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ECONOMIC EVALUATION OF ALTERNATIVE FARM WATER SOURCES IN THE CLAYPAN AREA OF ILLINOIS

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ABSTRACT

ECONOMIC EVALUATION OF ALTERNATIVE FARM WATER SOURCES

IN THE CLAYPAN AREA OF ILLINOIS

The claypan area of Illinois is characterized by unreliable water supplies. In addition, water quality problems have recently been recognized in the form of widespread nitrate and coliform contamination of water in private wells in Washington County. A ten-square mile area in this county was selected for study. The nature of present water supplies was described and the costs of six alternative supply systems were estimated: (1) present on-farm sources, (2) treatment of pond water, (3) combination of present on-farm sources plus hauling, (4) hauling all water, (5) purchasing all water from nearby municipality via pipeline, and (6) combination pipeline plus present on-farm sources. The six alternatives were examined in terms of the net present value of costs associated with each alternative, considering a 40-year planning period. Although the present sources proved to be the least costly they are unsatisfactory for reasons of health and also reliability. Treatment of pond water was the least-cost source of meeting the quality requirements for water for the total area. However, the reliability of this source and questions of personal preference against drinking pond water may indicate a preference among some users for connection with a municipal system which was somewhat more expensive.

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I. INTRODUCTION AND PROJECT OBJECTIVES

Although Illinois has an abundant water supply, it is unevenly distributed throughout the state. In 1967 it was estimated that the total quantity of water available in the state was about three times greater than the quantity used[33]. The claypan area of Southern Illinois is one of the areas characterized by frequent water shortages. The particular claypan area selected for this study is in Washington County, in southwestern Illinois.

Pryor[24] reports that the most important aquifers in southern Illinois are deposits of sand and gravel, sandstone, limestone, chert, and dolomite. Sand and gravel deposits are water-yielding because of their relatively high porosity and permeability. The water-yielding characteristics of sandstone, like those of sand and gravel, are dependent upon grain size and sorting. The sandstone strata in southern Illinois are generally fine grained and cemented. They have relatively low porosities and permeabilities and yield water only from interconnected cracks and crevices. Thus, the best potential sources of large supplies of water are the sand and gravel deposits in the major valley systems. However, sand and gravel aquifers are virtually absent in much of the claypan area.

The claypan area is also characterized by high susceptibility to drought. Huff and Changnon[17] have analyzed the frequency distribution of droughts varying from 3 to 60 months and found that the relative severity of droughts is highest in the southeastern, extreme southern, and southwestern regions of the state. In general, the regions of greatest drought severity are elongated with the orientation of the major axis for shorter length droughts to be from southwest to northeast, thus, the Washington County area does lie within the general pattern of shorter duration droughts (less than 36 months). In addition to the high probability of drought occurrence in the claypan area, the soils have low potential for retention of moisture. The surface soils are underlain with subsoils of high clay content and are thus slowly permeable. These conditions give rise to the high year-to-year variation in crop yields in southern Illinois [29].

The lack of reliable water supplies in this area is aggravated by the high nitrate content in the wells. Nitrate concentrations in excess of the U. S. Public Health Service standards of 45 parts per million have been found in water from shallow wells in Washington County.

The overall purpose of the research project was to identify and evaluate a minimum-cost combination of alternative methods of supplying both the quality and quantity of water required by farmers in a selected area of southern Illinois. Some of the possible sources to be considered were:

1. Individual farm ponds
2. Individual farm wells, both shallow and drilled
3. Individual cisterns
4. Central reservoir serving a number of farms
5. Central well serving a number of farms
6. Connection to municipal water system

Treatment alternatives of both ground and surface water were considered where appropriate, in combination with the above sources, in evaluating the minimum cost combination of methods.

The specific objectives of this study were as follows:

1. To select a specific area within the claypan region of Illinois in which (a) water supplies are sufficiently uncertain to warrant an examination of alternative water sources, and (b) there exists the potential for the establishment of several alternative water sources such as those mentioned above.
2. To estimate the total farm water requirement, both amount and quality, for household and livestock purposes on the basis of present and expected farming practices, of the farmers in the selected area.
3. To develop the necessary data and to estimate costs for each of the possible water sources and treatment processes, including construction, maintenance, and operating costs, both on an individual farm and total area basis.
4. To compare alternative sources or combinations of sources in economic terms in order to arrive at a minimum-cost method of providing the necessary amount and quality of water for the farmers in the specified area.
5. To suggest possible organizational structures which would provide incentives for implementation of the optimal plan derived in objective four above.

