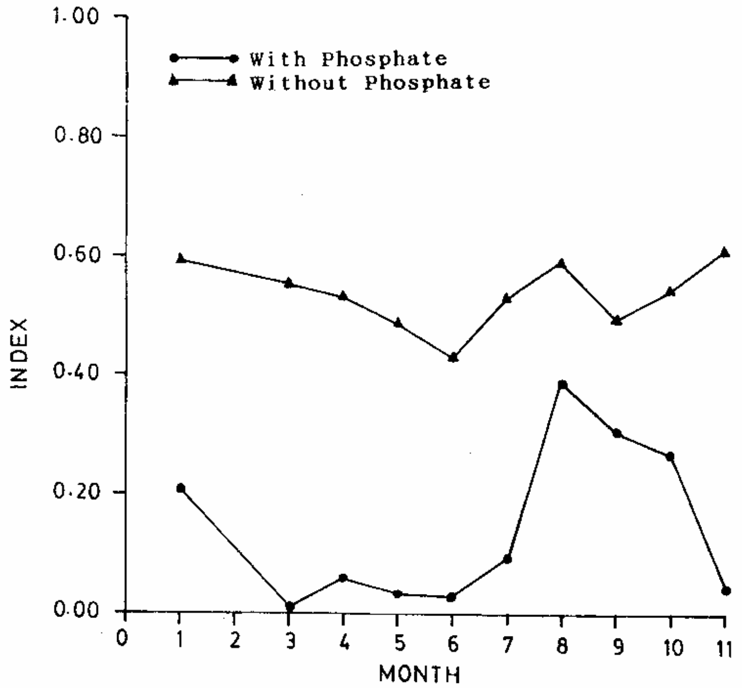

FIG.7 : MONTHLY VARIATION IN WATER QUALITY AT EXISTING SITE NO.4

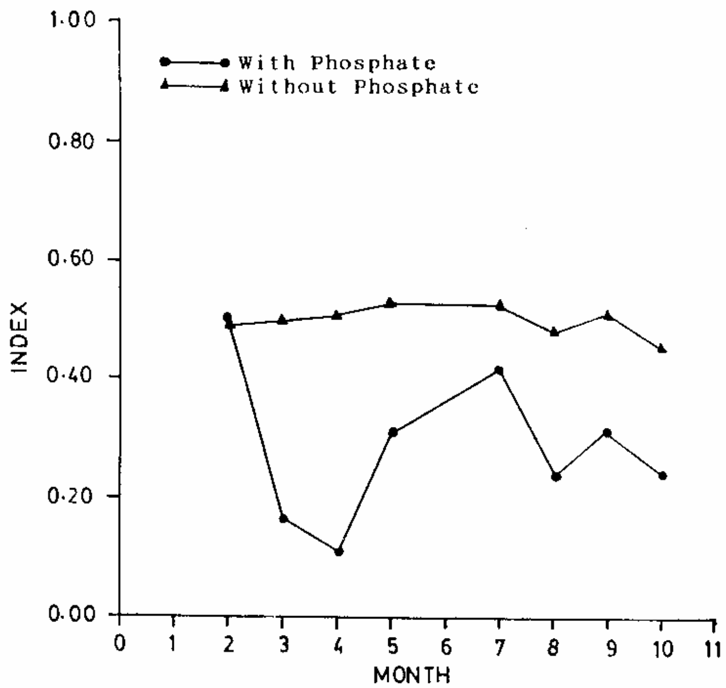

FIG.8 : MONTHLY VARIATION IN WATER QUALITY AT EXISTING SITE NO.5

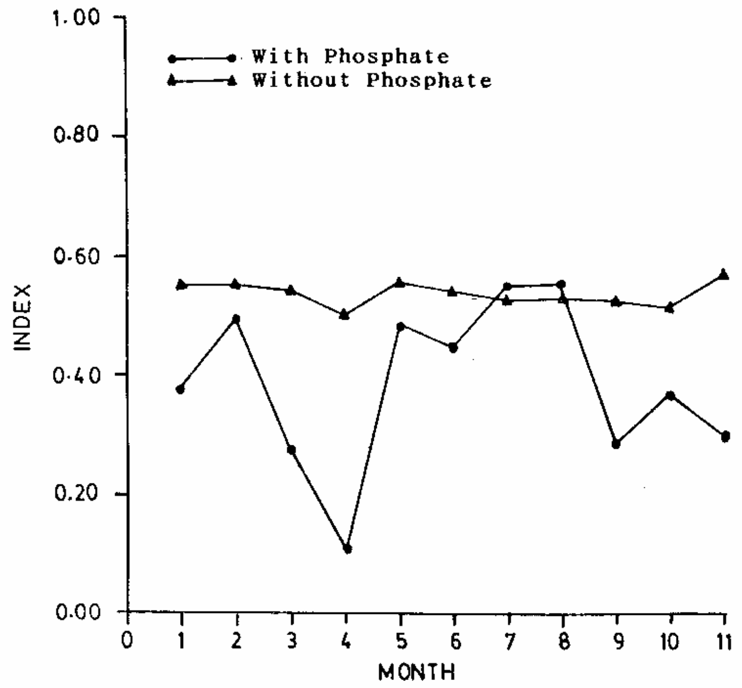

FIG.9 : MONTHLY VARIATION IN WATER QUALITY AT EXISTING SITE NO.6

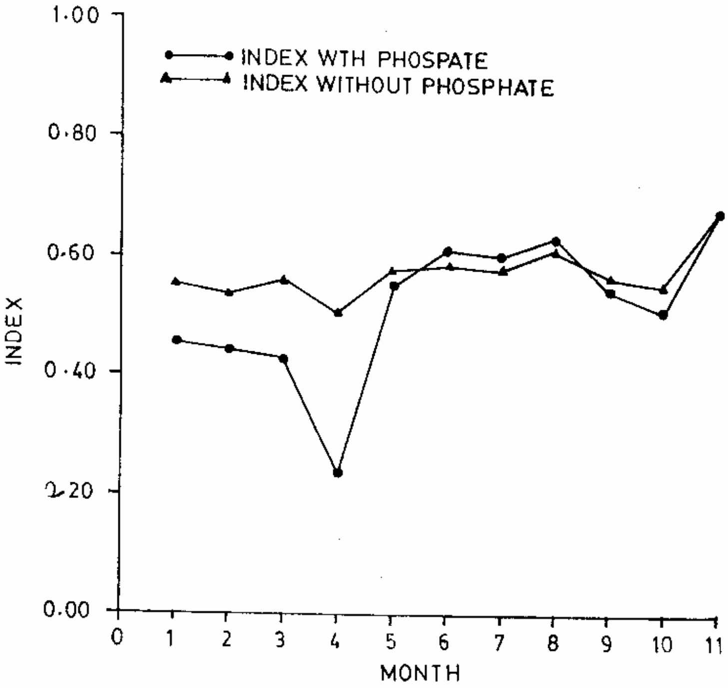

FIG.10: MONTHLY VARIATION IN WATER QUALITY AT EXISTING SITE NO.7

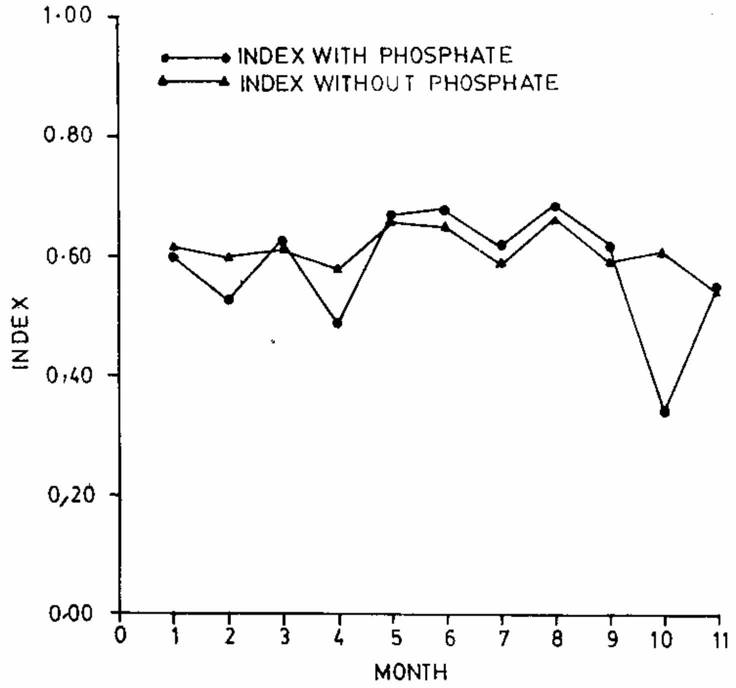

FIG.11: MONTHLY VARIATION IN WATER QUALITY AT EXISTING SITE NO.8

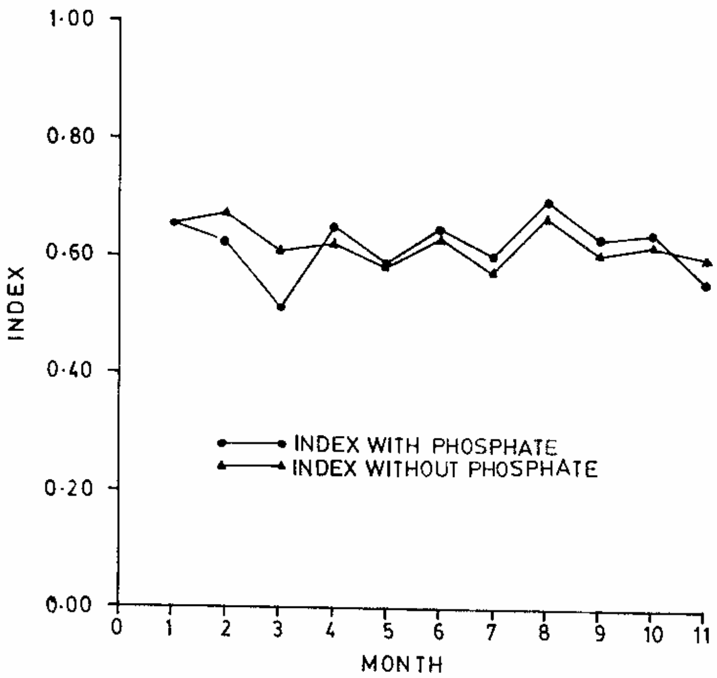

FIG.12: MONTHLY VARIATION IN WATER QUALITY AT EXISTING SITE NO.9

iii) As far as monitoring is concerned, first 7 sites should have more water quality monitoring sites. At sites no.8 and 9, one may even drop those stations as there is no seasonal water quality impairment at these sites. It may be possible that whatever pollution is present at these sites, may be it is due to the predecessor sites. However, to a certain that a single monitoring site may be sufficient to serve this purpose.

6.2 Spatial Variation in Water Quality in different months :

Spatial water quality variation is demonstrated for each month in Fig.13 to Fig.23. Following facts can be drawn on studying these plots :

i) First four sites are worst affected by the phosphate related pollution throughout the year. The water quality index shows that winter season is more critical than the other period of the year. This fact suggests that first four sites must be very closely monitored so that the cause and preventive measures could be taken up.

ii) At site no. 7 and 8, water quality is not affected by the phosphate, whatever water quality impairment is present at these sites, this may be due to other constituents. Phosphate pollution is seen up to site no.7. However from site no. 5 and onwards it is seen that effect of phosphate is going on decreasing and water recovers from phosphate pollution at site no.7.

From the above discussion, it can be concluded that first priority of setting monitoring sites should be between site no.1 and site no.4 and the second priority should be between site no.4 and site no.7 and the last priority should be between site no.7 and site no.8.

6.3 Identification of Macrolocations for Water Quality Monitoring of Kshipra River :

Sharp's procedure (1971) had been successfully used in the allocation of sampling sites on a river by a number of research workers. The method is originally based on Horton's stream

