Water Pollution Control in Low Density Areas

Proceedings of a Rural Environmental Engineering Conference

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Published for the
University of Vermont
by the University Press of
New England
Hanover, New Hampshire
1975

The papers in this book were delivered at a Rural Environmental Engineering conference on water pollution control technology in low density areas, chaired by William J. Jewell and held September 26–28, 1973, at the Sugarbush Inn, Warren, Vermont. The meeting was sponsored jointly by the Environmental Program and Water Resources Research Center of the University of Vermont and the Environmental Studies Center and Land and Water Resources Institute of the University of Maine.

Co-sponsors:

U.S. Environmental Protection Agency
Agency of Environmental Conservation, State of Vermont
American Society of Civil Engineers
American Society of Agricultural Engineers
American Water Works Association

Library of Congress Catalogue Card Number 74-82975
International Standard Book Number 0-87451-105-4
Printed in the United States of America

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Engineering Economics of Rural Water Supply and Wastewater Systems

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PART I. ELEMENTS OF SYSTEM DESIGN

A Rural Problem

Millions of Americans, especially in remote, economically depressed regions, e.g. "Appalachia" and rural minority centers, do not have safe drinking water or sanitation facilities. Consider the following facts from the studies which have been done:

(A) Some 75 percent of the population is served by public water systems, but a recent Public Health Service survey of selected systems found that 41 percent of these systems failed to meet PHS Drinking Water Standards. Only 50 percent of the systems serving fewer than 500 people met even the minimum standards (McCabe et al., 1970).

(B) In 1971, 70 percent of the population was on central sewer systems and 92 percent of these were provided with some sewage treatment, but only 54 percent were estimated to have adequate treatment. Americans without sewer service or with inadequate sewage treatment thus number nearly 65 percent of the total population. The dominant portion of the unsewered population can be classified as rural, and poor sewage treatment is also more common in rural areas than in large cities (Wenk, 1971).

(C) A 1969 study by the Farmers Home Administration (FmHA) identified over 30,000 communities with populations below 5,500 which needed assistance in either building a water system for the first time or improving an inadequate one. A similar number of communities needed assistance for sewer systems. The study did not cover communities considered by FmHA to be unsuitable for central systems (U.S. Department of Agriculture, 1969).

(D) Surveys which have been done of individual water supplies suggest that they are worse than community supplies. Recent field studies in three southern states found a substantial majority of the individual supplies contaminated, in some cases as high as 90 percent. Nearly one quarter of the American population, most of them in rural areas, relies on individual water supplies (U.S. Environmental Protection Agency, 1972). From these figures and the studies of rural community water supplies, an estimated 20 to 30 million Americans in rural areas are drinking unsafe water.

These and other data lead to one conclusion: existing water and sanitation facilities in the United States are inadequate, and it is rural America that is hardest hit. This is due partly to weaknesses in the present system and partly to the nature of rural life itself (Morgan and Cobb, 1973).

Pollution and population dispersal are the main causes of the rural water problem. Most of the nation's streams are now polluted by human and industrial wastes, and groundwater aquifers, which are the major source of water in rural areas, have also been adversely affected. As a result, an ample and sanitary supply of water can be obtained only by drilling, pumping, treating, piping, and storing. But the scattered rural population, especially those living outside any incorporated municipality, cannot usually be reached by central water systems.

Weaknesses in the National Delivery System

While the national delivery system for rural water and sanitation has reached many rural residents in the past, the increased pollution of water supplies, the need for more complex and expensive facilities, and the general shift of human and financial resources away from rural areas have made this system progressively less satisfactory in recent years. The following are major weaknesses in the present system:

(1) *Policy and Priority*. There is no coherent and adequately supported national commitment to the provision of basic sanitation services, both water and wastewater, for rural residents or to assistance for areas most in need.

(2) *Financing*. Subsidized and nonsubsidized financing is not available in many rural areas to residents who need it most.

(3) *Development*. The limited availability of public and private developers prevents many rural residents from assembling and managing the resources required to provide sanitation services.

(4) *User Support*. Users, who generally want adequate domestic sanitation services, are not aware of the steps involved in obtaining and sustaining the service and the role they must play in this endeavor.

(5) *Technology*. Design and construction of facilities is not sufficiently directed at meeting technical problems in rural areas, although most common problems can be overcome at a reasonable cost with existing technology.

(6) *Operation and Maintenance*. Inadequate attention to operation and maintenance has often meant that services which have been

established could not be maintained over the long period (Zimmerman, 1973).

The Responsibility for Action

In order to develop a national commitment to good water and sanitation facilities the responsibilities of the public and private sectors must be determined. The private sector does play a major role in water and sewerage in the United States, especially in the development of groundwater technology, sewer treatment, etc. In addition, about 15 percent of all water companies are private, profit-making concerns. They serve approximately 15 million people mostly in rural areas.

Profit-making interests have not been able, however, to extend service to all rural residents. Scattered, low-income rural families cannot afford a central distribution or collection system, nor even individual facilities constructed by private contractors. According to the Office of Economic Opportunity, low-income families cannot pay water bills or meet loan payments for water supply or sanitation facilities much in excess of $7.00 per month.

What seems to be required is some form of public subsidy for the construction and operation of facilities. This kind of public assistance is now so common that it is no longer considered a public subsidy. Certainly schools and roads for all citizens would have been impossible without governmental support.

Local governments, in one way or another, operate the vast majority of the nation's water systems. State governments, through health departments and planning bodies, provide research, regulation, and sometimes financing. The federal government, long involved with research in water and sanitation through such agencies as the U.S. Public Health Service, the U.S. Office of Water Resources Research, the U.S. Geological Survey, and the U.S. Environmental Protection Agency, has been an important source of funding or significant technical assistance for water and wastewater projects.

There is substantial precedent for public support of water supply systems. Indeed, between the early 1940's and 1968, the U.S. Agency for International Development contributed close to one billion dollars to the development of water supply systems in foreign countries (McJunkin, 1969). Within the United States, however, there has been no public effort of a scope and cohesiveness to match the effort which has been made abroad.

Weaknesses in Funding Policy

Although financing by the Farmers Home Administration has significantly advanced the quantity and quality of rural water facilities, it is not unfair to point out that their eligibility requirements for individual loan programs (numbers 502 and 504) have kept funds from reaching the rural poor. These people sometimes lack clear title to their property and often cannot meet loan payments when the life of the loan is a short ten years. A persistent shortage of grant funds, recently deteriorating into complete stoppage, has also limited the agency's ability to respond to low-income residents.

Even more importantly perhaps, grant and loan funds for the community systems have by and large been extended only to "central" systems with one water source and treatment facility, mostly on the grounds that efficiency and continuity of operation are best assured by such systems. Rural communities or clusters of houses not meeting FmHA criteria for central systems have thus been excluded.

Policy for the Future

Public assistance to those who need help and are willing to help themselves hardly needs a justification; nor should there be any misunderstanding about the extent to which low-income residents help themselves. Under the previous FmHA water association plan, where systems were financed by a combination of 50 percent grant and 50 percent loan funds, users in the end would pay about 79 percent of the total cost of the system (initial capital plus operating expenses) or 62 percent of the present value of the total system cost. Loan funds should have lower interest rates and longer repayment periods so that low-income families can use them.

In any case, future funding agencies should be less restrictive about the kinds of water systems they will finance. The difficulties involved in reaching low-income residents by traditional central systems have led in recent years to attempts to devise a new approach based on the experience of rural electric cooperatives. This approach makes possible the kind of effort which is broadly endorsed in the American ethic, a combined public-private effort.

The public-private approach is being tested in various parts of the country by the National Demonstration Water Project (NDWP). NDWP has developed a number of model projects all designed to demonstrate the effectiveness of local organizations in providing water and sanitation facilities for rural residents.