II. DESCRIPTION OF STUDY AREA

Washington County has been the focus during the last two years of widespread concern about the water supply. In 1970 there were reports of baby pig losses on several swine farms in the county. Local veterinarians suggested that excessive nitrate in the water might be involved. This led to a countywide nitrate survey by Smith, Hill, and Walker[28]. This survey consisted of sampling some 72 farm ponds and 244 wells, 213 of which were large diameter dug or augered wells ranging in depth from 6 to 30 feet, and 31 were small diameter drilled wells ranging from 85 to 230 feet in depth. None of the ponds sampled contained more than 13 parts per million nitrate (NO_3) and most had less than 5 ppm NO_3 at the time of sampling. These amounts are far below the U. S. Public Health Service standard of 45 ppm NO_3. However, nearly 75 percent of the shallow wells and nearly 20 percent of the drilled wells were over the 45 ppm level. The results are summarized in Table I. Thus, the widespread nitrate contamination of ground water supplies as well as variability of weather conditions in this part of the state seem to warrant examination of alternative sources of water supply. Thus, Washington County was selected as the general study area.

Washington County is located in the southwestern region of the state (Figure I). The county has a land area of 565 square miles or approximately 361,216 acres. The 1969 Census of Agriculture[6] shows 325,765 acres or 90.2 percent of the total area as farmland. In 1969[6] there was a total of 1386 farms with an average size of 235 acres per farm as compared to 1440 total farms with an average size of 223 acres in 1964.

Table I - Summary of Washington County Nitrate Survey, 1970

Nitrate Content ppm	Shallow (dug) Wells	Drilled Wells
0	33	25
1-45	24	--
46-100	21	1
101-150	46	1
151-200	16	--
201-250	23	--
251-300	20	1
301-350	7	1
351-400	7	1
401-450	8	1
451-over	8	--

SOURCE: Smith, W. D., R. O. Hill, and W. H. Walker[28].

FIG. 1 WASHINGTON COUNTY, ILLINOIS

In 1969 in Washington County, 42.0 percent of the farm operators were full owners, 36.8 percent part owners, and 21.2 percent tenants. In comparison, the 1964 figures were 34.4 percent, 39.0 percent, and 26.5 percent, respectively. The average age of the farmers in the county was 49.8 years in 1969, down from 50.2 years in 1964. It is interesting to note that in 1964 there were only 27 farmers under 25 years old, however, in 1969, there were 40 in this age group.

The population of Washington County has steadily declined from 1900 to 1965 when it reached a low of 12,900 persons. The 1965 population was 65 percent of the 1900 total with slightly more than 20 percent being classified urban. The entire population was classified as all rural until 1950[18]. The 1970 population shows 13,780 people residing in the county.

The Hoyleton area of Washington County was selected for several reasons. The County Extension Adviser pointed out that several farmers in this area had approached him wanting assistance with their water problems. Some of the larger dairy farmers in this area have hauled several thousand gallons of water each month because of the poor quality and reliability of their present water sources. Other dairy farmers, who were experiencing dairy breeding problems, believed that their water supply was the causal factor. A few large pork producers had also reported the belief that the dysentery problems in their swine herds were caused by nitrate contamination of their water supplies. These farmers had also experienced large water shortage problems. Also, nine of the 244 wells tested in the survey by Smith, Hill, and Walker[28] were in this area. Seven of the nine contained nitrate in excess of the

45 ppm NO_3 recommended limit. Over 70 percent of the farmers have existing farm ponds, all farmers have existing shallow wells and cisterns, and the Village of Hoyleton serves as a source for connecting to a municipal system. Therefore, the Hoyleton area appeared to be typical of the general problems being experienced in Washington County and was selected as the specific area to be examined (Fig. 2).

A. Ground Water Availability

In this area, water can be found everywhere below the top of the zone of saturation, i.e., the top of the water table. However, it is not everywhere available for withdrawal. Successful wells can be constructed only where strata are present that will easily transmit and yield water. Most of the study area does not have good water-yielding capabilities, due to the limited bedrock sources and the general absence of adequate sand and gravel deposits. The large diameter wells most common in this area are able to provide water in these conditions due to their inherent storage capacity. All but one of the wells on the 38 residences in the study area were the shallow, large diameter type, therefore, these wells on the average would be less than 26.5 feet deep, the average depth to bedrock. This helps to explain the widespread contamination of the ground water aquifers that exist in this area.

