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REGIONALIZATION IN WATER POLLUTION ABATEMENT PROGRAMMES

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I INTRODUCTION

With the shift of public attention towards environmental problems there is a general awareness of the ecological impact of man's activities and a desire for the improvement of the physical environment we live in. In the technical aspects of the development of water pollution abatement programmes, emphasis is on the so-called three R's: regionalism, reliability and recycling.(1) On the other hand, regionalization is encouraged officially in the United States by providing an additional ten per cent of Federal grants for regional water pollution abatement projects. This increase often means millions of dollars for a single project. The same point was further emphasized in the Federal Guidelines on Design, Operation and Maintenance of Wastewater Treatment Facilities issued late in 1970.(2) According to the guidelines, regional approaches should be critically examined for every proposed project especially in connection with existing regional wastewater management plans and water quality requirements as well as economic, operational and other appropriate considerations. This Federal all-out support for regionalization will no doubt have pronounced effect on the shaping of water pollution control strategies for the decades to come in the United States. The United

States are not alone in adopting regional approaches as a means for optimizing pollution abatement programmes. In Western Europe, the International Commission for the Protection of the Rhine against Pollution was created to put the planning of pollution abatement programmes on a basin-wide basis long before the importance of stream pollution control was realized in other parts of the world. The countries concerned include Switzerland, France, West Germany, Luxemburg and the Netherlands. The length of the river is 760 mi (1 230 km) and the population in the basin is more than 50 million. In order to maintain the water quality requirements of the region, it was found necessary to treat biologically the entire flow of 1 000 cfs (286 cu m/ses) of the Emscher River, a tributory of the Rhine, in the Ruhr district of West Germany.(3) Regionalization may take many different forms. Two possible extremes are: a number of separate sewerage systems operated by a simple authority on one end and a single connected sewer system serving several municipalities with one central treatment plant on the other. The latter will be the subject of the present study since this type of regional system has a greater impact on the management of water quality of the receiving stream. A word of caution has been expressed regarding the danger of the indiscriminate adoption of this kind of system. One point raised was that such a regional system replaces otherwise well distributed BOD (biochemical oxygen demand) loads from a number of smaller treatment plants along the receiving stream with a concentrated BOD load from the regional plant. This may have serious adverse effects on the stream quality.(4)

The purpose of the present presentation is to use a realistic example and a simulation technique

1) To demonstrate the effects of the regionalization of pollution abatement programmes on stream water quality; and

2) to explore and compare various alternatives from the viewpoint of water quality management as well as that of overall water resources utilization.

II STUDY AREA

The Connecticut River Basin was probably the most important area in the early stage of industrial development of the United States. Several major industries still operate along the Connecticut River and its tributaries. One of the manufacturing centres in the basin is the Holyoke-Springfield region in the State of Massachusetts. As shown in Figure 1 (Annex II), the study area includes four communities of this region: city of Springfield and towns of Ludlow, West Springfield, and Agawan. The combined 1970 census population within the study area was approximately 228 000. The present average daily wastewater flow is estimated to be 33 mgd. Industrial contributions amount to a third of the total flow.

There are three existing sewage treatment plants in the area: one in Ludlow for the town of Ludlow, one at Indian Orchard in Springfield serving the northern part of Springfield, and one at Boni Island handling wastewater from most of Springfield and the townships of West Springfield and Agawan. Both the Ludlow and Indian Orchard plants discharge effluent into the Chicopee River. The Bondi Island plant empties its effluent into the main stem near the confluence of the Westfield River. All three plants provide primary treatment only. The city of Springfield operates the Bondi Island and Indian Orchard plants and the town of Ludlow, the Ludlow plant. The city treats wastewater from West Springfield and Agawan on contract basis.

All four municipalities have been ordered by the State pollution control agency to upgrade their water pollution abatement facilities for achieving the state stream quality objectives on a fixed time schedule.

III STREAM QUALITY OBJECTIVES

As shown in Figure 1 (Annex II), the stretch of the main stem in Massachusetts has the following classifications: B above the Holyoke Dam and C below the dam. Figure 1 also shows the classifications for the tributaries relevant to the study.