NDWP has also established a national clearinghouse for rural water information. Developmental work for the NDWP program has been funded by OEO. FmHA has provided much of the money for construction of water supply and sewage facilities. EPA is now granting funds for construction of sewage facilities. Private social and technical research organizations representing the groundwater industry and various community organizations have participated in the development activities.

The original NDWP project sprang from the effort of low-income residents in a five-county area around Roanoke, Virginia, to obtain adequate water supplies (*Water Well Journal*, 1971). With funding from the U.S. Office of Economic Opportunity, NDWP established a series of separately incorporated water companies and trained residents to operate the companies as nonprofit associations. After a considerable struggle, the necessary approvals were obtained and financing secured from the Farmers Home Administration for the construction of facilities. Several companies are now in full operation and others are in various stages of development. Water is now being supplied to residents who never before had an adequate water supply.

With the Roanoke experiment a success, NDWP is testing this model in various areas with different problems. A project now under way in Logan, West Virginia, includes wastewater facilities as well as water. Figures 1 and 2 are typical of the West Virginia project area. Another model project in Beaufort-Jasper counties of South Carolina is an attempt at a cooperative arrangement with a local municipality in one area and a water system which included fire protection in another. NDWP is working on a field demonstration project in conjunction with the National Rural Electric Cooperative Association (Zimmerman and Cobb, 1972).

The NDWP Approach

The precise choice of implementing organization is not the crucial issue. What is important is that the present lack of an organization to implement a program of rural water development is a serious weakness in the present national delivery system. To meet this weakness in national delivery, NDWP adopted certain concepts in the development of its field projects (Zimmerman and Cobb, 1972; Campbell and Lehr,

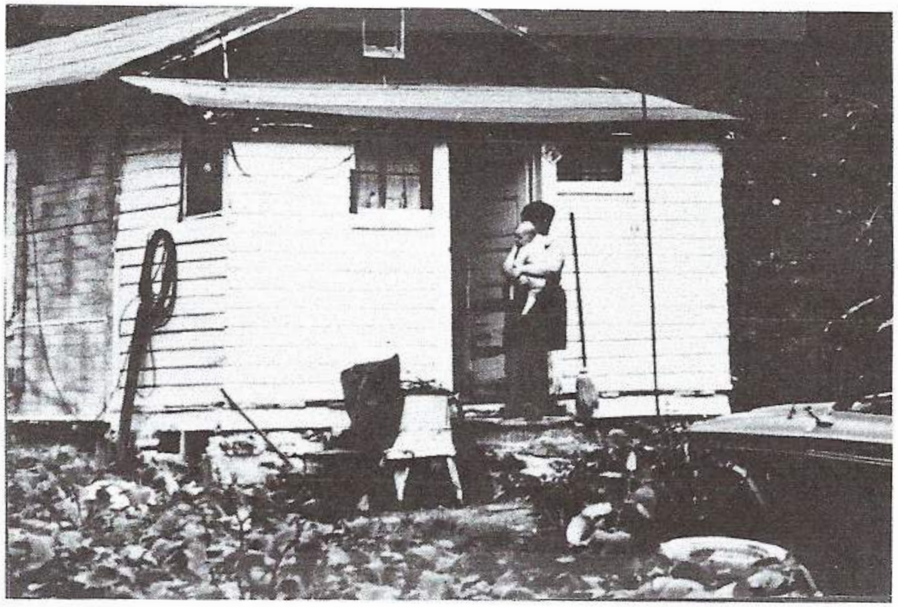

Figure 1.

1973a; Goldstein and Moberg, 1973). For example, governmental agencies have tended to feel that only a central water source or a central treatment facility could provide satisfactory service and quality (Andrews, 1971), because central *management* has been critical to the performance of these facilities. NDWP has felt, however, that central management need not be tied to central systems in the physical sense. NDWP early recognized the possibility of employing central management for a number of water sources and sewage disposal facilities. Wells and small treatment plants could serve a varying number of people all as part of the "system" in the sense of management.

In NDWP experience, the local conditions and their respective impact on the specific project are critical to ultimate configuration of the system. These conditions or field parameters fall into three broad categories:

(1) Geographical (topography, population density, surface reservoir proximity, suitability, etc.)
(2) Hydrological (surface water quality and availability, groundwater quality and availability, etc.)
(3) Political (state and federal regulatory agency attitude, etc.)

Figure 2.

In one NDWP project geographic factors such as frequent bedrock exposure and a clustered population density in isolated areas motivated a design which reduced the extent of distribution-line construction between each isolated group of homes as much as possible. Areas of low relief having unconsolidated sediments at the surface require less capital for distribution-line construction.

With regard to the hydrologic parameter, local water availability and quality are reviewed with respect to either a surface-water or groundwater source. Since a groundwater source is usually favored on economic grounds, its quality becomes a significant factor (Campbell and Lehr, 1973; Mirshleifer et al., 1960; Bourcier and Forste, 1967). If previous test drilling and production analyses indicate that significant treatment will be required to remove iron, manganese, etc. from the groundwater, the use of an available surface-water source may be more economical. And sometimes it is less expensive to construct a water reservoir with its attendent treatment plant than a well system drawing from the groundwater reservoir.

The third field parameter which affects the design of the system is the political factor. Problems often arise when a specific design is presented to the regulatory agency for approval. One agency historically prohibits PVC pipe. Another may require specific well sizes. Most states apparently require system design based on a per capita usage of 100 gpd, an unrealistically high figure even for many affluent suburban homes and one which places an unduly high construction burden on the rural community. A strong tendency exists for regulatory agencies to favor systems that are overdesigned and economically unsuited to the project's local conditions. This tendency most likely stems from the agencies' concern for the system's longevity and operational simplicity. The common preference for a central high-capacity well system is based more on operational control considerations than on engineering grounds.

Local Parameters Translation

There are four generally accepted system types or alternatives for obtaining a community water supply in rural areas:

A. Treatment of raw surface water, e.g. small surface reservoir, river, etc.
B. Purchase of treated surface or ground water, e.g. extension of existing water lines, etc.
C. Construction of a single high-capacity well system, e.g. one well, central treatment plant, extensive distribution system.
D. Construction of multiple or "cluster" well system, e.g. more than one well, additional treatment plants, less extensive distribution systems.

NDWP field affiliate projects have so far employed all but Alternative A. In the NDWP approach the relative impact of the local parameters is translated into these possible system types and the *total* cost of each of these systems is compared by means of the following equations:

$$S_R = P_W + T_{CR} + D_{CR} + 0_{CR} + M_{CR} \text{ (Raw Surface Water System)}$$

$$S_T = P_P + D_{CE} + M_{CE} \text{ (Purchased Water System)}$$

$$S_C = W_{CC} + T_{CC} + D_{CC} + O_{CC} + M_{CC} \text{ (High Capacity Well System)}$$

$$S_M = \sum_{i=1}^{n} (W_{CM_i} + T_{CM_i} + D_{CM_i} + O_{CM_i} + M_{CM_i}) \text{ (Medium-Low Capacity Well Systems)}$$

Where: S_R, S_T, S_C and S_M = Total Cost of System Over Project Life

P_W = Pumping Plant Construction Cost

P_p = Purchased Water Cost Estimation Over Project Life

$T_{CR,\ CM,\ CC}$ = Treatment Plant Construction Cost

$D_{CR,\ CE,\ CC,\ CM}$ = Distribution System Construction Cost

$W_{CC,\ CM}$ = Well System(s) Construction Cost

$O_{CR,\ CC,\ CM}$ = System(s) Operation Cost Over Project Life

$M_{CR,\ CE,\ CC,\ CM}$ = System(s) Maintenance Cost Over Project Life

Each factor on the right side of the equations can be evaluated in terms of the effect of every significant local parameter on total system costs. Furthermore, comparison of equivalent factors, e.g. maintenance costs for a central-well system and a multiple-well system, can be made.