The well logs indicated that several test wells had been drilled in an attempt to locate an aquifer capable of furnishing the Village of Hoyleton with a reliable source of water. All reports showed that the test wells were unsuccessful in locating such an aquifer.

Personnel at the Illinois State Water Survey and those at the Illinois State Geological Survey concurred that there are no adequate

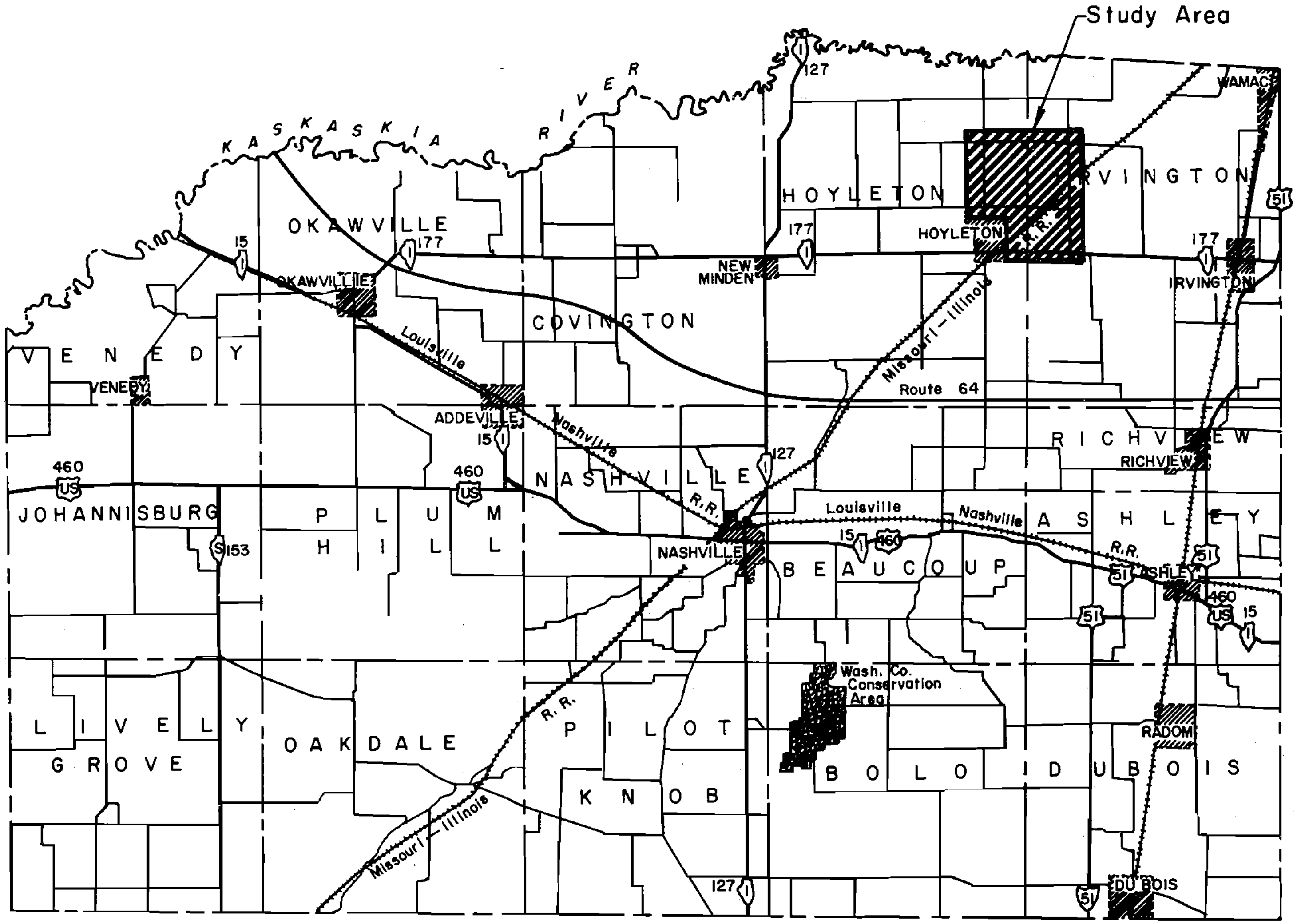

FIG. 2 SELECTED AREA FOR STUDY WITHIN WASHINGTON COUNTY

continuous aquifers in this area. Ground water is obtainable only from small, discontinuous collections of sand and gravel. They also agree that the probability of finding a reliable drilled well in this area is extremely small or non-existent.