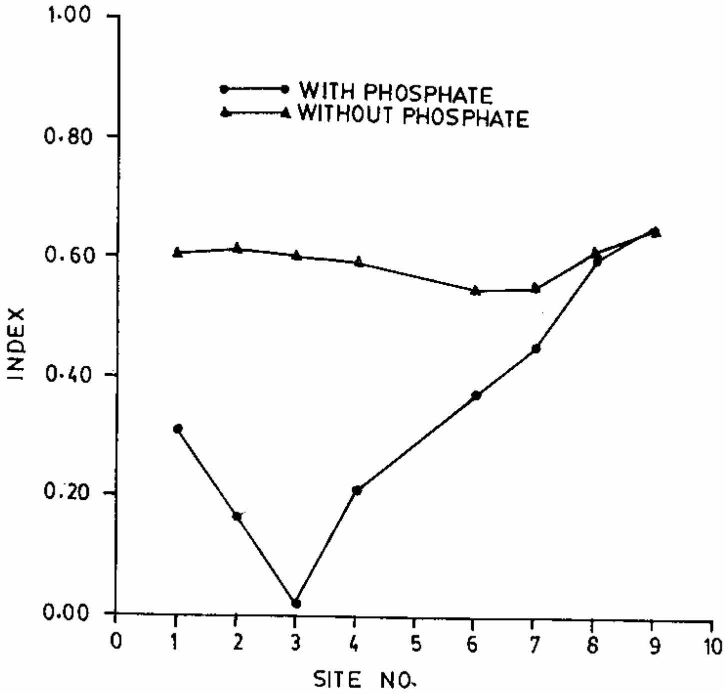

FIG. 13: WATER QUALITY VARIATION AT DIFFERENT SITES IN THE MONTH OF SEPTEMBER

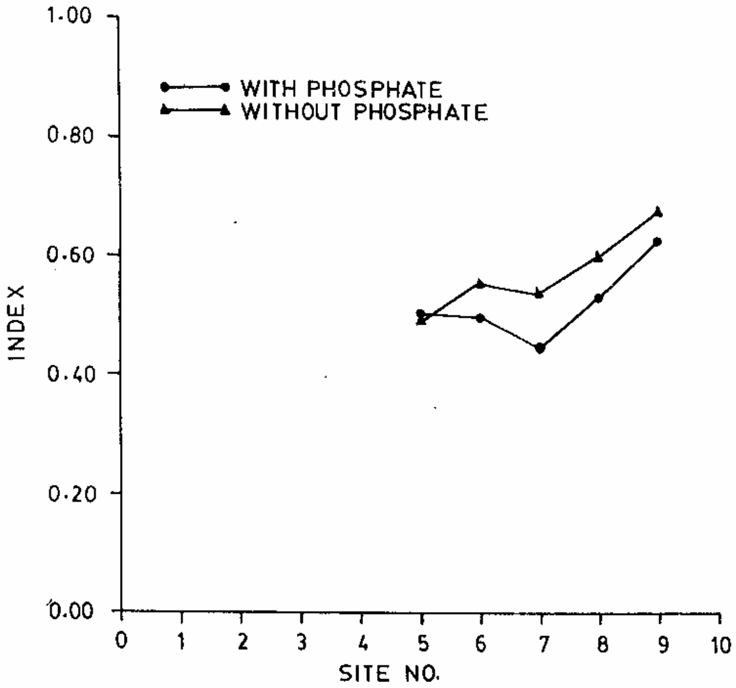

FIG. 14: WATER QUALITY VARIATION AT DIFFERENT SITES IN THE MONTH OF OCTOBER

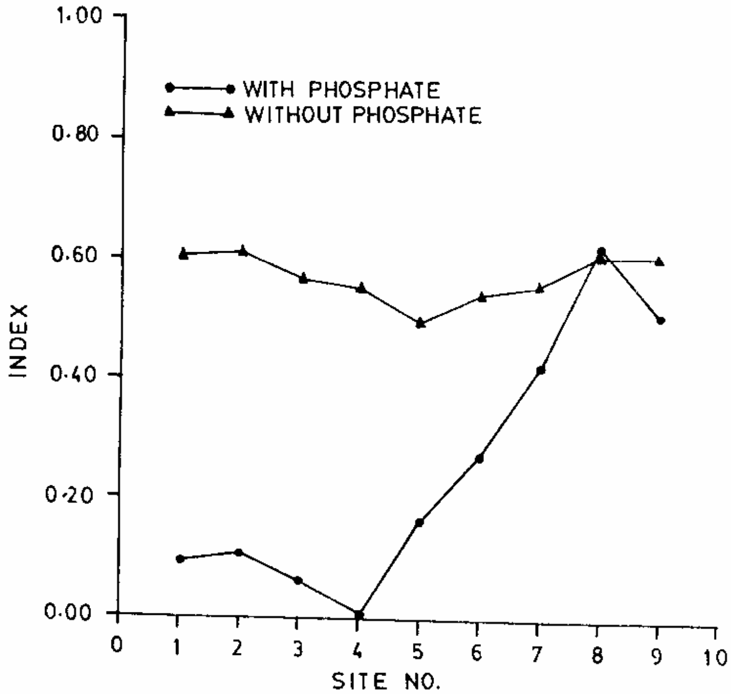

FIG.15: WATER QUALITY VARIATION AT DIFFERENT SITES IN THE MONTH OF NOVEMBER

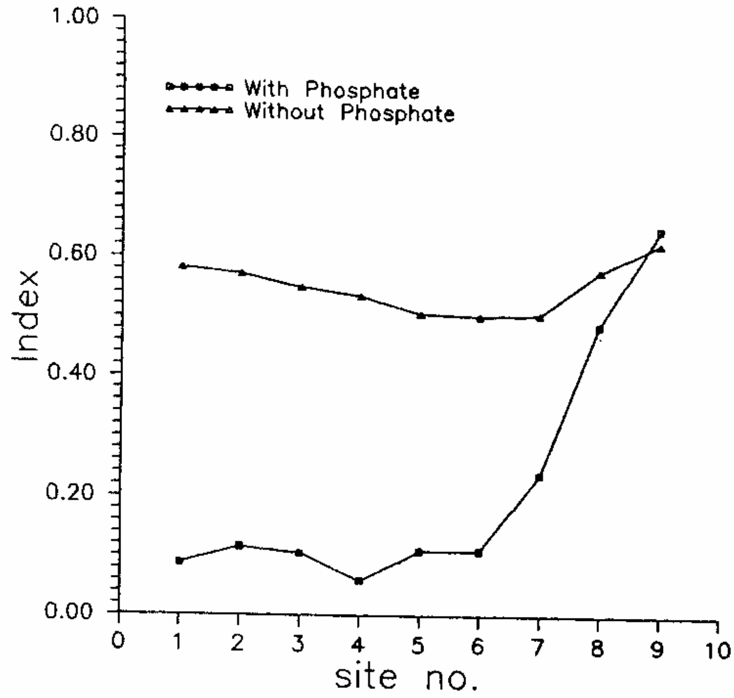

FIG.16: WATER QUALITY VARIATION AT DIFFERENT SITES IN THE MONTH OF DECEMBER

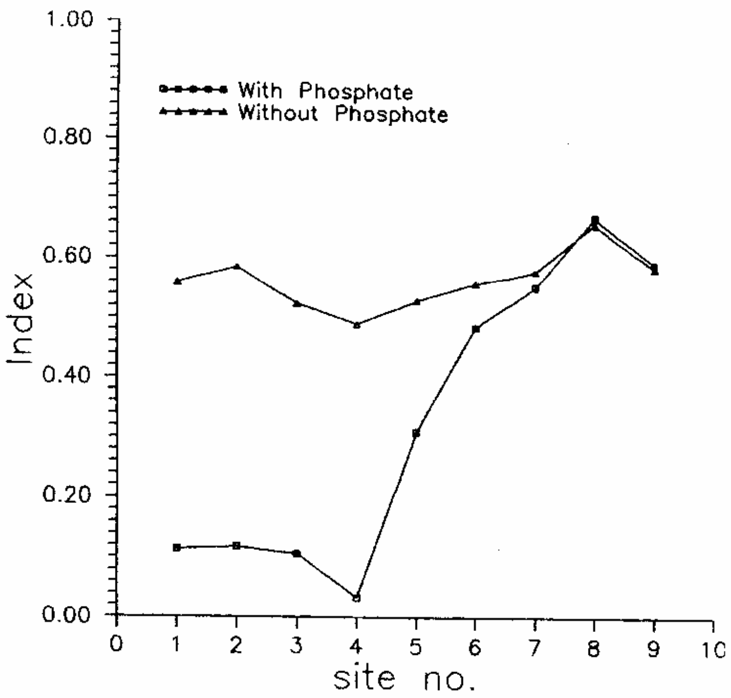

FIG.17: WATER QUALITY VARIATION AT DIFFERENT SITES IN THE MONTH OF JANUARY

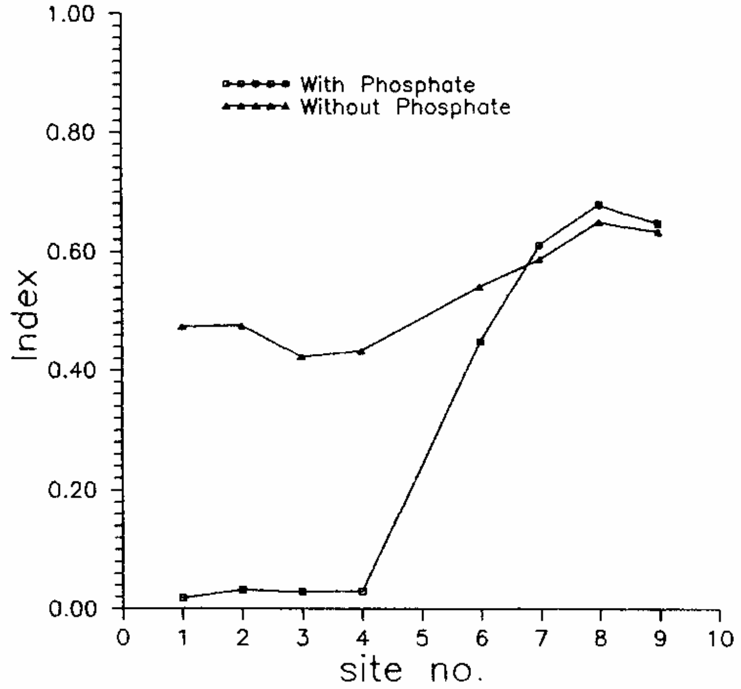

FIG.18: WATER QUALITY VARIATION AT DIFFERENT SITES IN THE MONTH OF FEBRUARY

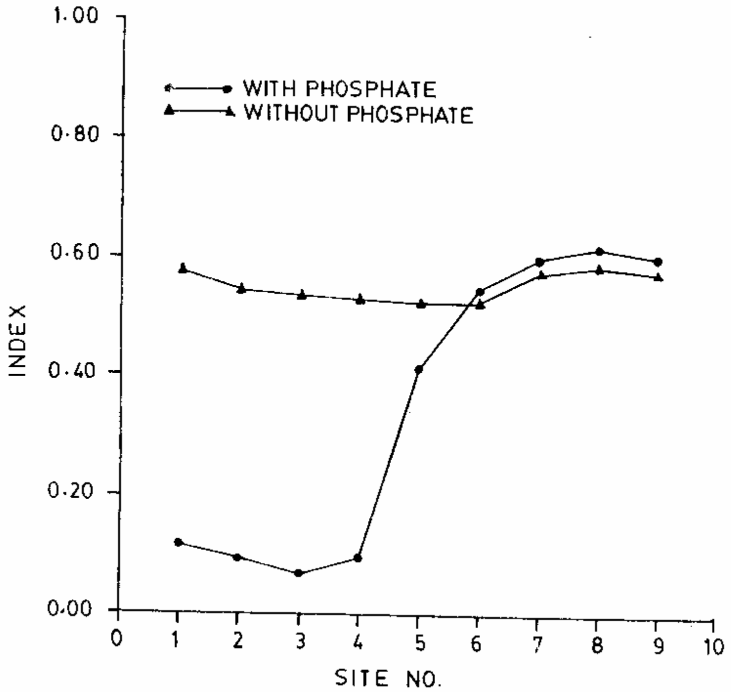

FIG.19: WATER QUALITY VARIATION AT DIFFERENT SITES IN THE MONTH OF MARCH

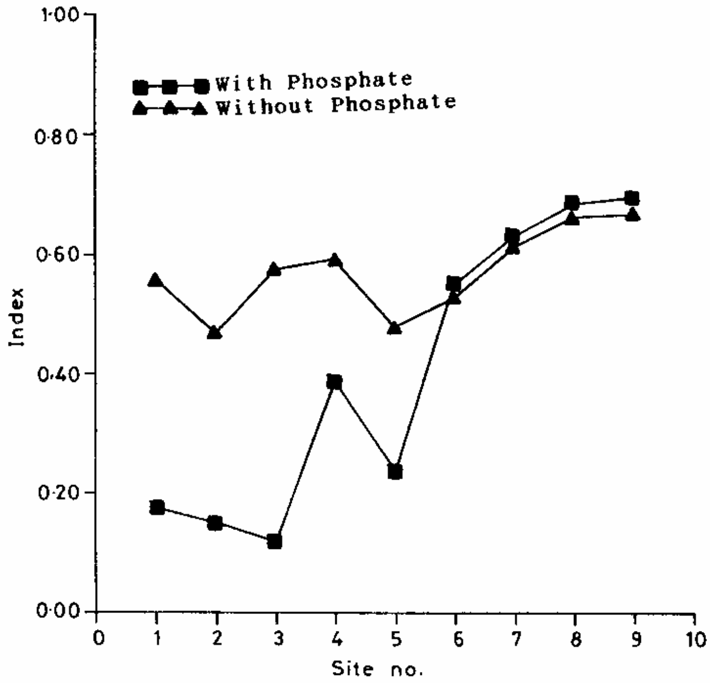

FIG.20: WATER QUALITY VARIATION AT DIFFERENT SITES IN THE MONTH OF APRIL

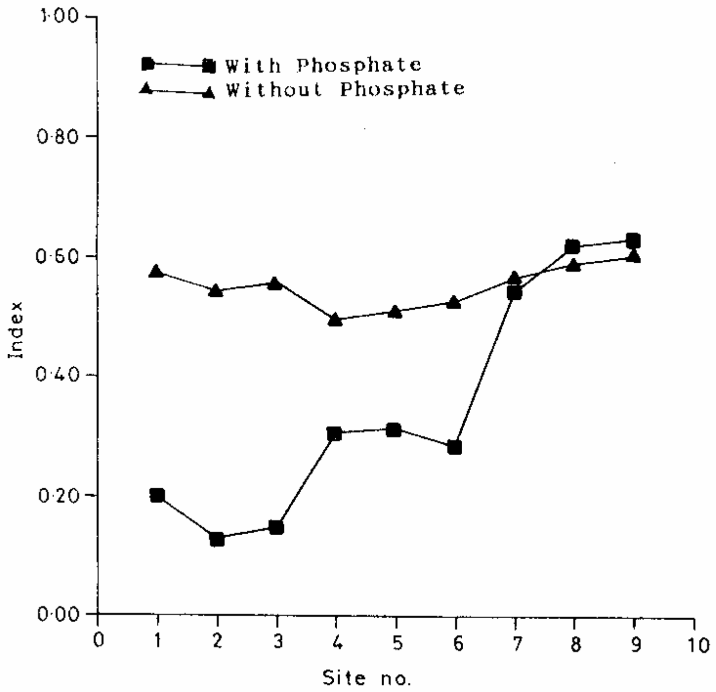

FIG.21: WATER QUALITY VARIATION AT DIFFERENT SITES IN THE MONTH OF MAY

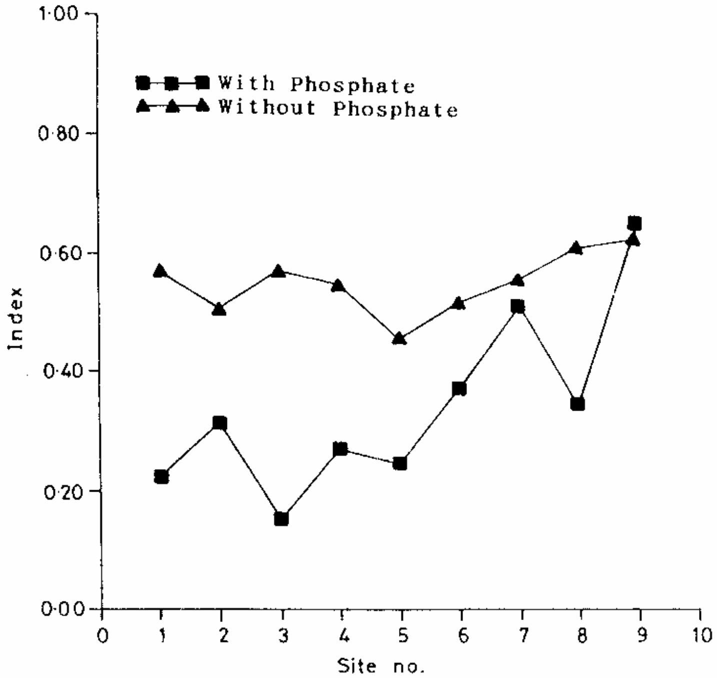