Central-Well Systems Versus Cluster-Well Systems

As previously mentioned, the single high-capacity or central-well system has advantages of central management, efficiency, and continuity in system operation, particularly if the central management is a governmental body. The principal drawback of this system, however, is that it cannot be extended to many scattered rural residents except at a prohibitive cost.

This drawback has led NDWP to the development of the cluster-well alternative. Several wells of medium to low capacity are constructed. Each well serves a small cluster of homes, but the multiple system of wells and low capacity treatment plants is centrally managed. Both low construction cost and efficient operation may thus be achieved. In Figure 3 a number of cluster well systems are shown, all of which are under central management.

The distance between homes to be served is the key factor when comparing the costs of the central-well system with the cluster-well system. There is a point beyond which it becomes more economical to construct a second well than to lay pipe to connect a distant house

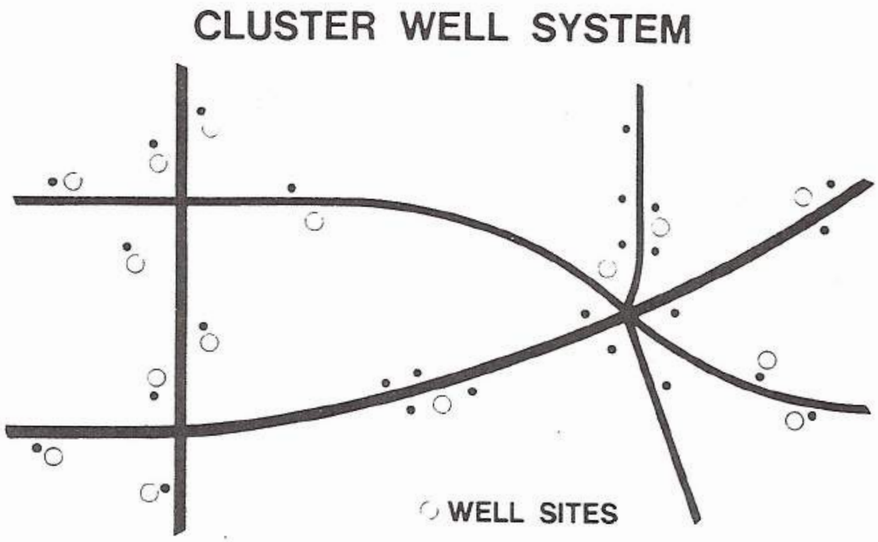

Figure 3.

to an existing well. NDWP has developed the following equation for comparing these costs:

$$\frac{S_c}{S_M} = C_R$$

$$\text{or: } \frac{W_{CC} + T_{CC} + D_{CC} + O_{CC} + M_{CC}}{\sum_{i=1}^{n} W_{CM_i} + T_{CM_i} + D_{CM_i} + O_{CM_i} + M_{CM_i}} = C_R$$

Where: C_R = Total System Cost Ratio

S_C = Total System Cost of High Capacity or Central Well System

S_M = Total System Cost of Medium-Low Capacity or Multiple Well System

Central Well Extensions

$$P_C > W_{CM} + T_{CM} + D_{CM} + O_{CM} + M_{CM}$$

Where: P_C = Total Interconnecting Distribution Cost (in Place)

After translating the effects of local field parameters into estimated dollars, estimated cost components are entered into the respective expressions and the equations solved for total systems, i.e. S_C for the central system and S_M for a multiple system. If the total system cost ratio is unity (one) or less, the central well system should be the superior design for the particular project area and vice versa. In the lower part of the preceding equation, a useful relationship is shown. If the following is valid, then one or more outlying wells are justifiable:

$$P_C > (W_{CM} + T_{CM} + D_{CM} + O_{CM} + M_{CM})$$

$$\text{Or:} \quad P_C > S_M$$

Where: P_C = Total Interconnecting Distribution Cost (In Place)

If P_C is greater than S_M, a cluster system is more economical. If P_C is less than S_M, an extension of the existing system is more economical.

Operation and Maintenance

The pipe-laying cost is not the only critical factor. The effect of operation and maintenance (O&M) must also be carefully estimated. Although O&M costs are difficult to calculate, they can be approximated with far greater accuracy than is currently attempted by many consulting engineers, who often resort to convenient, but inappropriate rules of thumb. Under sponsorship of the NDWP and the Commission on Rural Water two guides are in preparation for the operation, maintenance, and management of support companies for rural utilities.* These guides should be available for public dissemination by late 1974.

Local field parameters dictate the scope of operation and maintenance required for the system. In one area well incrustation and/or corrosion may be a problem. The water supply may require an iron treatment plant. Some systems even require additional treatment to remove other dissolved minerals. As treatment needs increase, and with them both initial construction costs and the attendant operation and maintenance costs, the suitability of treatment-plant consolidation also increases (Campbell and Lehr, 1973b).

* Michael D. Campbell and Jay H. Lehr, 1974, *Rural water systems operation and maintenance: A guide for the engineer and operator* (Houston: Commission on Rural Water, National Water Well Association Research Facility); Edwin L. Cobb and Steven N. Goldstein, 1974, *Managers' guide for the support of rural water-wastewater systems* (Washington, D.C.: Commission on Rural Water).

NDWP Focus on Operation and Maintenance

No matter how well and how inexpensively water and wastewater systems are constructed, the rural problem cannot be solved unless these facilities are adequately operated and maintained. Probably the biggest mistake made by the U.S. Agency for International Development in financing water development in foreign countries was ignoring maintenance needs. After facilities were constructed, the developers simply went away, leaving the residents to shift for themselves. Without any real local maintenance, the systems deteriorated, wells failed, treatment plants malfunctioned, distribution lines broke, etc. The lesson was not that development will not work in rural areas but that development must include a strong awareness of operation and maintenance.

Whether future rural water systems are administered by municipalities, public service districts, or nonprofit corporations, the administering authority must have enough funds and expertise to keep the system running effectively and efficiently. Wells and treatment plants must be inspected and repaired, meters read, bills collected, records kept, and loan payments made. The officers of a water company themselves must be able to carry out all its functions from seeing that wells operate at peak efficiency and remain uncontaminated to making sure that taxes are paid. These tasks will not be easy where users' incomes are low and where reliable public services have not been a part of the heritage of the area. The problem can be tackled either by training the members of each individual water company to perform the necessary work or by developing a separate support company to manage operations for all companies in a project area.

At the present time, maintenance provisions for rural water systems are generally poor. There is inadequate inspection of community water systems, and individual facilities are rarely checked at all. System designers usually underestimate the maintenance requirements during the life of a loan made for the construction of facilities. Reports and other devices for evaluating the performance of water systems are spotty. It is not surprising that small rural water companies have obtained a reputation for performing badly.

No attempt has been made here to discuss all the technical problems and developments that relate to water and wastewater systems. A few of these problems will be elaborated in Part II of this presentation. It is clear in any case that the major weaknesses of the national delivery system for rural areas are not solely technical. Indeed there are *no* technical problems that cannot be solved with the proper political and financial backing. The major needs, commitments and funding, can be met only by state and federal government. System development, centralized management, economically sound engineering, and strong operation and maintenance are features the National Demonstration Water Project is attempting to implement in its field projects. As the present NDWP projects age, their performance will test the effectiveness of the NDWP approach.