B. Description of Soils

The Washington County Soil Report by Smith and Smith[27] provides information concerning the movement of water from precipitation through the soil for recharge of aquifers. Nearly 100 percent of the Hoyleton area has either Cisne silt loam or Hoyleton silt loam soil types. Each type occupies about one-half of the area.

The Cisne type as described by Smith and Smith, developed under prairie grass vegetation and is characterized by an almost impervious subsoil. The soil drains extremely slow and is often wet and cold in the spring. "Slick spots" frequently occur in conjunction with this type of soil, and they, in fact, do occur in most of the Cisne soils in this area. Slick spots are commonly known as scalds or alkali spots, and are of a much lighter color than the rest of the soil. The subsoil in these spots is very tough and is exposed in much of the area where erosion has been active. Underdrainage is extremely slow and, when dry, slick spots are very hard and resist penetration of water. Due to the lack of water movement in this type of soil, surface drainage is recommended as the first step for soil improvement and to attempt to capture some of the water that is usually lost as runoff.

The Hoyleton silt loam as compared to Cisne has relatively good surface drainage, but it too has very slow underdrainage and does not lend itself to artificial drainage with tile. Slick spots also occur in this soil but are not as numerous or as large as with the Cisne silt loam. The surface soil is a few inches deeper than with Cisne silt loam, however, the subsoil is again very compact and a plastic-like clay.

Appreciable ground water recharge usually occurs only twice each year, during the spring from rains and melted snow and during heavy fall rains. During the winter months ground water recharge is limited because of frozen ground. During the summer, precipitation may only percolate a few inches below the surface before it is lost due to evaporation, which is accelerated because of the high temperatures. From the description of the soils in this area, it is easily seen that due to the texture of the surface soil and the impervious nature of the subsoils, water may be available for recharge but may never reach the water table.

C. Climatology

It is extremely difficult to find data to describe the climatology of a region as small as the one selected (9.55 sq. mi.). Therefore, a brief description of the climatology of the southwestern region of Illinois will be presented. Huff and Changnon[17], using percent of normal precipitation to define drought severity, reported that on the average, once in 2 years, the Washington County area can expect a 3-month period with as little as 48 percent of the 3-month normal precipitation. The probability of 3-month droughts is higher in the winter season in the northern part of the state than in the spring, summer, or fall. The reverse is true in the southern regions. Thus, crop failures due to drought are more likely in the southern regions of Illinois even though the annual precipitation in the south is larger. Recharge of ground water supplies is also lower in the south due to the timing of the rainfall. Heavy rains occur in the winter when the soil is frozen.

Huff and Changnon also report that a comparison of the spatial pattern of coefficients of variation of annual precipitation with the drought patterns shows remarkable similarity between the incidence of precipitation and drouth. The relatively low coefficients occur in conjunction with relatively low drought severity in the northeast and east, whereas high coefficients of variation correspond to peaks in drought severity in the southwest, south and southeast. High relative variability of annual precipitation appears to correspond with 12-month drought severity, i.e., droughts are more severe where the year-to-year variation in rainfall is greatest. This may occur despite the fact that average precipitation is considerably greater in most of the severe Illinois drought areas.

The nearest weather station to the Hoyleton area is the Nashville station located four miles northeast of the city of Nashville, Illinois. Precipitation data for the period since 1947 were obtained from Climatological Data, Illinois[8]. The mean annual precipitation for this period was 39.45 inches. The variance and standard deviation about the mean are 70.40 and 8.38 respectively. Thus, there is considerable year to year variation in mean annual rainfall in the study area. This variation indicates that the area has relatively severe droughts which directly influence the amount of water available for recharge of ground water supplies and surface sources.

Since temperature has a direct influence on evaporation, it needs to be mentioned. In the study area, the yearly mean temperature is 54.9 degrees Fahrenheit. The mean maximum temperature in the months June through August is approximately 90 degrees. The mean minimum temperature for these months is 65 degrees. The mean maximum temperature for the months December through February is approximately 45 degrees and the mean minimum is approximately 26 degrees. These temperatures are approximations from charts presented in Water for Illinois - A Plan for Action[33].