FIG.22: WATER QUALITY VARIATION AT DIFFERENT SITES IN THE MONTH OF JUNE

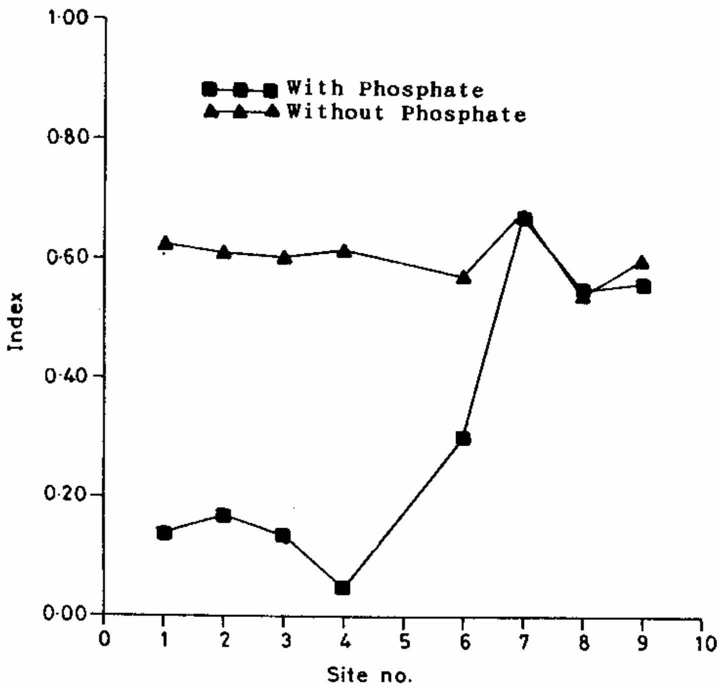

FIG.23: WATER QUALITY VARIATION AT DIFFERENT SITES IN THE MONTH OF JULY

ordering procedure (Horton,1945) to describe a stream network. Sharp(1970) used Horton's approach to measure the uncertainty involved in locating the source of pollutants observed at the outlet of a network. Sanders et al. (1983) followed Sharp's procedure by selecting sampling sites on the basis of the number of contributing tributaries. Further in 1971, he modified the same method by considering the pollutant discharge (BOD loading etc.) as external tributaries.

In the present study various water quality parameters were measured on monthly basis at nine different location on the Kshipra river for one year. The flow data is not available. In this situation, the pollutant loading can not be calculated. Now question arises how one can use this available data for justifying the existing monitoring sites i.e. whether existing sampling sites are adequate, inadequate or some of the sites are unnecessary. To answer these question it is essential to locate the sampling sites on the basis of the available data.

For this purpose the same method(Sharp, 1971) is applied by considering the pollution index (derived from water quality index as tabulated in Table-4)of the pollution discharged by the external tributaries. The monitoring sites are identified for both the situation of including and excluding phosphate. Fig.24 to Fig.33 shows the proposed network of sequential monitoring water quality sites on the Kshipra river from September to June. The existing monitoring location have also been shown on the maps. The proposed monthly locations are summarised in tabuler form as presented in Table-6 and Table-7.

From Table-6, it can be concluded that 5 sampling sites are required to get the adequate water quality information. These sites are :- existing site no.9, u/s of 4, d/s of 4, d/s of 2 and d/s of 6. On the other hand, when phosphate is not considered, the Table-7 gives the 4 sampling sites as:- site no.9, d/s of 4, d/s of 2, and d/s of 6.