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13.
Engineering Economics of Rural Water Supply and Wastewater Systems

Michael D. Campbell
and Steven N. Goldstein

PART II. APPLICATION OF ECONOMIC CRITERIA TO THE EVALUATION OF PROJECT FEASIBILITY (A CASE STUDY)

Problem Statement and Study Objectives

The subject of this case study is the Big Creek Public Service District's proposed water supply and wastewater collection and treatment systems in Logan County, West Virginia. The engineering objectives were: to design domestic water supply and wastewater treatment facilities serving the 250 buildings in the district, to design a system meeting all applicable quality standards both for supply and treatment, to incorporate simplicity, durability, reliability, and maintainability into the design and materials, and to provide first-class service at a total monthly cost that the residents could reasonably afford to pay. In order to accomplish the objectives, several alternative approaches for both water and wastewater systems were evaluated and compared.

Generally speaking, a water and wastewater system for a small community widely dispersed over inhospitable terrain would be prohibitively expensive to set up and would probably not be maintained in proper operating condition for any appreciable period. As previously stated in Part I, the National Demonstration Water Project approach is to provide for centralized management of the utility, including operation and maintenance, while relegating decisions about centralizing the physical facilities to considerations of economic and technical feasibility. A major constraint is that the services must be provided at a price that is within the ability of all subscribers to pay, and this requires that full advantage be taken of all available grant and favorable loan programs.

Description of the Big Creek Public Service District

General Description

The service area of the Big Creek Public Service District consists of eight square miles of steep slopes with level areas in the Guyandotte River and creek bottoms (Figure 1). The 250 buildings to be served include convenience commercial buildings such as a neighborhood sundries shop, small motel, and gasoline station, a grammar school at the mouth of Big Creek Hollow, and several churches.

No industrial hookups are included, nor are any anticipated in this essentially residential public service district. The area currently has neither central water nor sewer services. Some residences have no source of water on the premises. The median family income is below $4,000, and 75 percent of the families have an income below $6,000. Because of the scarcity of flat land with access, there are not 400 suitable building lots available in Logan County for relocating the families who will be displaced when a nearby highway is constructed. About 25 additional building lots could be developed if sanitary (water and sewer) services were available to qualify them for development grant funds.

Population and Existing Facilities

Demographic and housing characteristics of the community and existing facilities are summarized in Tables 1 to 4. The detailed data were collected during the early phases of the project by the Guyandotte Water and Sewer Development Association and are based on detailed information supplied by 154 families. The statistics of Table 1 do not reveal a number of harsh realities in the Big Creek Public Service District. For example, while about half of the families appear to be served by either septic tanks or cesspools, the soil in the area is generally ill suited to subsurface effluent disposal and ponded, daylighted septic effluent is not an uncommon sight. Many sanitary disposal facilities are located dangerously close to wells. Many wells are shallow dug wells which intersect a generally high water table. The quality of water from drilled wells is variable and often not suitable for drinking, and many families with wells haul in drinking water from outside sources. It can be conservatively estimated that close to half of the sewage runs off with only minimal treatment to the creeks which feed the Guyandotte River. Thus existing water and wastewater services for the Big Creek Public Service District must be

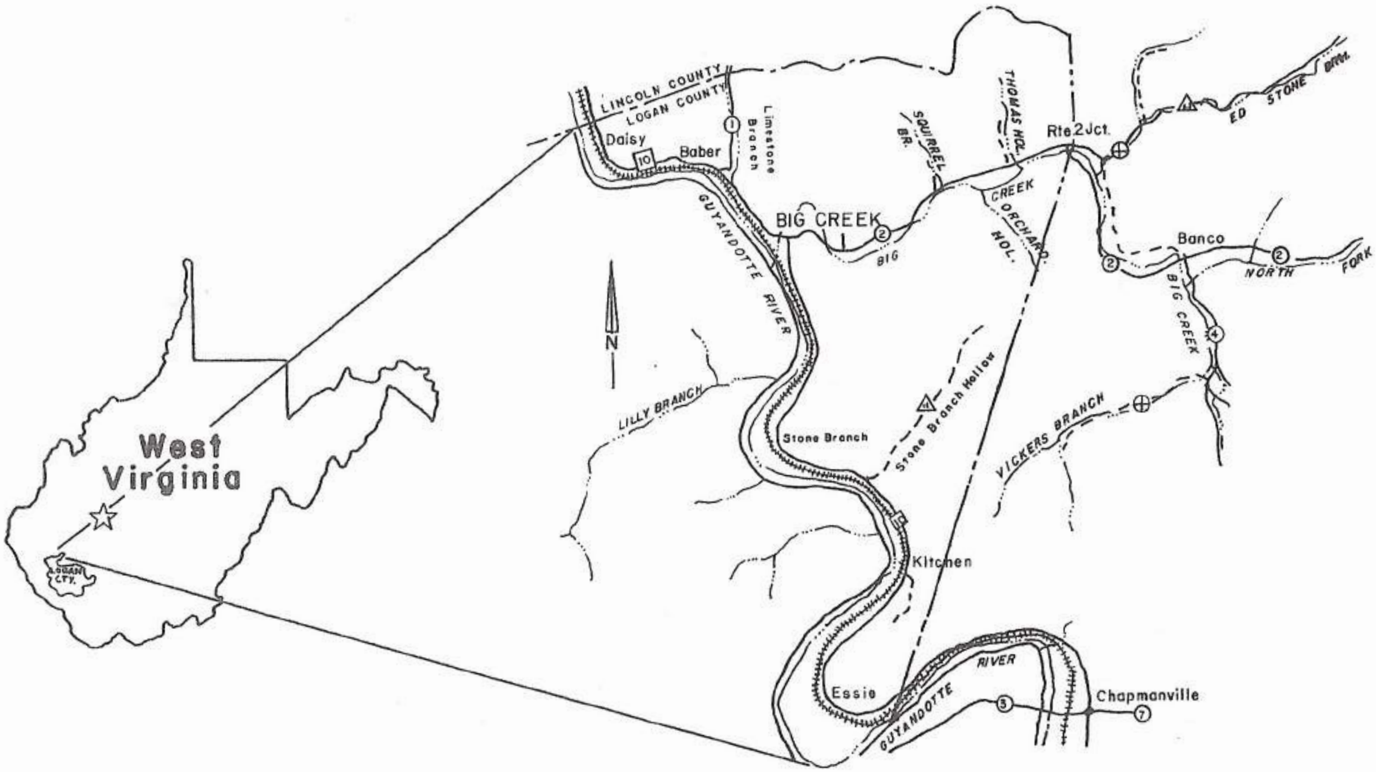

Figure 1. Big Creek Public Service District.

Table 1
Population Size and Household Characteristics

Number of people currently in service area (Estimate based on 251 houses and 3.43 people/house county-wide occupancy rate from 1970 census)	860
Design Population	950[a]
Number of children enrolled in Big Creek Elementary School	142
Number of families responding to detailed household survey (100% of sample)	154
Owner occupied homes	69%
Renter occupied homes	31%
Families using well water	82%
Families using cisterns for collection and storage of drinking water	1%
Families without wells	10%
Families using outdoor privies	44%
Families with bathrooms	56%
Families with septic tank systems	47%
Families with cesspool systems	3%
Families discharging raw sewage to creek	6%

[a]1%/year compound growth for 10 years—1983 design year.

Table 2
Distribution of House Size

Rooms per home	1	2	3	4	5	6	7	8	9	10	11
% homes in category	0	2	3	34	29	19	5	3	1	3	1

considered almost totally inadequate in an age of technological enlightenment and public health awareness. There are few areas that would present a greater challenge to the ingenuity of the project developer or system designer than this one.

Physical Features of the Big Creek Public Service District and their Effect on System Design

Topography

The topography of the Big Creek Public Service District is characterized by significant relief. Land flat enough for homebuilding is

Table 3
Distribution of Children Living at Home

Number of children living at home	0	1	2	3	4	5	6	7	8–12	13
% families in category	44	18	17	6	6	5	1	2	0	1

Note: 28% of sampled population were children.