III. PRESENT WATER SITUATION IN THE STUDY AREA

An interview schedule was constructed to gain information pertaining to the water situation in the area.* The physical yield or amount of water available from a source, the quality of the water from a source, and the intensity of use of a particular source are all factors which determine whether or not a source is "adequate." One source may be adequate for a household of three, but not for a dairy farmer with 100 head of cattle. The schedule was used to gather information pertaining to the respondents' daily use of water, (i.e., the number of persons in the household, the maximum number of livestock on the farm at any one time, etc.), present sources of water, adequacy of present supplies, means of alleviating shortages if and when they occur, and general attitudes concerning alternative means of insuring an adequate, reliable water supply.

I. Summary of the Present On-Farm Sources

Nearly all of the 38 households in the study area use two or more different sources to meet their daily requirements. The few that reported only one source were farmers or rural residents with little or no livestock, with the primary demand being for household uses. Over 70 percent of all respondents reported the existence of a pond on their property. Table 2 shows the number of respondents that use a given source to fulfill the various daily requirements. A distinction is made between shallow well sources on the basis of treatment. Several wells were reported to have had sporadic batch chlorine treatments. None of these wells were equipped mechanically for continuous chlorination or

* A copy of the schedule appears in the appendix.

other treatment. The column headed "combination"(Table 2) indicates that the respondents reported two or more sources for that specific use. Only one of the farmers in the study area had a functional deep well. Even though this farmer considers this well to be very reliable, he uses it only for drinking and for his 12,000 chickens. For household uses other than drinking he still uses cistern and shallow-well water. Approximately half of the respondents indicated their source of drinking water was shallow wells and about half indicated cisterns. The group indicating use of shallow wells was very much opposed to drinking cistern water because of the high bacteria content associated with cistern water. They reasoned that even though there was a possibility of a high nitrate content in the shallow wells, they preferred this source. The group that indicated cisterns as their source of drinking water were just as adamantly opposed to using water from shallow wells because of all the publicity about nitrate contamination of ground water in this area. More will be said about the water quality in a later section. Two respondents reported that they are presently hauling all of the water that is used in the house, both for drinking and other household uses, from the Village of Hoyleton. One of these farmers is also hauling the water that is used in the milk house for his 150 dairy cattle. The individual that indicated "combination" as the source of his drinking water reported that about once every two weeks he buys approximately 20 gallons and brings it home from Hoyleton in glass bottles in addition to using water from a shallow well.

Water supply problems are not generally short-run problems; over a period of time the farmer either solves the problem or adjusts his operation to the available supply. Many times a farmer does the

Table 2 - Present Water Source and Use

	Deep Well	Shallow Well Untreated	Shallow Well Treated	Cistern	Haul From Hoyleton	Pond	Combination
Human Consumption	1	15	2	17	2	0	1
Other Household Uses	0	6	1	21	2	0	8
Milk House	0	3	5	2	1	0	0
Watering Dairy	0	0	0	0	0	9	3
Watering Other Livestock	1	10	0	1	0	7	3

latter without being aware of doing so. This seems to be the case in this area. When the respondents were asked if they considered themselves to have a water problem or if they were satisfied with their present supply, over 75 percent answered that they were satisfied with their present source. Only three of those reporting some type of livestock indicated that their livestock operations were limited because of water supply. However, over 21 percent of those reporting livestock on their farms presently, indicated that if they had an unlimited source of good quality water, they would either expand their present operation or initiate some new enterprise. There were only 14, or 37 percent of all the respondents that felt that the possibility of a water shortage was great enough to merit examination of alternative sources. Nearly 70 percent indicated they would be interested in obtaining all or part of their water from an off-the-farm source. Nearly 50 percent of those showing an interest in some off-the-farm source of water indicated that they would in fact change their water use habits if they had access to an unlimited supply of water at some reasonable price. These changes included such things as acquiring automatic washers, dishwashers, and expanding other household uses to plans for automatic sprinkling systems for hog barns and automatic preparation stalls for dairy cattle. Another example which indicates that the people in this area have adjusted to their presently available water supplies rather than searching for new sources or treatment possibilities follows. Over 75 percent of the people in this area were satisfied with their present sources. However, nearly all of these people haul water or have water hauled for them sometime during the year. It appears that the people in the study area have had water problems for many years and have made adjustments to the quantity and quality of water presently available.