The water quality of class B streams should be suitable for bathing and other recreational purposes including water contact sports, acceptable for public water supply with appropriate treatment, excellent as fish and wildlife habitat, and high in esthetic value. For Class C streams, the water should be suitable for recreational boating, acceptable under certain conditions for public water supply with appropriate treatment, habitat for wildlife and common food and game fish indigenous to the region, and good in esthetic value.(5)

The minimum DO (dissolved oxygen) requirements for Classes B and C are, respectively, 75 per cent saturation and 5 mg/l interpreted as the condition at the minimum average daily low flow for seven consecutive days expected once in ten years.(5)

The results of a pollution survey conducted by the State Water Pollution Control Division of Massachusetts in 1966 indicated that the stream DO below the above minimum values occurred quite frequently during low flow period.(6)

IV MODEL DESCRIPTION AND BASIC DATA

The Streeter-Phelps equation was selected as the basis for the simulation model and the stream DO was used as the indicator of the extent of stream pollution and the attainment of the water quality objectives. The main reason for selecting the former was that the available stream parametres were adequate only for such a simpler mathematical **model.** A deterministic model could also serve the present purpose better by demonstrating the effects of regionalization and other alternatives on stream quality in terms of simple figures. It is, however, important to keep in mind the limitations in employing a simplified approach to a complex problem. A detailed description of the equation is given elsewhere.[7]

The section of the river system studied was divided into six reaches as shown in Figure 2 (Annex III), which also shows the reach identifications and the location of the hypothetical sewage treatment plants assuming that each town treats its own wastewater and the city of Springfield retains its two treatment plants. Other pollution sources and upstream background BOD inputs included in the study are indicated, respectively, by unidentified but numbered dots and arrow signs. The length, flow, time of flow in the reach and stream parametres for each reach are presented in Table I. These were either taken from the FWQA (Federal Water Quality Administration) Report or estimated from other official reports.[5] [6] [8]

TABLE I

REACH CHARACTERISTICS

Reach	Length		Flow*		Time of Flow	k_1**	k_2**
	Miles	km	cfs	cu m/sec	days	per day	per day
C1	6.0	9.65	1979	56.05	0.975	0.437	0.783
C2	5.4	8.69	2129	60.29	0.726	0.437	0.783
C3	4.6	7.40	2269	64.26	0.603	0.437	0.783
Ch1	2.8	4.51	122	3.46	0.288	0.383	0.738
Ch2	5.9	9.49	122	3.46	0.606	0.369	0.619
W1	4.3	6.92	90	2.55	0.596	0.588	1.056

* Minimum average daily low flow for seven consecutive days expected once in ten years.

** Both at 20°C and base 10.

k_1 = de-oxygenation constant.

k_2 = re-areation constant.

Because the critical DO condition occurs during the low flow periods in the summer months for the Connecticut River, the maximum stream temperature of 83°F (28.4°C) allowed by the state water quality regulations was used in the study. A background first-stage BOD of 2 mg/l was assumed for estimating the BOD load in the stream entering the study section. The stream DO level at the upstream station of Reach C1, Ch1 and W1 was assumed to be 75 per cent saturation. This is the minimum permissible DO level for Class B streams and all the three upstream reaches of the section of the river system studied have a B classification. The reason for the inclusion of Reach C1 in the study was to facilitate the assumption of the initial DO in the main stem.

The estimated pollution contributions for the year 2020 expressed at 20°C, first-stage BOD from various sources are given in Figure 2 (Annex III). In view of the official policy to provide at least secondary treatment for all municipal and industrial pollution sources, a BOD removal of 85 per cent has been applied in arriving at these figures.

An IBM 1130 digital computer was used for the simulation study.

V STUDY RESULTS AND DISCUSSIONS

Two sets of computer runs were made. Table II presents a summary of the results expressed as the minimum DO in each reach.

The purpose of the first set was to investigate the effect of regionalization on achieving the stream quality objectives. The set included two runs. Run 1 considered separate secondary treatment plants at all pollution sources. Run 2 considered a regional secondary treatment plant at Bondi Island to treat wastewater from all four communities in the study area (i.e., pollution sources 3 to 7 in Figure 2).

TABLE II

SUMMARY OF STUDY RESULTS

Reach	Classification	Minimum DO in 2020, mg/l			
		Set 1		Set 2	
		Run 1	Run 2	Run 3	Run 4
C2	C	5.41	5.98	5.93	5.94
C3	C	5.57	5.46	5.49	5.93
Ch1	C	5.28	5.74	5.28	5.74
Ch2	C	S*	6.04	5.20	5.73
W1	B	0.66	5.74	5.74	5.74

S* = Septic condition

Remarks: 1) Required minimum DO = 5 mg/l for C classification

2) Required minimum DO = 5.74 mg/l for B classification at the temperature used in the study.

It is obvious that a system of separate secondary treatment plants will not achieve the desired stream quality objectives. Septic condition may develop in Reach Ch2 coupled with an extremely low critical DO in Reach W1. With the regional plant, the stream quality requirements can be satisfactorily met and the conditions of the two tributaries will be greatly improved. This indicates that regionalization can be a necessary step for cases involving small tributaries joining with a relatively large main stem.

The second set of runs investigated two alternatives which could also achieve the desired stream quality objectives. The results are shown as Runs 3 and 4. Run 3 was to retain a separate secondary treatment plant for Ludlow with the Bondi Island treatment plant handling wastewater from the other three communities. This would increase the oxygen reserve at the critical point in Reach C3 at a rate of approximately 370 lb/day (170 kg/day).