Table 4
Distribution of Family Income Levels

Family Annual Income	*Percent of Families*
$ 300–3000	39
3000–4000	20
4000–6000	16
6000–8000	15
8000–10000	4
10000–12000	6
over 12000	0

located adjacent to creek bottoms in the hollows and along the Guyandotte River. The secondary roads are mainly dirt surfaces and deeply rutted from heavy truck traffic.

Geology

The Big Creek Public Service District area is underlain by alternating intervals of sandstone, shale, coal, and associated lithology. The relatively shallow sandstone beds are the major aquifers of this area. Abandoned coal mine shafts along with active coal mining and highly ferruginous sandstone aquifers present water-quality problems to any groundwater development program.

Hydrology

Rarely is a well found which meets the standards for chemical content of the West Virginia State Department of Health. Iron concentrations vary from 0.05 to 9.75 mg/l, and manganese from a trace to 0.7

mg/l. The pH varies from 7.4 to 8.4, though at one well the pH dropped to 4.6 and the manganese concentration reached 3.7 mg/l. Small amounts of H_2S are detected in most wells. The chloride concentration ranges from a trace to 125 mg/l. In cases where a salty interface is penetrated at an elevation of about 550 feet, the chloride concentration reaches as high as 1675 mg/l.

Records of groundwater development in Logan County show that the yields of standard vertical drilled wells of 8 to 10 inch diameter range from 50 to as much as 300 gpm. Yields of 100 and 200 gpm are actually common in properly developed wells where the saltwater interface is relatively deep.* In the Big Creek Area, however, controlled pumping and relatively low-capacity wells will most likely be necessary to prevent saltwater coning from below.

The Guyandotte River, which will be the recipient of discharged effluent, has a mean flow of about 1,500 cubic feet per second (cfs) with a maximum of over 16,000 cfs and a minimum of 89 cfs.

Soils

The soils in the area are generally unsuited to septic tank–soil absorption systems because of at least one of many limiting factors: excessive slope, shallow water table, shallow layer of impermeable material (mainly bedrock), and periodic flooding. For example, near the creek bottom, the soil may be of sufficient depth and permeability for septic tanks but poorly drained because of a shallow water table.

Governmental and Administration Relationships

The Big Creek Public Service District was established on February 5, 1973, by the County Court of Logan, West Virginia, under the provisions of Chapter 16, Article 13a, Section 2 of the West Virginia Statutory Code to provide water supply and wastewater treatment services to the residents within the boundaries. As a municipal body, the Big Creek Public Service District qualifies for state and federal construction grant and loan funds. Administratively and legally, the Big Creek Public Service District is the applicant for all grant and/or loan funds, the mortagee, and the owner and operator of all water and wastewater facilities that are proposed in this report. The com-

*Wilmoth Benton, 1972; personal communication.

munities within the service area are all unincorporated, and many are unnamed.

The critical importance to project development of working through existing political institutions and agencies cannot be overemphasized. In this regard, both the Big Creek Public Service District and its agent, the Guyandotte Water and Sewer Development Association, enjoy excellent and cordial working relationships with all levels of local and state government.

Water Supply System

Basic Objectives

The design objective is to provide safe drinking water for domestic purposes in adequate quantities for the existing community of about 860 people with allowance for moderate growth to 950 people over a decade.

Description and Evaluation of Alternatives

The alternatives for the water supply system in the preliminary engineering study are as follows:

Alternate 1: Centralized treatment of Guyandotte River water. A central water treatment and distribution system would withdraw 100,000 gallons per day of water from the Guyandotte River. In addition to chlorination costs of about $.02/1,000 gallons, other physical and chemical treatment costs of about $.07/1,000 gallons are anticipated for a total treatment cost estimate of $.09/1,000 gallons. This is by far the highest treatment cost of any of the alternatives—which is to be expected, since the other alternatives all involve the use of groundwater.

Alternate 2: Purchase of treated water from the town of Chapmanville. The purchase of water from Chapmanville would necessitate a water main connection to Chapmanville and a distribution system for the project areas. The assumed water demand per household is 4,000 gallons per month (Table 5). Using the basic rate for water purchase from Chapmanville of $126.40 for the first 100,000 gallons per month and $90.00 per 100,000 gallons per month thereafter and the state design standard of 100 gcpd and four people per house, the

Table 5
Cost Comparison of Water Supply System Alternatives

	Alternate 1 Guyandotte River Water Central System	*Alternate 2 Chapmanville Purchase Central System*	*Alternate 3 Single Well Central System*	*Alternate 4 (Recommended) Five Cluster Well Systems*
Total first costs	$496,024	$388,188	$526,886	$368,152
First cost annualized at 5%, 38 yr. (.05928)	29,404	23,012	31,234	21,824
Annual labor costs	6,604	5,010	6,610	8,210
Annual nonlabor costs	10,862	15,703	8,307	9,543
Total annual cost (estimate)	46,876	43,725	46,151	39,577

Basic Assumptions:
- Skilled operator and assistant at $4.00/hr., including fringe benefits.
- Bookkeeper/Administrative Assistant at $2.50/hr., including fringe benefits.
- Meter Readers, pump-house checkers, part-time, at $2.00/hr.
- 4 hr./wk. skilled labor or 1 hr./wk. skilled plus 6 hr./wk. unskilled labor per well treatment-storage facility, on the average.
- Meter-reading monthly at average rate of 6 per hour.
- Maintenance of equipment at 2.5% of capital cost.
- Distribution pipe maintenance of $2000/year labor, based on $.04/ft for Alternate 4.
- Treatment chemicals for ground water at $.02/1000 gal; $.09/1000 gal for surface water.
- Electric power at $.025/kilowatt hour.
- System components capitalized at 6% (for replacement) at reasonable lifetimes.

annual estimated cost of water purchase from Chapmanville would be $32,832 (compared to $11,280 based on 4,000 gallons per month per connection).

Alternate 3: Central water supply and distribution system based on single well field. A single well field would be drilled and an iron (and perhaps manganese) removal and chlorination water treatment plant installed. This alternative would include a 100,000 gallon storage facility (standpipe), which, based on 4,000 gallons per connection per month (or 35,140 gallons per day for 251 connections), would provide almost three days' storage capacity. The cost of the storage facility is estimated to be $45,000 installed, which is included in the cost estimate for Alternate 3 in Table 5. (The technical feasibility of this alternative is clouded by uncertainties about the saltwater interface.)

Alternate 4: Five individual water systems. Five individual (cluster) systems, each composed of a well field, treatment facility, storage tank and distribution system, would be installed. They would provide for the various communities a total of 105,430 gpd, which satisfies the full 100 gpcd design standard.

Cost Comparison

It can be seen from Table 5 that Alternate 4 (five separate systems) has the lowest first cost, lower by $20,000 than its nearest competitor, purchase from Chapmanville; but that would amount to a savings of only $.04 per month per customer. The choice should be based on the annual costs of operation and maintenance (including a reserve for equipment replacement, repair, and overhaul) and the annual loan payment on debt services as well as first costs. Annualizing total first costs with debt service figured on the full cost of the system shows the total burden on society, irrespective of who pays for what. The costs of the alternatives are presented in Table 5.

Alternative 4, the five-cluster system as conceived, not only has the lowest first costs, but also the lowest total annual costs. Even though the annual operation and maintenance costs of Alternate 4 are higher than the O&M costs of Alternates 1 and 3, the high debt burden of the latter two dominates the annual payment. Alternate 2, water purchase from Chapmanville, looks attractive as a second choice, but it should be recalled that the cost is estimated on the basis of 4,000 gallons per connection per month (or about 40 gpcd).

Uncertainties

This preliminary appraisal is highly dependent on the suspected but unknown yields and quality of groundwater supplies. If the groundwater should require extensive treatment, the costs will change. Test wells must be drilled to establish the quantity and quality of the groundwater.