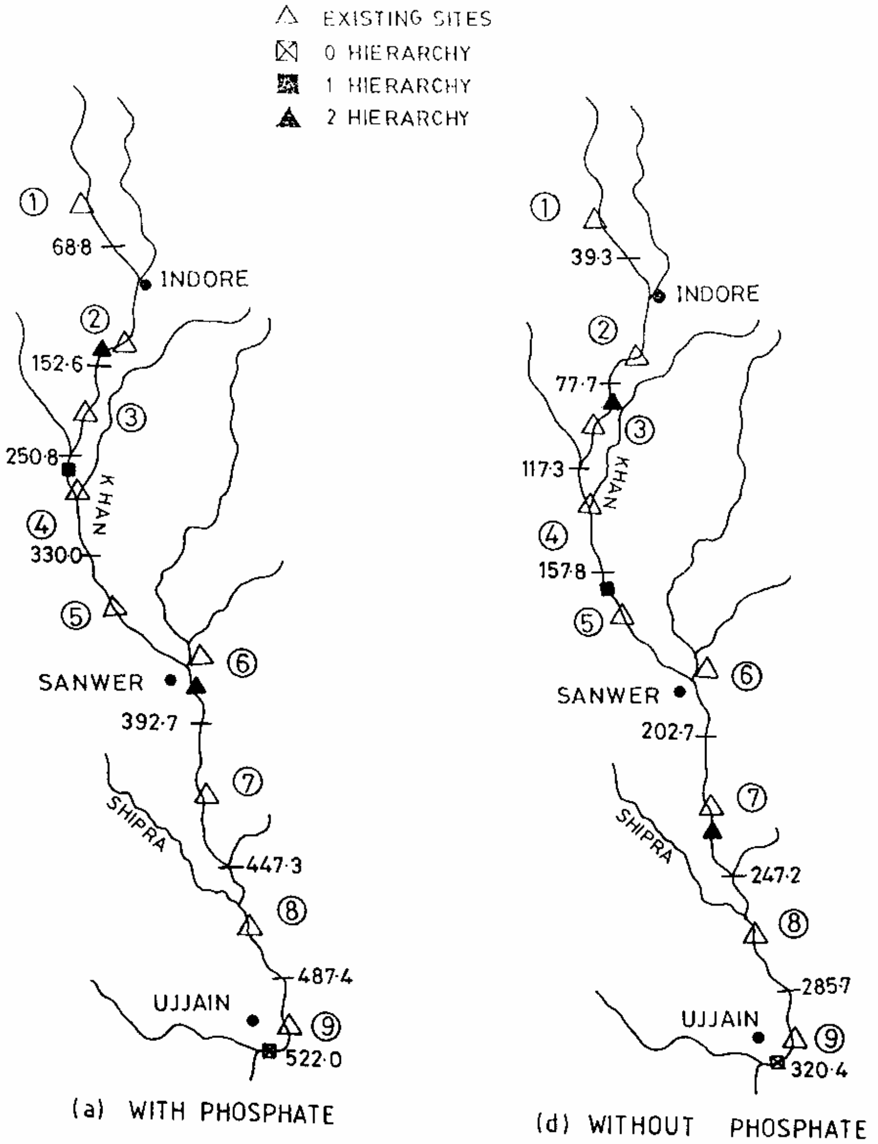

FIG.24. NETWORK OF SEQUENTIAL MONITORING WATER QUALITY SITES ON THE BASIS OF INDEX FOR THE MONTH OF SEPTEMBER

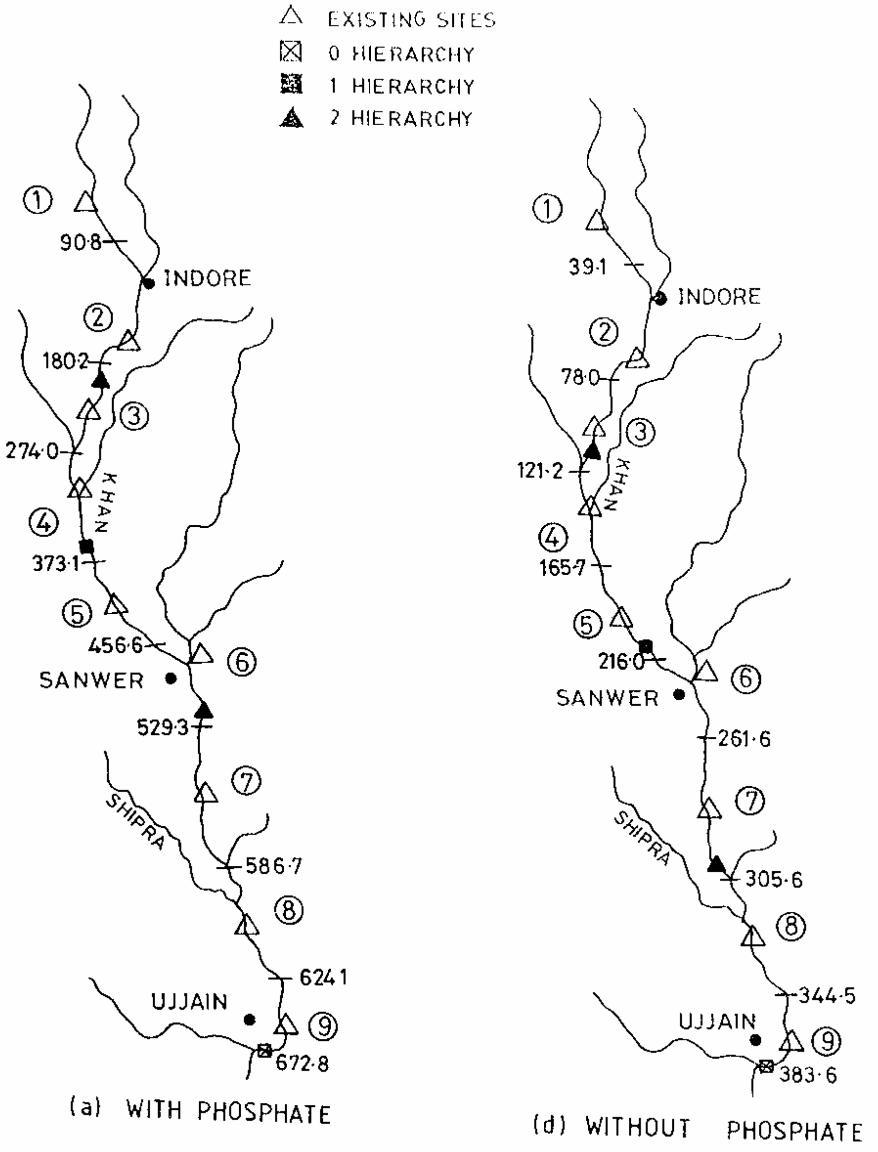

FIG.25. NETWORK OF SEQUENTIAL MONITORING WATER QUALITY SITES ON THE BASIS OF INDEX FOR THE MONTH OF NOVEMBER

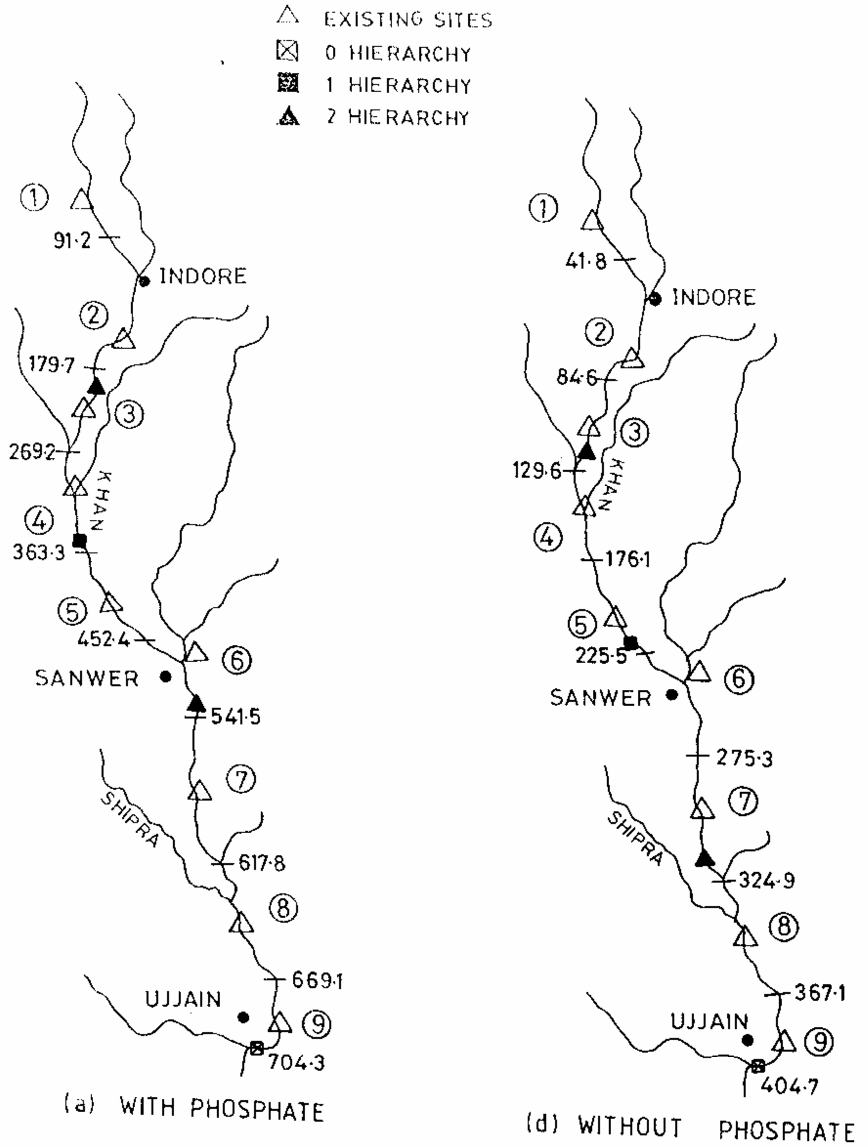

FIG26 NETWORK OF SEQUENTIAL MONITORING WATER QUALITY SITES ON THE BASIS OF INDEX FOR THE MONTH OF DECEMBER

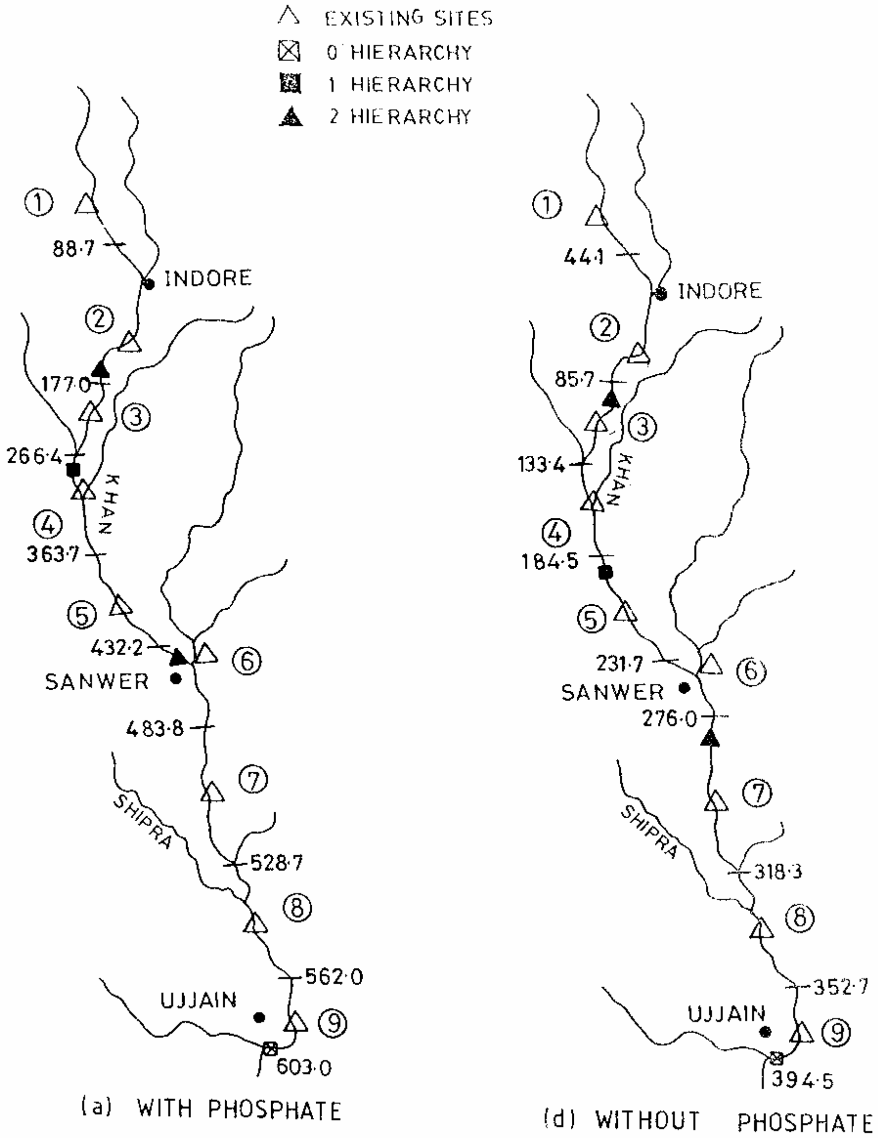

FIG.27 NETWORK OF SEQUENTIAL MONITORING WATER QUALITY SITES ON THE BASIS OF INDEX FOR THE MONTH OF JANUARY

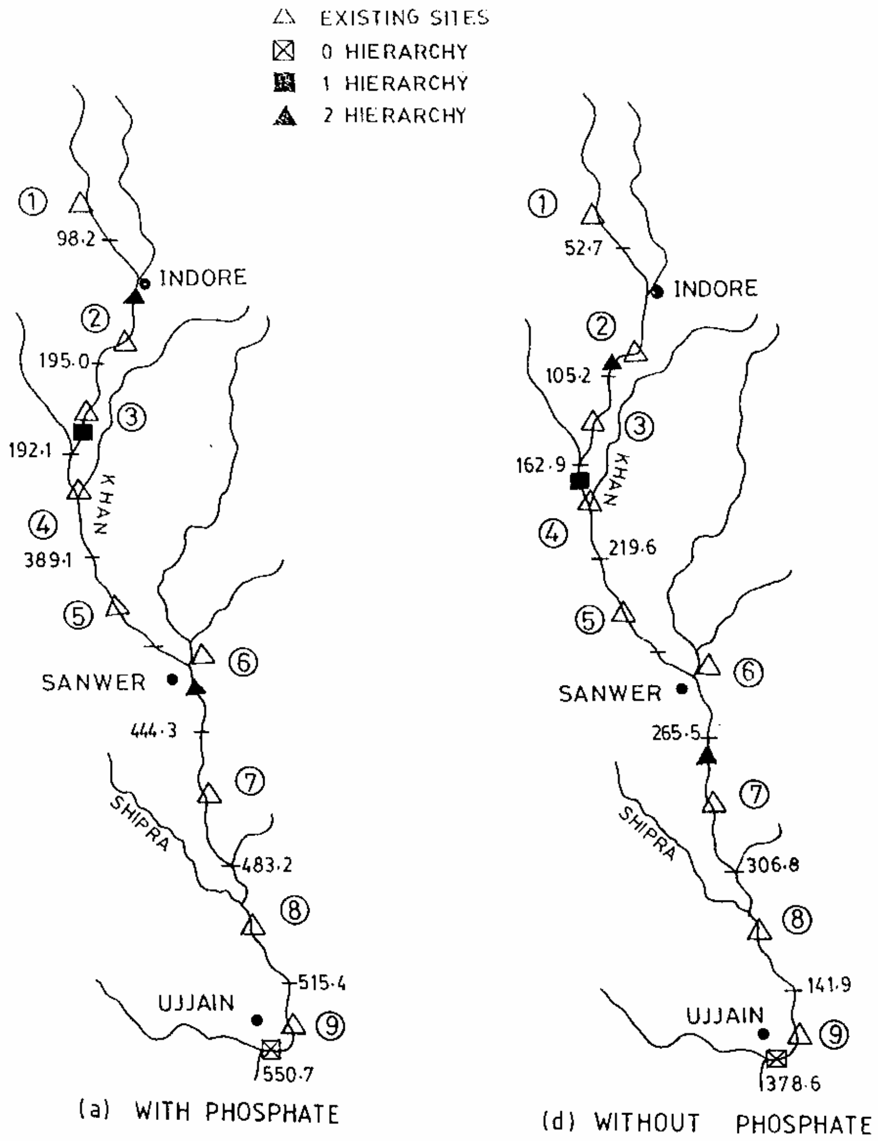

FIG.28 NETWORK OF SEQUENTIAL MONITORING WATER QUALITY SITES ON THE BASIS OF INDEX FOR THE MONTH OF FEBRUARY

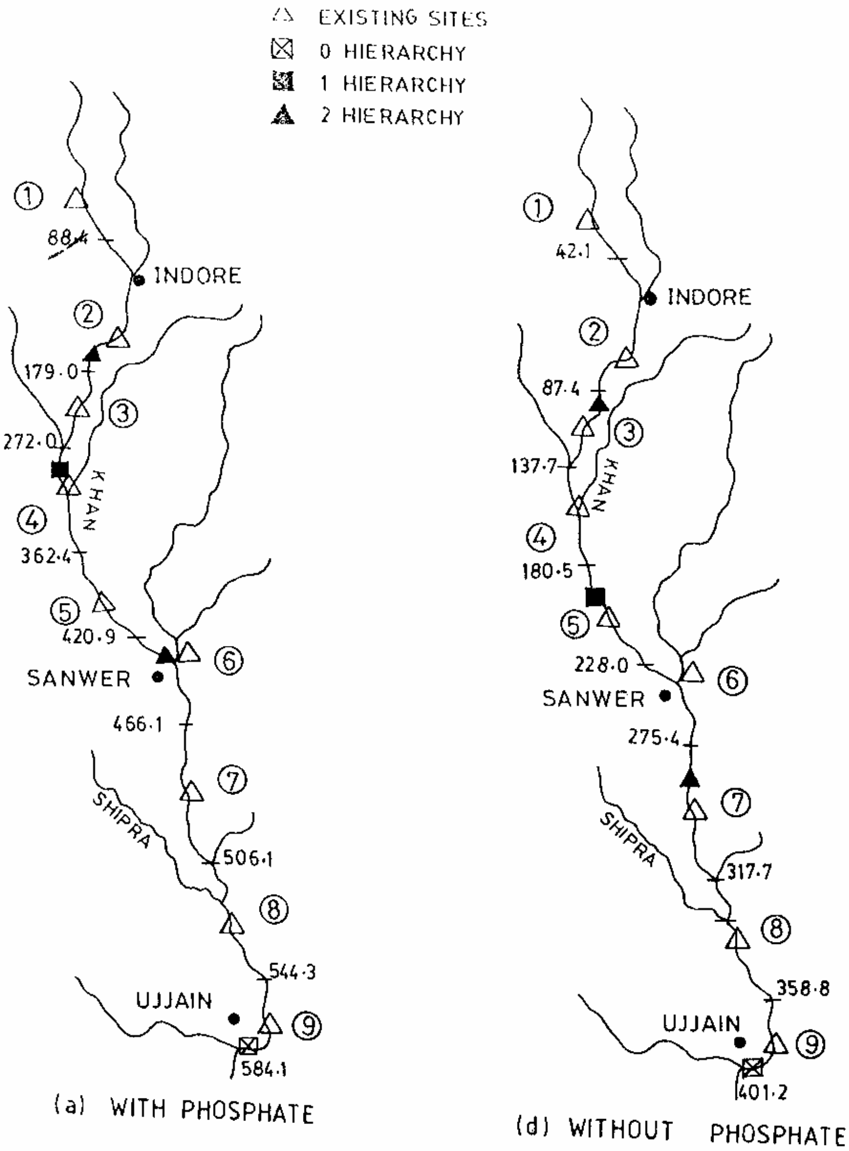

FIG.29. NETWORK OF SEQUENTIAL MONITORING WATER QUALITY SITES ON THE BASIS OF INDEX FOR THE MONTH OF MARCH

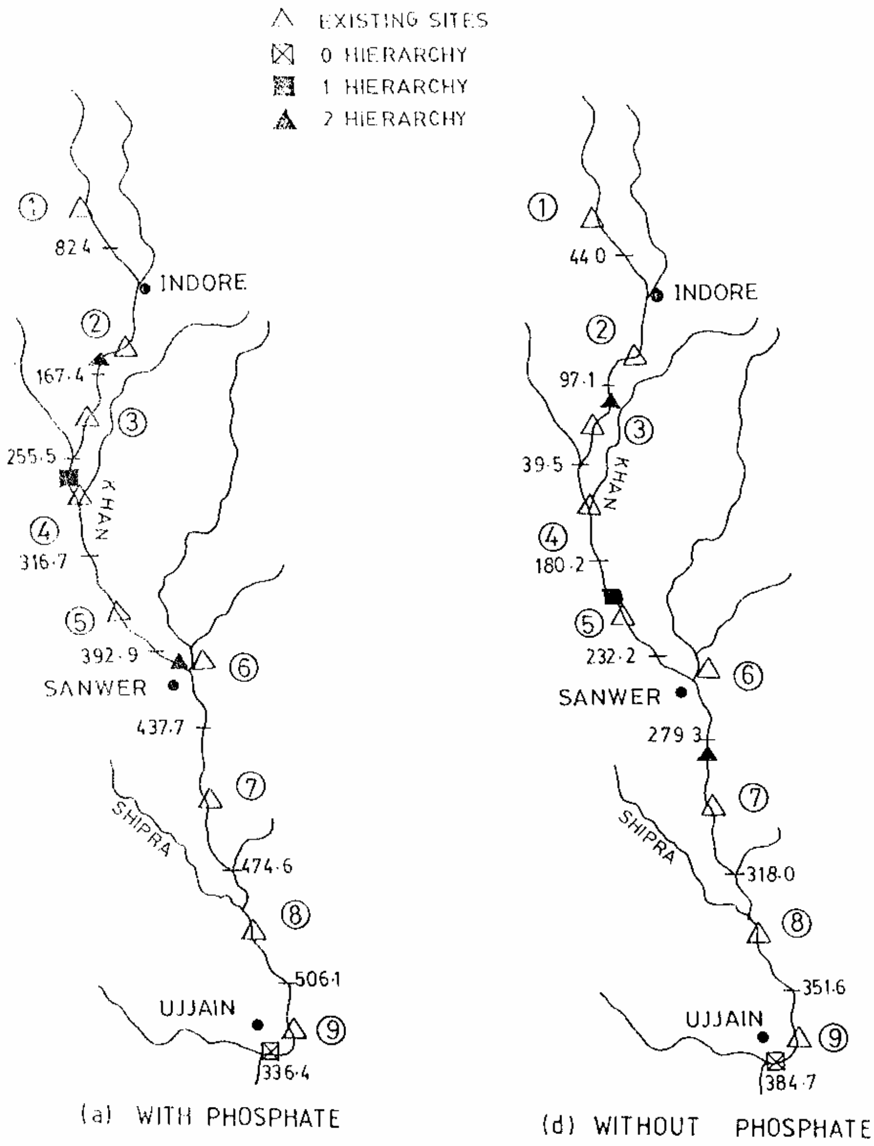