Run 4 considered separate plants at Ludlow and Indian Orchard with advanced treatment for wastewater from Ludlow and northern Springfield and a secondary plant at Bondi Island to treat wastewater from the rest of the study area. It was found that a 99 per cent BOD removal at the Ludlow and Indian Orchard plants was necessary to maintain the required minimum DO in the Chicopee River. To achieve such a high degree of treatment, a combination of conventional secondary treatment with chemical coagulation, sedimentation, filtration and carbon bed absorption is often necessary.(9) Nitrogenous BOD removal may also be needed. The possible benefits of such a system are:

1. Increase in oxygen reserve at the critical point in Reach C3 at a rate of 5,900 lb/day (2,280 kg/day) compared with the system with a regional secondary plant at Bondi Island to handle all municipal and industrial wastewater from the study area.

2. Upgrading of Reaches C2 and C3 in the main stem to B classification.

3. Re-use of the effluent from the advanced treatment plants for industrial and other suitable purposes to reduce the demand on public water supply.

The last item may also offset directly some of the high costs involved in advanced treatment.

VI SUMMARY AND CONCLUSIONS

Under certain circumstances, regionalization may represent the necessary step for achieving the desired stream quality objectives.

With a large regional treatment plant to replace a number of stream smaller treatment plants, there is an adverse effect on the critical dissolved oxygen reserve in the downstream reaches. The significance of this effect presumably varies with local conditions.

Alternatives to regional systems with a single central treatment plant should be investigated from the viewpoints of stream quality management and water resources utilization.

ANNEX I

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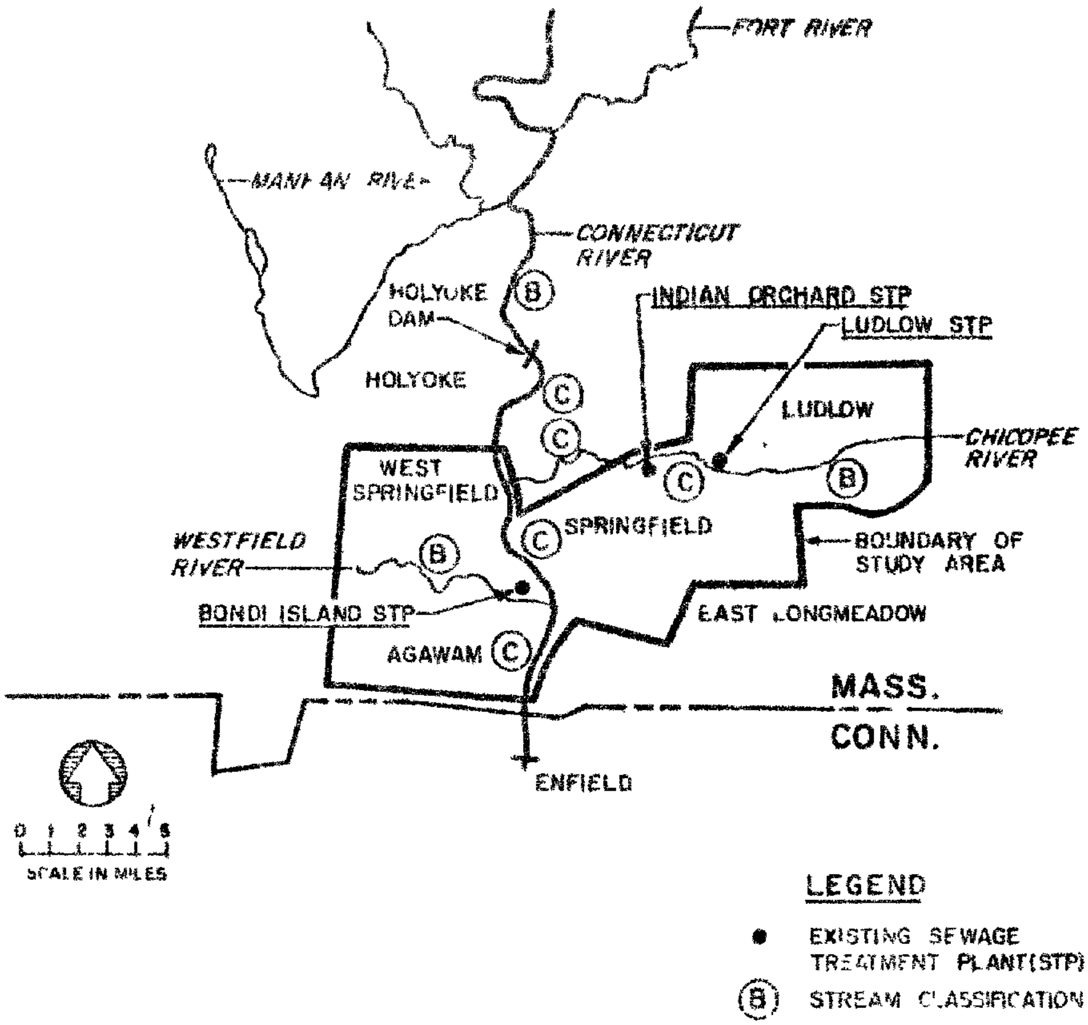
ANNEX II