An effort was made to gain information about the reliability of the water sources in the area. Questions were asked pertaining to actual water shortages that have occurred in the area, when these shortages occurred, their duration, causes of the shortages, i.e., excessive use, drought, contamination, etc., and how the shortages were alleviated. The respondents were not willing or able to provide adequate answers to these questions. Several respondents did not answer some of these questions. When asked about the frequency of shortages, answers such as "a couple of times" or "I guess only once or twice" were offered. There were several that reported either that shortages occurred every year at the present time, or every year until some specified time such as, for example, the time that the pond was built or extra wells were dug. When asked about dates of specific shortages, 14 of the 28 reporting water shortages did not answer, 10 gave ranges admitting lack of memory, and only 4 gave specific dates. No one offered answers to questions concerning duration. It was hoped that dates and durations of reported shortages and climatological data could have been secured and that some estimate of the probability of a shortage could be made. This was unable to be accomplished. When asked the reason for each shortage, 15 responded lack of precipitation, one indicated excessive use, and nine indicated a combination of the two. No one indicated that the quality of the water was ever a reason for shortage. All of the shortages appeared to be alleviated in the short run by hauling, however, 12 of the 28 who reported shortages proceeded to construct new ponds, to expand existing ponds, or to dig additional wells. No one indicated that they sold any livestock as a direct result of any of the shortages, although it seems that water shortages have played a major role in determining the amount of livestock on these farms.

Possibilities for expanding the on-the-farm sources in the study area appear to be primarily expanding existing ponds or constructing additional ponds. The possibility of digging more wells does exist, but few people indicated this as a means of insuring a water supply.

2. Quality of the Water from Present On-Farm Water Supplies

The quality of the water supplies in Washington County has been of widespread concern at least since early 1970 when reports of the baby pig deaths were released. It is appropriate at this point, to define the relevant U. S. Public Health Standards[30]. The recommended upper limit for nitrate (NO_3) is 45 parts per million. There are recommended limits for many other chemical substances, but nitrate is the one that is most relevant to this research. Bacteriological quality standards are specified somewhat differently. Standards are specified depending upon the technique used to determine the presence of bacteria of the coliform group. The appropriate standard is that no coliform counts shall exceed 4/100 ml in two consecutive samples.

Two studies have already yielded reports concerning the quality of water existing in Washington County, one by Smith, et al. [28], and another by Gunderson and Craun[12]. Smith's study has been discussed earlier. Gunderson and Craun's research provides additional information about the effect of high doses of nitrate on young children in Washington County. The study was conducted in April through June, 1971. The study involved children 1 to 8 years of age consuming high nitrate water. In the process of the study, water samples were taken from 146 shallow dug wells. The results were very much the same as those of Smith's study. Some 64 percent had over 45 ppm NO_3 and 49 percent had over 100 ppm. Bacteriological analysis was made on 46 wells, 32 with high nitrate content and 14 with low nitrate content. Only three were acceptable according to U. S. Public Health Service Drinking Water Standards.

Reports of analysis that had been made on water samples taken from any of the residents in the study area were requested from the Regional Diagnostic Laboratory at Centralia, Illinois. The laboratory forwarded reports of 10 farmers with a total of 12 wells and 7 ponds being sampled. Bacteriological analysis was performed on only 2 of the 12 wells. Arrangements were made with the Diagnostic Laboratory to analyze samples from the remainder of the residents in the study area. Samples from both wells and cisterns were collected from all but three of the remaining 28 residents in the area. One pond was also sampled. Combining the two groups of water samples, a total of 36 wells, 35 shallow dug and 1 drilled, 21 cisterns, and 8 ponds in the study area were sampled.