FIG.30 NETWORK OF SEQUENTIAL MONITORING WATER QUALITY SITES ON THE BASIS OF INDEX FOR THE MONTH OF APRIL

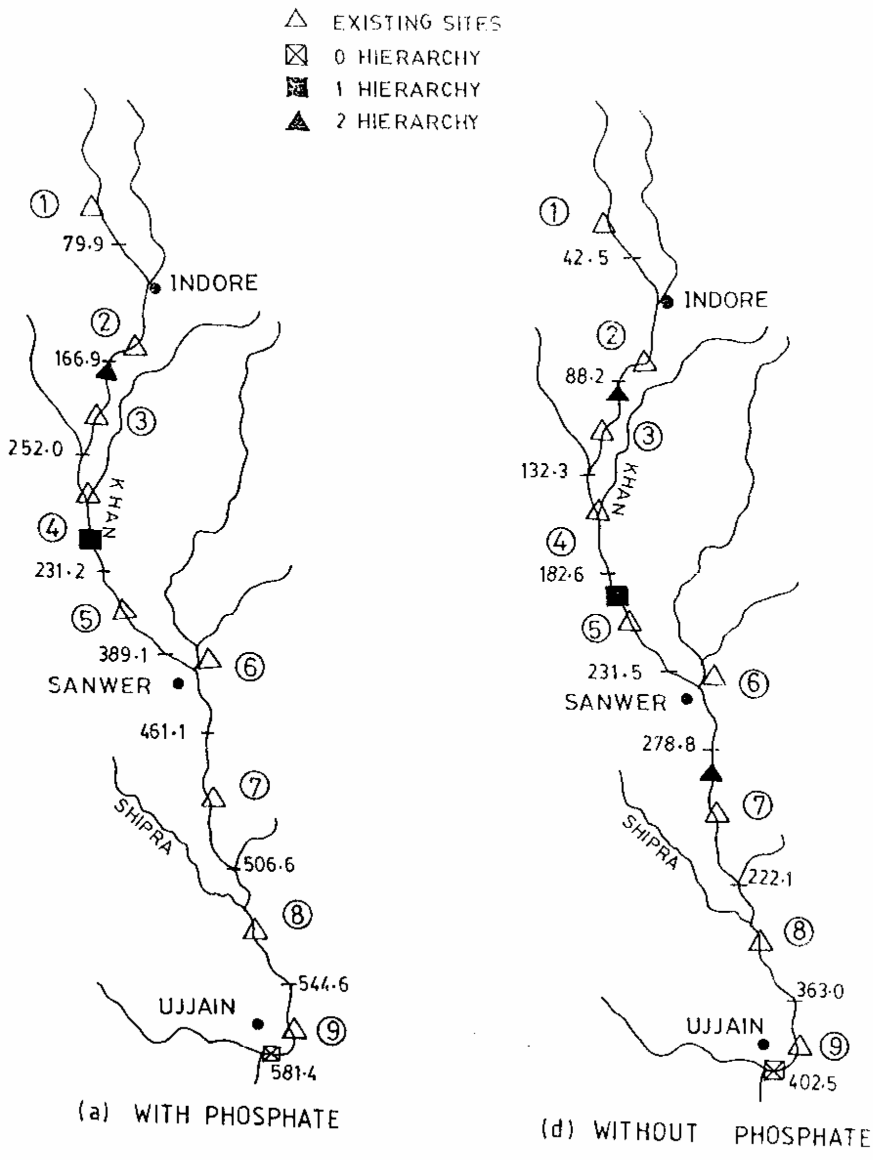

FIG.31. NETWORK OF SEQUENTIAL MONITORING WATER QUALITY SITES ON THE BASIS OF INDEX FOR THE MONTH OF MAY

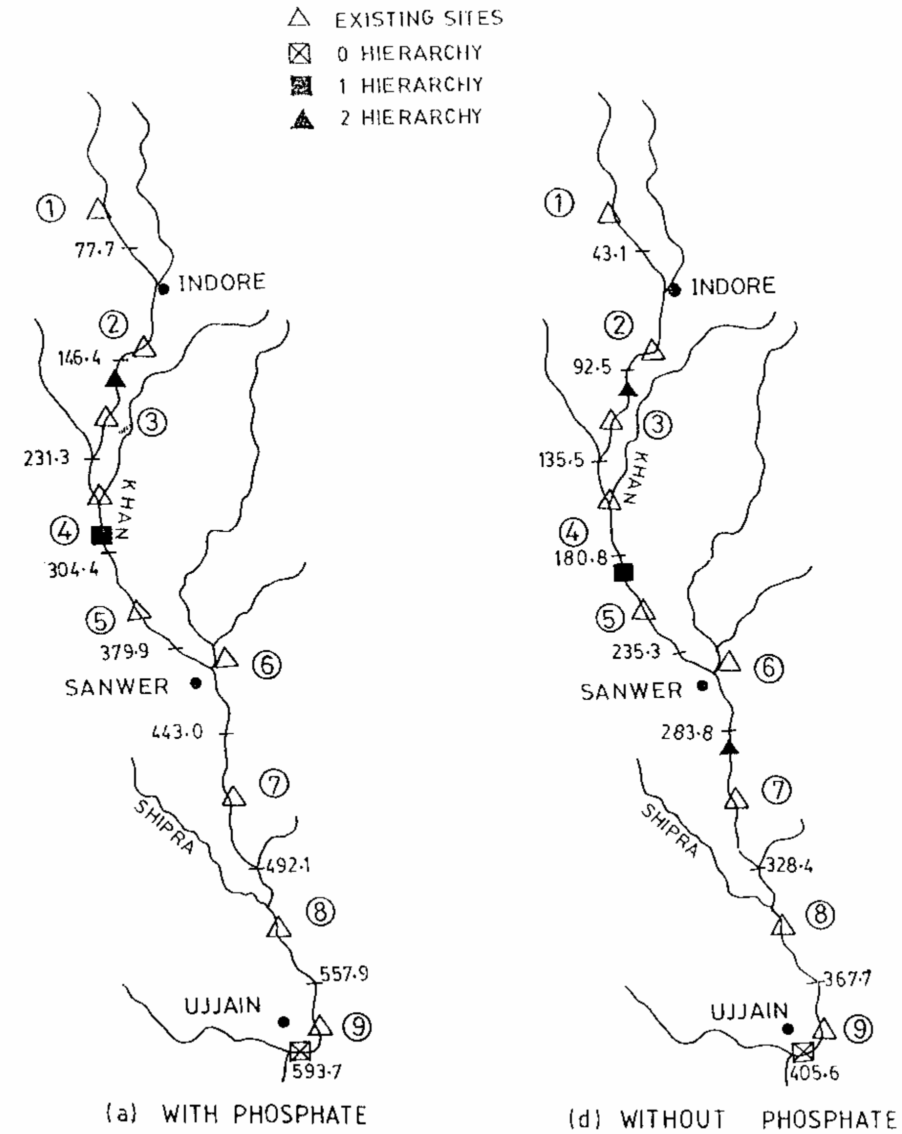

FIG.32. NETWORK OF SEQUENTIAL MONITORING WATER QUALITY SITES ON THE BASIS OF INDEX FOR THE MONTH OF JUNE

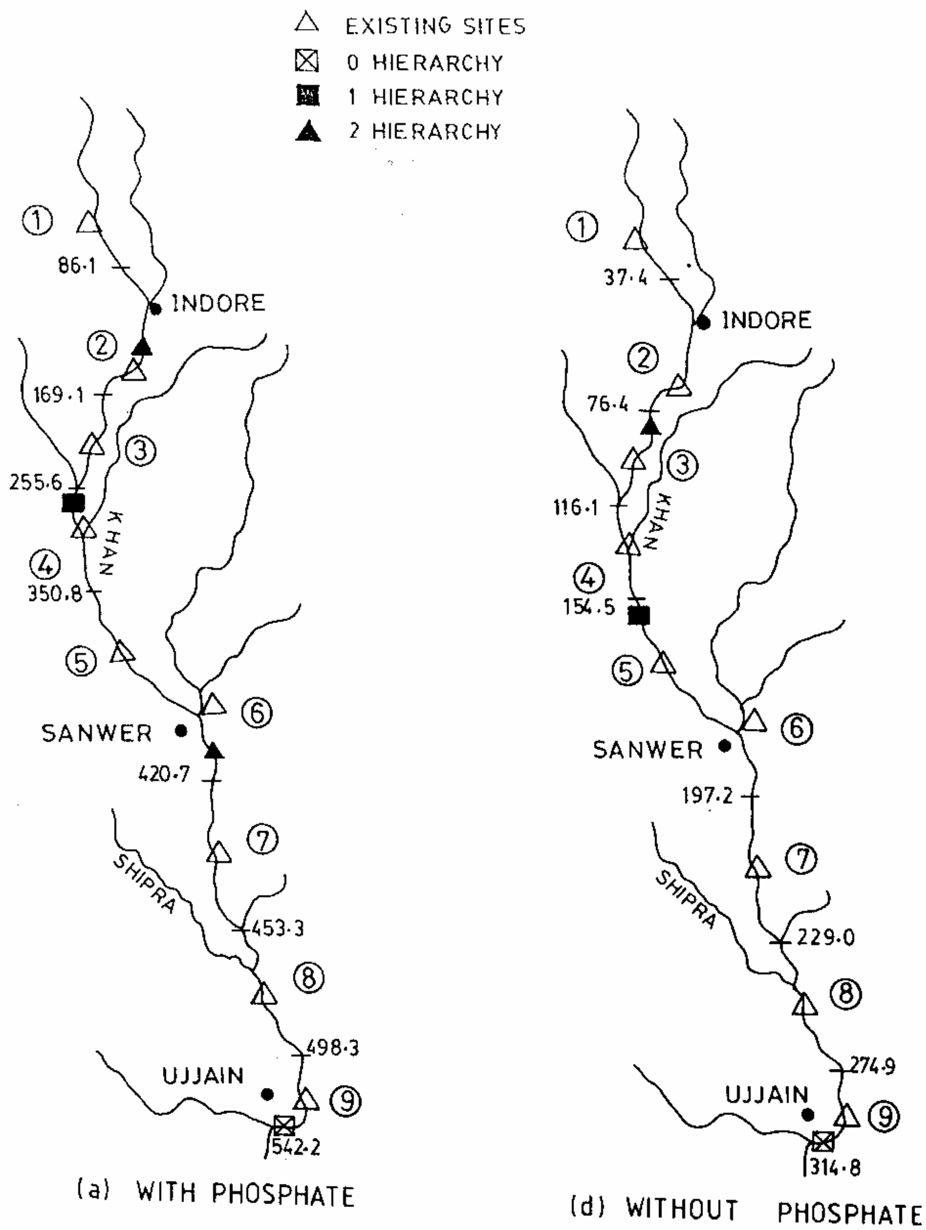

FIG.33. NETWORK OF SEQUENTIAL MONITORING WATER QUALITY SITES ON THE BASIS OF INDEX FOR THE MONTH OF JULY

Table-6 : Proposed Monitoring Sites in different months (with Phosphate)

Month	Hierarchy		
	0	1	2
Sept.	9	u/s of 4	d/s of 2, d/s of 6
Oct.			
Nov.	9	d/s of 4	d/s of 2, d/s of 6
Dec.	9	d/s of 4	d/s of 2, d/s of 6
Jan.	9	u/s of 4	d/s of 2, u/s of 6
Feb.	9	u/s of 4	u/s of 2, d/s of 6
Mar.	9	u/s of 4	d/s of 2, u/s of 6
Apr.	9	u/s of 4	d/s of 2, u/s of 6
May	9	d/s of 4	d/s of 2, d/s of 6
Jun.	9	d/s of 4	d/s of 2, d/s of 6
Jul.	9	u/s of 4	d/s of 2, d/s of 6