Cost Estimates

The estimated total in-place costs and O&M costs are given in Table 6. The engineering fee estimate is based on a resident construction

Table 6
Total In-Place Costs and O&M Costs

In-Place Costs	
Construction cost	$290,405
Land acquisition	9,500
Engineering fees (Includes resident construction engineer; approximately 10% of construction costs)	29,041
Legal fees (Approximately 2% of construction costs)	5,808
Interest during construction (1% per month for three months on half of total construction cost)	4,357
Contingencies (Approximately 10% of construction costs)	29,041
Total In-Place Cost	$368,152

O&M Costs	
Utilities (electric power, heat)	$ 718
Chemicals and other consumable supplies	763
Equipment overhaul/repair/replacement	6,062
Service equipment (truck)	1,500
Purchase of services	—
Rental (provided at wastewater treatment plant site)	No charge
Insurance	500
Subtotal, nonlabor O&M	$ 9,543
Field personnel (chief operator, assistant, meter readers)	6,960
Office personnel	1,250
Subtotal, labor	$ 8,210
Total Operative Costs (excluding debt service)	$17,753

engineer whose services will be provided by the Guyandotte Water and Sewer Development Association. The estimate of 10 percent for contingencies includes miscellaneous small fittings and similar small cost items as well as uncertainties related to the difficult terrain and geological conditions. Approximately $2,000 annually was projected for repairs to the water distribution system. This estimate was by analogy with the $.04/foot estimate for sewer maintenance costs. Since the cost of pipeline maintenance and repair will be almost entirely labor, it is grouped with the labor costs.

Wastewater System

Basic Objectives

The State Board of Health has stated: "On and after July 1, 1970, the date these regulations become effective, every dwelling or establishment whether publicly or privately owned where persons reside, assemble, or are employed, shall be provided with toilet facilities and a sanitary system of sewage or excreta disposal.... The use of a cesspool as a means of sewage disposal is prohibited."

Consequently, from the standpoint of both the community's health and enacted legislation, the existing sanitary facilities of the project area are inadequate.

Wastewater disposal involves two basic functions, collection and treatment. Consideration of the requirements for waste collection via a system of laterals and trunk line sewers readily indicates that most of the smaller hamlets are too widely dispersed to be economically served by a *conventional* gravity system terminating at a single central treatment facility. These limitations suggest that meeting the design objectives will involve trade-offs between central treatment and collection costs.

Description and Evaluation of Alternatives

The following alternatives for the wastewater system were examined in the preliminary study:

Alternate 1: Centralized. This consists of a single 120,000 gpd rotating biological surface bio-disc treatment plant served by a combination of gravity and pressurized sewer systems. This configuration is

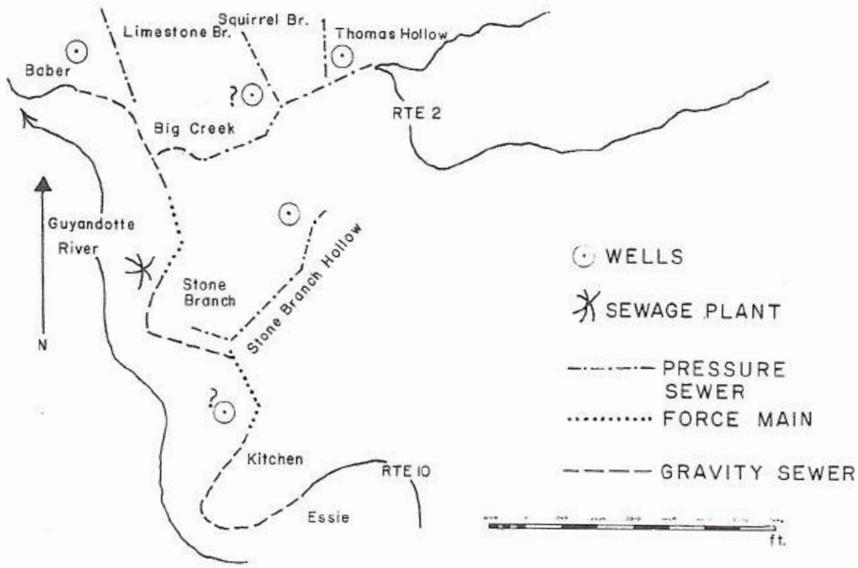

Figure 2. Schematic Representation of Sewer System.

depicted schematically in Figure 2. The centralized approach is made economically feasible by the use of new pressure sewer technology.

Alternate 2: Decentralized with eight treatment plants. This approach uses many smaller sewage plants (eight extended aeration plants ranging between 500 and 30,000 gpd capacity) served by individual cluster collection systems. Central management would ensure proper operation of all the plants.

Alternate 3: Decentralized with sixteen treatment plants. At an earlier stage of the design investigation, clustering to as many as sixteen individual extended aeration treatment plants was examined. These included several "individual home aerobic" plants which would serve as few as one or two connections. Consultation with the Environmental Health Service of the West Virginia State Department of Health indicated that decentralization to this extent would be most impractical to operate and maintain.

Cost Comparison

The full, unsubsidized first cost is annualized to remove any bias from arbitrary allocations of grant, loan, and community funds. Recurring annual expenses of operation and maintenance are separated into labor, including field work and office work, and nonlabor, including utilities, equipment repair and replacement, rents, service vehicles, and outside services such as sludge removal. The alternative approaches to the wastewater collection and treatment system are presented in Table 7. Alternate 1, the central system, is preferred. Even with the obstacles to central sewers, the use of pressure sewers makes first costs lower for Alternate 1 than for Alternate 2 (eight plants).

The eight individual plants can treat sewage as effectively as the single plant, if they receive the necessary attention. Performance would be degraded mainly by the greater variations in loading that could be expected in smaller systems as well as by the overcapacity design that would result from the 100 gpcd design loading requirements, but small, batch-treat, extended aeration plants are available which could accommodate variable loadings. Water quality in the creeks would be somewhat degraded with the decentralized plants. Given the steep terrain, however, groundwater recharge from effluent discharged to the creeks would be minimal. In summary, the superiority of the central system is mainly on the basis of annual cost; in other respects the two systems would be about equally effective.

Table 7
Cost Comparison of Wastewater System Alternatives

	Alternate 1 (Recommended) Central	*Alternate 2 Eight Plants*	*Alternate 3 Sixteen Plants*
Total first costs	$751,425	$763,629	$700,630
First cost annualized at 5%, 38 yr. (.05928)	44,544	45,268	41,533
Annual labor costs	7,356	9,838	16,238
Annual nonlabor costs	12,977	16,729	16,729
Total annual cost (estimate)	64,877	71,835	74,500

Basic assumptions:

Skilled operator and assistant at $4.00/hr., including fringe benefits.
Bookkeeper/Administrative Assistant at $2.50/hr., including fringe benefits.
4 hr./wk. skilled labor for each small wastewater plant on the average.
12 hr./wk. skilled labor for single large wastewater plant.
Sludge handling and disposal at $25/1000 gallons, about 95,000 gal/year.
Sewer annual O&M at $.04/ft. gravity; $.06/ft. pressure or force mains.
Chlorine at $.02/1000 gallons.
Electric power at $.025/kilowatt hour.
System components capitalized (for replacement) over reasonable lifetimes at 6%.

Detailed Description of Recommended Wastewater System Approach

The wastewater treatment plant is fairly new to the U.S., but it is based on designs well tested in Europe. The plant uses plastic media disks which rotate on a horizontal shaft, half-submerged in a basin of wastewater and half-exposed to the air. This arrangement obviates the need for control of mixed liquor solids. There are no air compressors or air diffusers. When underloaded with respect to nominal design capacity, the plant responds by giving more complete treatment. For example, at the required 120,000 gpd design loading, the type of plant envisioned would reduce the BOD_5 by 93 percent. At an anticipated loading of less than 60,000 gpd, the same plant will reduce BOD_5 by 97 percent, according to manufacturer-supplied design curves (*Bio-Surf Design Manual*). As a further illustration of the importance of this property, the final stage disks in the plant are covered with nitrifying bacteria which oxidize ammonia, thereby considerably lowering the nitrogenous oxygen demand on the receiving waters.