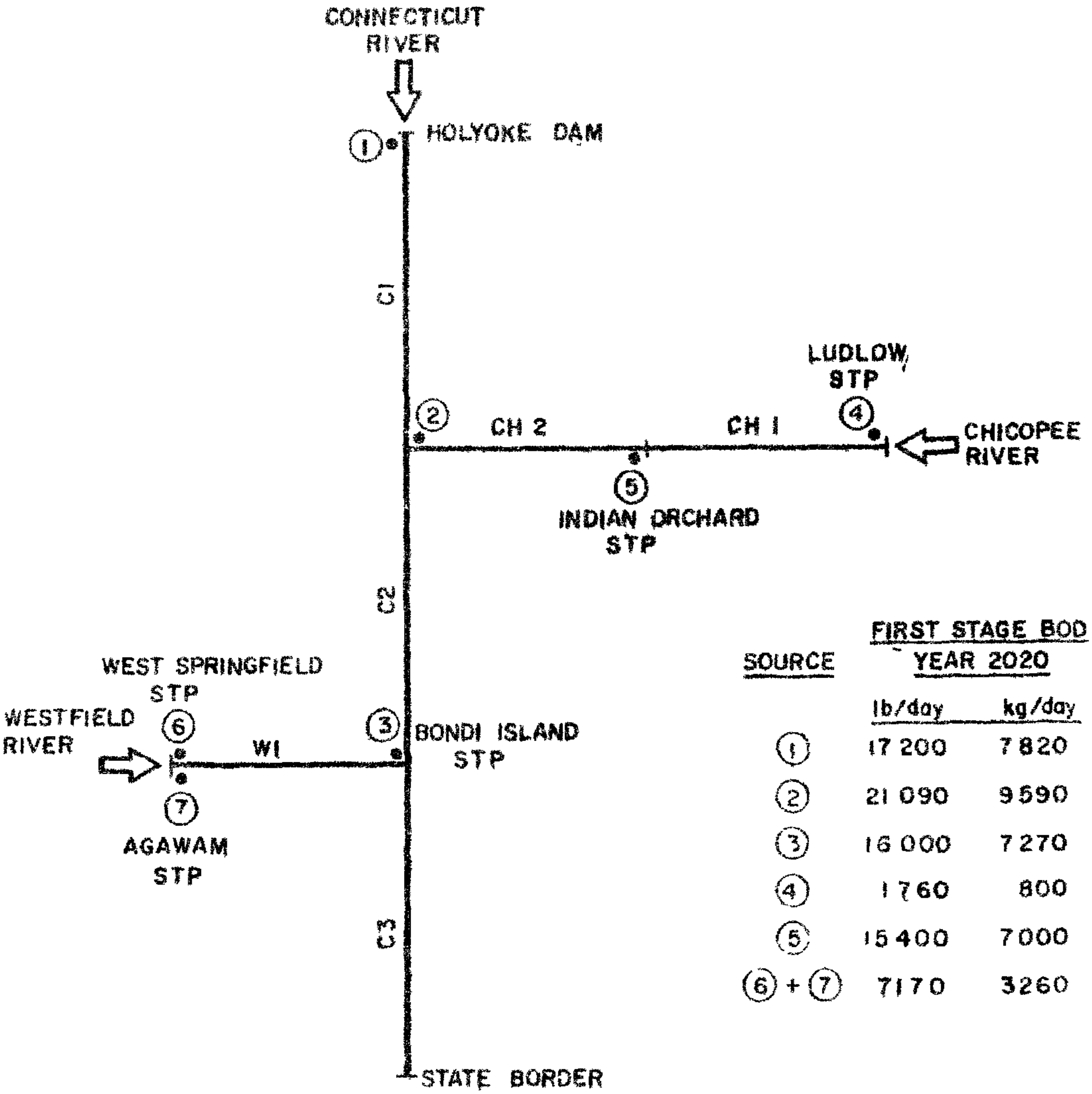
FIGURE 1

DESCRIPTION OF STUDY AREA



ANNEX III
FIGURE II

REACH DESCRIPTIONS



SOURCE	FIRST STAGE BOD YEAR 2020 lb/day	FIRST STAGE BOD YEAR 2020 kg/day
(1)	17 200	7 820
(2)	21 090	9 590
(3)	16 000	7 270
(4)	1 760	800
(5)	15 400	7 000
(6) + (7)	7 170	3 260