Of the eight ponds tested, all eight were found to be free from any nitrate contamination. All 21 of the cisterns were also free of any nitrate contamination, however, not one was rated satisfactory in terms of coliform counts. Coliform counts ranged from the border line 4/100 ml to what was considered "excessive" even in a special culture. It is of interest to note that several of the cisterns sampled contained water that had been hauled, in presumably "uncontaminated" tank trucks or wagons, from the Village of Hoyleton. However, the high coliform count still occurred. This indicates that poor construction and improper maintenance are probably the causes of contamination in most of the cistern supplies. Eight of the 35 shallow wells were below the 45 ppm nitrate level. The one drilled well contained 57.2 ppm, slightly over the recommended limit. Table 3 shows a summary of nitrate content in shallow wells in the study area as compared to the 213 wells in the Smith's county survey[26]. Of the 26 shallow wells analyzed for coliform bacteria, only one was considered satisfactory and water from this well tested 0/100 ml. Coliform counts in the other wells ranged from 6/100 ml to again what was considered to be "excessive" in a special culture. Because of the high coliform counts on the one sample, it was recommended that immediate steps be taken to treat these sources and to resubmit a sample to the Diagnostic Laboratory as soon as possible.

From an examination of Table 3, one can see that the study area very closely resembles the county as a whole. Approximately 22.80 percent of the study area wells are under the 45 ppm recommended limit, whereas

Table 3 - Summary of Shallow Well Nitrate Levels in the Study Area and the County

Range of NO_3 ppm	Frequency Hoyleton Area	Percent Hoyleton Area	Frequency[a] Washington County	Percent[a] Washington County
0	4	11.42	33	15.49
1-45	4	11.42	24	11.27
46-100	2	5.71	21	9.86
101-150	5	14.2	46	21.60
151-200	7	20.0	16	7.51
201-250	2	5.71	23	10.80
251-300	3	8.57	20	9.39
301-350	4	11.42	7	3.29
351-400	3	8.57	7	3.29
401-450	0	0.00	8	3.76
451-over	1	2.85	8	3.76
TOTAL	35		213	

[a] Smith, W.D., et.al.[28]

26.75 percent of the countywide group falls below the 45 ppm level. Over 75 percent of the study area wells are above 100 ppm whereas only 63 percent of the countywide group are above this level. Thus, the two groups of wells do show much similarity with the study area having a slightly higher percent of its wells with higher concentrations of nitrate.

Thus we conclude that the quality of the present on-farm sources of water supply in the study area is very poor. The average nitrate content in the 36 wells sampled is 179.8 ppm, well over the Public Health Service's recommended limit. Nitrate content over 45 ppm is much more dangerous for infants of less than one year of age than it is for adults. While the nitrate contamination is definitely a problem, the bacterial contamination may well be a more severe problem.

3. Village of Hoyleton Water System

A reason for selecting this study area was that one of the alternative sources of water is an extension of a municipal system. The Village of Hoyleton in May, 1970, completed a waterworks system for the "...gathering, filtration, distribution, and sale of water to the residents of the Village and to residents of certain areas outside the Village"[31]. Individual supplies for residents, businesses, fire protection, etc., were becoming inadequate. The Village had made unsuccessful attempts to find a ground water source which could be used as a central source for the Village supply. The Village of New Minden (refer to Figure 2), five miles to the west of Hoyleton, was having similar water problems. Therefore, these two communities entered into an agreement to purchase "finished" municipal water, i.e., water that had been treated via some treatment facility, from the City of Nashville, seven miles south of New Minden. The agreement was such that both communities would jointly finance the transmission line from Nashville to New Minden. Hoyleton would then extend the line from New Minden to the Village of Hoyleton. The two Villages would share the expense of the water loss that occurred between Nashville and New Minden after which the expense was all Hoyleton's. The billing arrangement for water purchased from the system is as follows: Nashville bills Hoyleton for all water metered at the edge of Nashville. New Minden reads meters and bills persons on line from Nashville to New Minden as well as persons in the Village. New Minden then pays Hoyleton for this amount of water. Hoyleton is responsible for customers in the Village of Hoyleton and those on the line from New Minden to Hoyleton.

The physical structures in the system consist of a six-inch transmission line from Nashville to New Minden, then to Hoyleton. Hoyleton has a standpipe for collection and storage, while New Minden does not. The residents of New Minden use directly from the line. At New Minden there is a means of pressure reduction because of the increase in pressure that is realized due to the drop in elevation from Nashville to New Minden. At the present time, the standpipe at Hoyleton is never filled to capacity. Because of this a booster station is being considered to insure maximum storage for emergencies. The consideration of a booster station was precipitated by an elevator fire that drew the water level uncomfortably low.