Chlorination of the effluent will most likely be accomplished by means of a powdered or compressed powder-tablet form of chlorine.

Pressure Sewers

Pressure sewers either create positive pressures at each house with pumps or a negative pressure in the system with a central vacuum pump. The sewers range in size from about 1¼ to 4 inches, and they are normally made of plastic pipe. Pumping station costs are about $250 to hook up a house to a gravity sewer and around $1,000 to hook up to a pressure sewer.

Pressure sewer systems can either grind up the wastewater contents and convey a pressurized slurry, or they can use a modified septic tank to settle the solids and pump relatively clear septic tank effluent. In either case, the sewers must be designed so that a scouring velocity of about two fps (feet per second) will be achieved at least once a day in order to flush out settled solids and keep the lines from clogging. The requirement is much more critical with systems that convey ground-up sewage than with systems which convey septic tank effluent, especially since the sewage in the former contains greases. In terms of initial costs, the pump and septic combination will cost about the same or perhaps slightly less than the grinder pump. Since sewage is partially stabilized (i.e. BOD is reduced) and settled in the septic tank,

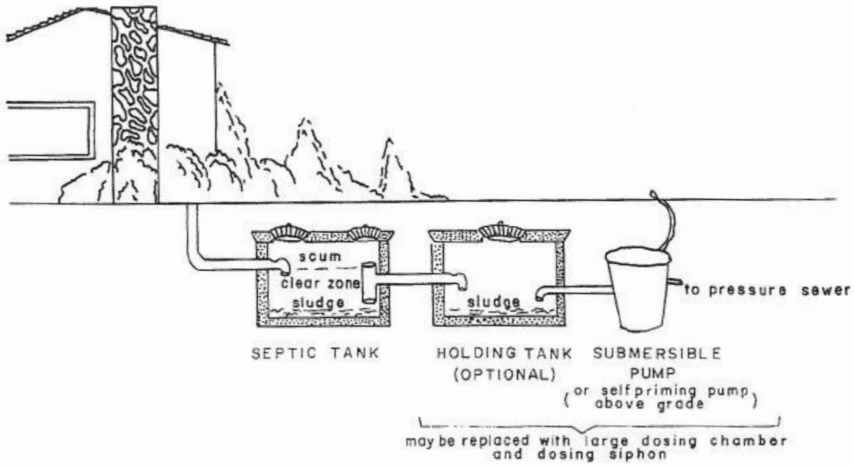

Figure 3. Septic Tank and Pump Preceding Pressure Sewer.

the treatment plant that receives septic tank effluent will be faced with a lower organic and solids loading than one which receives grinder pump effluent, although septic effluent will require more aeration. The septic tanks will, of course, have to be pumped out every few years, and the pumpings will require sanitary disposal.

A cost comparison between pressure and gravity sewers is determined by considerations of population density and population size and by local parameters such as prices, topography, and state and local codes. Gravity sewers have considerable excess capacity built into their design and therefore are to be preferred in certain locations where significant growth is imminent. If a community is composed of both densely and sparsely populated areas with low growth rates, the most economical solution may be to serve the former with gravity sewers and the latter with small-diameter pressure sewers.

The system recommended for the Big Creek Public Service District will employ a combination of gravity sewers along the main highway, connecting force mains where necessary, and pressure sewers in the sparsely populated hollows that have inhospitable geology for gravity sewers. The septic tank with pump version (Figure 3) is recommended to minimize problems of grease clogging of the lines. A holding tank of volume equal to the septic tank will be interposed between the septic tank and the pump. The holding tank will fill from the top (as a septic tank), but it will drain from the bottom (as a bathtub), so that it will normally empty. Its function is solely to provide two to three days' worth of effluent storage in the event that a prolonged power failure, blockage, or other emergency makes the pressure sewer inoperative. Wherever possible, several houses have been clustered onto a single septic (collector) tank, and the four-inch house sewer has been extended out beyond the normal house-sewer hookup point to make this possible. The septic tanks and excess house sewers will be the property of the Big Creek Public Service District, and they will be located on land either owned by the Public Service District or transferred to the Public Service District under easement. Therefore, the entire pressure collection system should qualify as an allowable cost for Environmental Protection Agency grant funding.

The sewers will be of PVC plastic with solvent welded joints or materials of equivalent performance to minimize infiltration. Infiltration specifications will be written into the construction bid package, and the sewers will be tested for watertight integrity before acceptance.

Inflow will be minimized by strict sewer use regulations prohibiting the hookup of household storm drains, downspouts, etc. Manhole covers will either be sealed or raised in areas subject to flooding. One exception will be that the backwash brine from the domestic water treatment units at the pump houses will be connected to the sewers, but through a flow equalization tank with small orifice to prevent shock loading of salts at the wastewater plant.

Operational Performance and its Effect on the Receiving River

The anticipated performance of the waste treatment plant well exceeds 90 percent reduction of BOD_5, with 93 to 97 percent expected. Ammonia removals of about 80 percent are expected.

Flows of the Guyandotte River vary from 89 to 16,200 cfs. Assuming an effluent from the Big Creek Public Service District of 125,000 gpd, 25 mg/l BOD (based on a conservative 90 percent removal and 250 mg/l influent), and zero dissolved oxygen (again, conservative), the dilution at low flow will be

$$\frac{125{,}000}{52{,}518{,}208^{*}} = .002 \text{ or } 500{:}1$$

The change in BOD will then be

$$\text{BOD} = \frac{25 \text{ mg/l}}{501} = .05$$

or the BOD of the stream will be raised only from 3.9 to 3.95 under

*89 cfs = 52,518,208 gpd.

worst conditions. The reduction in dissolved oxygen will be approximately

$$D.O. = \frac{10.1}{501} = .02 \text{ mg/l}$$

and the stream D.O. would be lowered from 10.1 to 10.08, a negligible decrease. Coliform count of the river is already extremely high. At a 500:1 dilution the maximum addition from sewage plant effluent will raise the coliform count from 800 to 820. Thus the treated wastewater will have no significant effect upon the quality of the receiving river. When completed in 1976, the R. D. Bailey Dam upstream of Big Creek will even the flows and should therefore reduce even further the impact of Big Creek sewage plant effluent.

Cost Estimates for Wastewater Treatment System

A construction cost estimate for the treatment plant is given in Table 8. The estimate is based in part on manufacturer-supplied information

Table 8
Construction Cost Estimate for Treatment Plant (950 Design Population, 120,000 gpd)

Life station preceding plant	$ 5,500
Primary treatment—screen	3,500
Flow equalization tank (4 hr. flow = 20,000 gal.)	10,000
Feed mechanism (bucket)	1,000
Shaft with biological surfaces (20 ft. 4 element, 64,900 ft.^{2} of surface will give 93% BOD removal when loaded at 120,000 gpd, 97% at 60,000 gpd for fresh sewage, and 92% removal for 24 hr. septic tank effluent)	
Scoop clarifiers—two 100 ft.^{2} area each, at $4,500	9,000
Sludge and primary screenings storage tank (at 3 ft.^{3}/population equivalent = 21,300 gal.)	10,000
Tankage for shaft, 35 yd.^{3} concrete at $200	7,000
for clarifiers (20 yd.^{3} each), 40 yd.^{3} at $200	8,000
Chlorinator	2,000
Basic plant cost, subtotal	$ 77,500
Transportation of plant components to site, 1500 mi. at $2	3,000
Installation and connecting utilities to plant at 20% of basic cost	15,500
Site preparation, including landfill to bring plant above flood level, access road, grading, landscaping, etc.	10,000
Shell enclosure around plant, including basic water laboratory, work space, and small office area	14,500
Total Treatment Plant Construction Cost	$120,000