Table-7 : Proposed Monitoring Sites in different months (without Phosphate)

Month	Hierarchy		
	0	1	2
Sept.	9	d/s of 4	d/s of 2, d/s of 6
Oct.			
Nov.	9	d/s of 5	d/s of 3, d/s of 7
Dec.	9	d/s of 5	d/s of 3, d/s of 7
Jan.	9	d/s of 4	d/s of 2, d/s of 6
Feb.	9	u/s of 4	d/s of 2, d/s of 6
Mar.	9	d/s of 4	d/s of 2, d/s of 6
Apr.	9	d/s of 4	d/s of 2, d/s of 6
May	9	d/s of 4	d/s of 2, d/s of 6
Jun.	9	d/s of 4	d/s of 2, d/s of 6
Jul.	9	d/s of 4	d/s of 2, d/s of 7

6.4 Limitation of the Study :

The present study has certain limitations which are given below :

i) Effect of meandering has not been taken into account.

ii) Because of availablity of data, the study has been carried out on River Kshipra which is having several dams and other controlling structures, however better results can be obtained by taking a virgin river which would provide excellent exhibition of Sharp's method.

iii) The indexing system adopted in the report can also be improved to take into account some more parameters.

7.0 CONCLUSION:

Following conclusions are drawn from the present study:

7.1 Seasonal effect:

It is seen that there is a water quality problems throughout the year. The problem get aggravated in the winter season.

7.2 Eutrophic Condition

The phosphate is the major cause for the water quality problems. Sites no.1 to no.4 are seen more affected by the phosphate pollution and its effect decrease up to site no.7 and sites no.8 and no.9 the effect is minimum.

7.3 Temporal and Spatial Variations

From the temporal and spatial variations in water quality and the sharp's procedure it is seen that upper reaches should have more water quality monitoring sites than the lower reaches. It is proposed that sampling should be made at the following sites - Site no.9, Site no.3, Site no.4, Site no.5, and Site no.7. Therefore, one can discontinue the sampling at site no.1, Site no.2, Site no.6, and at Site no.8 without compromising much information if funds are limited.

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