Table 9
Estimated In-Place Costs for Wastewater Collection and Treatment System

	Collection System	*Treatment System*	*Total*
Construction cost	$478,630	$120,500	$599,130
Land acquisition	6,500	5,000	11,500
Engineering fees (includes resident construction engineer; approx. 10% of construction costs)	47,863	12,050	59,913
Legal fees (approx. 2% of constructions costs)	9,572	2,410	11,982
Interest during construction (1% per month for three months on ½ of total construction cost)	7,180	1,807	8,987
Contingencies (approx. 10% of construction costs)	47,863	12,050	59,913
Total In-Place	$597,608	$153,817	$751,425

for a typical design which is believed representative of the cost of the final design. Estimated total in-place costs are given in Table 9. All operation and maintenance costs are summarized in Table 10. The annual cost of equipment repair and replacement was estimated by capitalizing over assumed equipment lifetimes at 6 percent. Pump lifetimes of seven years (replacement costs of $400), lift station life of 20 years for the structures (replacement at $3,000), seven years between pump overhauls (at $200), and 30 years of life for components of the treatment plant that might need repair or replacement (estimated at $30,000) were assumed. The overhaul, repair, and replacement annual costs for the 26 pumps, five lift stations, and treatment plant amount to $5,511.

In addition, sewer repair, based on an estimate of $.04/foot for gravity sewers and $.06/foot for pressure sewers, amounts to $2,906 annually, but most of the cost is associated with labor or outside services rather than materials. The sewer repair cost was estimated for gravity sewers by dividing national average per capita sewer O&M costs by national average lengths of sewer per capita for appropriately sized communities (Goldstein and Moberg, 1973). An arbitrary 50 percent was added to the estimate for pressure sewers in anticipation of greater O&M costs.

Table 10
Annual Operation and Maintenance Costs for Wastewater System

Utilities (heat and power for treatment equipment, pumps, and lift stations)	$ 1,836
Chemicals and other consumable supplies	830
Equipment overhaul/repair/replacement	5,511
Service equipment (truck)	2,300
Rental (rights-of-way)	500
Insurance	500
Subtotal, nonlabor O&M	$13,844
Field personnel (chief operator, assistant)	6,106
Office personnel	1,250
Subtotal, labor	$ 7,356
Total Operating Costs (excluding debt service)	$21,200

Estimated Costs and Funding for the Entire Project

Tables 11 through 13 show in-place costs, O&M costs, funding, and an annualized cash flow model for the recommended alternatives, the five-cluster water system and central wastewater system, in the project. The indebtnedness must be limited to about $70,000 if the monthly payment is to be in the $14 to $15 range per connection, which represents about 5 percent of the median family income in the service area. The annualized cash flow model (Table 13) shows that the monthly payment can be kept down to about $14 with 250 connections. If enough users, e.g. the country club or motel, exceed the 4,000-gallon minimum consumption base, the anticipated break-even rate may be reduced.

Conclusions and Discussion

The water supply system that is likely to be superior, both technically and economically, will be comprised of between three and five local "cluster" systems each of which will have a well, treatment plant, one or more storage facilities, and distribution lines. A preliminary estimate of the first costs for the water system amounts to about $1,472 per connection.

The recommended wastewater system will have a centralized collection system terminating at a single nominal 120,000 gpd treatment plant that will discharge wastewater (receiving up to 97 percent

Table 11
Recapitulation of Total In-Place and O&M Cost Estimates

	Water	*Wastewater*
Construction	$290,405	$599,130
Land acquisition	9,500	11,500
Engineering fees	29,041	59,913
Legal fees	5,808	11,982
Interest during construction	4,357	8,987
Contingencies	29,041	59,913
Total In-Place Cost	$368,152	$751,425
Utilities	$ 718	$ 1,836
Chemicals	7,763	830
Equipment repair and replacement	6,062	5,511
Service equipment	1,500	1,500
Purchase of services	—	—
Rental	—	500
Insurance	500	500
Subtotal, nonlabor annual costs	$ 9,543	$ 12,977
Field personnel	6,960	6,106
Office personnel	1,250	1,250
Subtotal, labor annual costs	$ 8,210	$ 7,356
Total Annual Operation and Maintenance	$ 17,753	$ 20,333
Monthly, for 250 Connections	$ 5.92	$ 6.78
Combined Total—$12.70/Connection/ Month		

BOD removal and chlorination) into the Guyandotte River. The hollows will employ septic tanks from which a settled effluent will be pumped under pressure in small-diameter pipes to the gravity sewers in the adjacent roadside communities. The communities will connect to the treatment plant with pressure mains. A preliminary estimate of first cost per connection for the wastewater system is $3,006. This is only about 5 percent more than the national average cost (in 1973 dollars) for systems that serve similarly sized communities (Goldstein and Moberg, 1973). Inasmuch as the Big Creek Public Service District area presents a most difficult terrain for sewer construction, this should be a most cost-effective system.

It would seem reasonable that the water and sewer bill should not exceed 5 percent of family earnings; otherwise it would become too burdensome for the residents to pay. Based on a median family income of around $3,500 (see Table 4), the 5 percent guideline amounts to about $14.60 per month. The recommended design should provide

Table 12
Allocation of Loan and Grant Funds to Big Creek Public Service District

	Water	*Wastewater*	*Total*
EPA grant	—	553,250	553,250
State of West Virginia grant	213,250	36,750	250,000
Guyandotte Water and Sewer Development Association grant	88,575	161,425	250,000
Farmers Home Administration Water system loan	66,325	—	66,325
Totals	368,150	751,425	1,119,575

fully adequate sanitation services for just under this figure (approximately $14 per connection per month).

Major equipment failure, lack of management ability, and an inflated initial membership (which after attrition leaves too few subscribers to pay the bills) have been indicated by Peterson (1971) as the three major causes of failure in rural water systems. Management includes the routine day-to-day operation of the system with systematic attention to the details of meter reading, bill collection, and maintenance. Major equipment failure after the initial warranty period can seriously threaten the continued operation of a system. Equipment repair and overhaul, which account for about 30 percent of total O&M costs, have been included in the O&M cost estimates for this project.

The National Demonstration Water Project has developed and is now revising training materials and programs for the management, administration, and support of water and wastewater companies. Operational experience with existing companies in the Roanoke, Virginia, and Beaufort, South Carolina, affiliated field projects is being factored into the revisions.

The public service district form of organization for the local com-

Table 13
Annualized Cash Flow Model

	Water	*Wastewater*	*Total*
Debt service (.05928)	3,932	—	3,932
Operation and maintenance	17,753	20,333	38,953
Totals	21,685	20,333	42,885
Monthly, per connection (based on 250 connections)	$7.23	$6.78	$14.01

pany should obviate the problem of inflated initial membership, since all homes in the service area will be legally required to subscribe and pay their bills. The existence of sanitary facilities should also spur a modest growth rate that would compensate for any subscriber attrition. Also, the public service district, unlike a private association, will qualify for state and federal grant programs.

This study illustrates quite conclusively that the Big Creek system or any similar rural system will require large grants of initial capital to minimize the debt service load and/or some form of subsidy for operating expenses if it is to be a feasible venture. Low cost loans such as the 5 percent, 40-year construction loans from the Farmers Home Administration, while by no means an insignificant form of subsidy, do not meet the financial needs of rural communities. For comparison, it is interesting to note that were this million-dollar project to have been installed and operated as an investor-owned venture without subsidy, the monthly rates per subscriber would very likely exceed $40, well beyond the financial capabilities of the community.

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