The present arrangement is that water is purchased from Nashville at the rate of 40 cents per thousand gallons of water that passes through a master meter at the north edge of Nashville. Subsequently, New Minden and Hoyleton establish their own rate schedules for their respective customers. The present rate schedule at Hoyleton is differentiated depending upon whether or not the customer lives within the Village limits. The differentiation is due to the lack of taxability of those customers outside the Village limits. The rate schedule is shown in Table 4.

It appears that there would have to be further graduations made in the schedule if large rural users such as dairy farmers were to be encouraged to hook onto such a system. It is not unrealistic for

Table 4 - Monthly Rate Schedule for Hoyleton Water System

GALLONS	RATE FOR VILLAGE	RATE OUTSIDE VILLAGE
2000 or less	$4.80	$6.25
Next 2000	2.20/thousand	2.70/thousand
Next 5000	1.95/thousand	2.40/thousand
Over 9000	1.50/thousand	1.90/thousand
Bulk Sale	$1.60/thousand	

estimated water requirements for large dairymen to run as high as 50 to 100 thousand gallons per month. Proposed rates for a rural water system in the Carlyle, Illinois area show rates graduated to over 65,000 gallon monthly usages. Some similar schedule would be appropriate if large customers were to become part of the Hoyleton system. Afifi and Bassie[2] provide a thorough examination of water pricing and rate determination in the state of Illinois.

The Nashville supply is furnished presently by a surface impoundment west of the City of Nashville. This system also has access to raw water from the Washington County Conservation Lake, south of the city, in times of emergency. An engineering evaluation of the Nashville system was made in 1969, showing the system to be adequate at the present, but that all phases of the system, impoundment, treatment, and storage should be expanded to meet projected usages. Plans for carrying out these recommendations have been made and some have been initiated. The Washington County Planning Commission is presently working on plans for the establishment of a large reservoir of the size that will give

Nashville essentially an unlimited supply for the future.

The Hoyleton-New Minden system was designed to handle expanded usages due to increased per capita usage as well as additional users hooking into the system. In view of the present improvements to the initial source of the "finished" water for Hoyleton and the original design of the Hoyleton system, it is assumed that the system does have adequate supply to handle the expanded usage due to part or all of the study area residents being included in the system.

4. Water Hauling Situation in the Study Area

Hauling water from an off-the-farm source is presently the means by which the residents in the study area make up the difference between their present supply and their water requirements. The source of most of the water that is hauled in the study area is the Hoyleton Water System. The "honor system" is used for persons wishing to purchase water in bulk amounts. Provisions have been made for loading (pumping) water into tank trucks, tanks on trucks or wagons, etc. The water is metered and the person hauling the water writes his name and amount of water taken on a ticket that is provided and places this bill in the collection box. The Village Clerk collects the tickets periodically and the hauler is billed in a monthly statement.

Arrangements were made with the Village Clerk to review the quantities of water that were purchased from Nashville and the quantities used at each point along the line from Nashville. A summary of the quantities of water used at various stages of the system is presented in [22]. The average amount hauled from the Village of Hoyleton was estimated to be 15.1 percent of all of the water that is available at Hoyleton.

The study area was divided into three subareas I, II, and III, as shown in Figure 3. The divisions were made based on daily requirements determined by the interviews taken of each resident in the study area. It was found that over 47 percent of the demand for water in the study area was along the road east and north of Hoyleton, designated Area I (Figure 3). Over 42 percent of the total area demand for water was found to exist in the area designated Area II, with the remaining 10 percent being in Area III. Therefore, it was felt to be of interest to determine the amount of water hauled into each of the three subareas. A summary of the subarea destinations of the hauled water is presented in Table 5.

Table 5 shows that nearly 80 percent of the water hauling occurs in Area I, with Areas II and III combined, accounting for only 20 percent on the average. This consistently high percent occurring in Area I is partially attributed to two respondents who reported that they hauled all the water for drinking, other household uses, and for their dairy milk houses. Table 5 also shows that residents of Area III either have exceptionally good on-the-farm sources, or that they do not have a demand for water as large as do residents of Areas I and II. Only four of the residents in Area III reported that they had any livestock with one of the four reporting only two horses and another around 500 chickens.

It is concluded that the water supplies in the study area are sufficiently inadequate that on the average it is necessary to haul nearly 30,000 gallons per month to meet demand requirements with more than double that amount hauled in critical shortage months. Hauling water not only costs $1.60 per thousand gallons, it requires a man and equipment each of which may have a high opportunity cost.

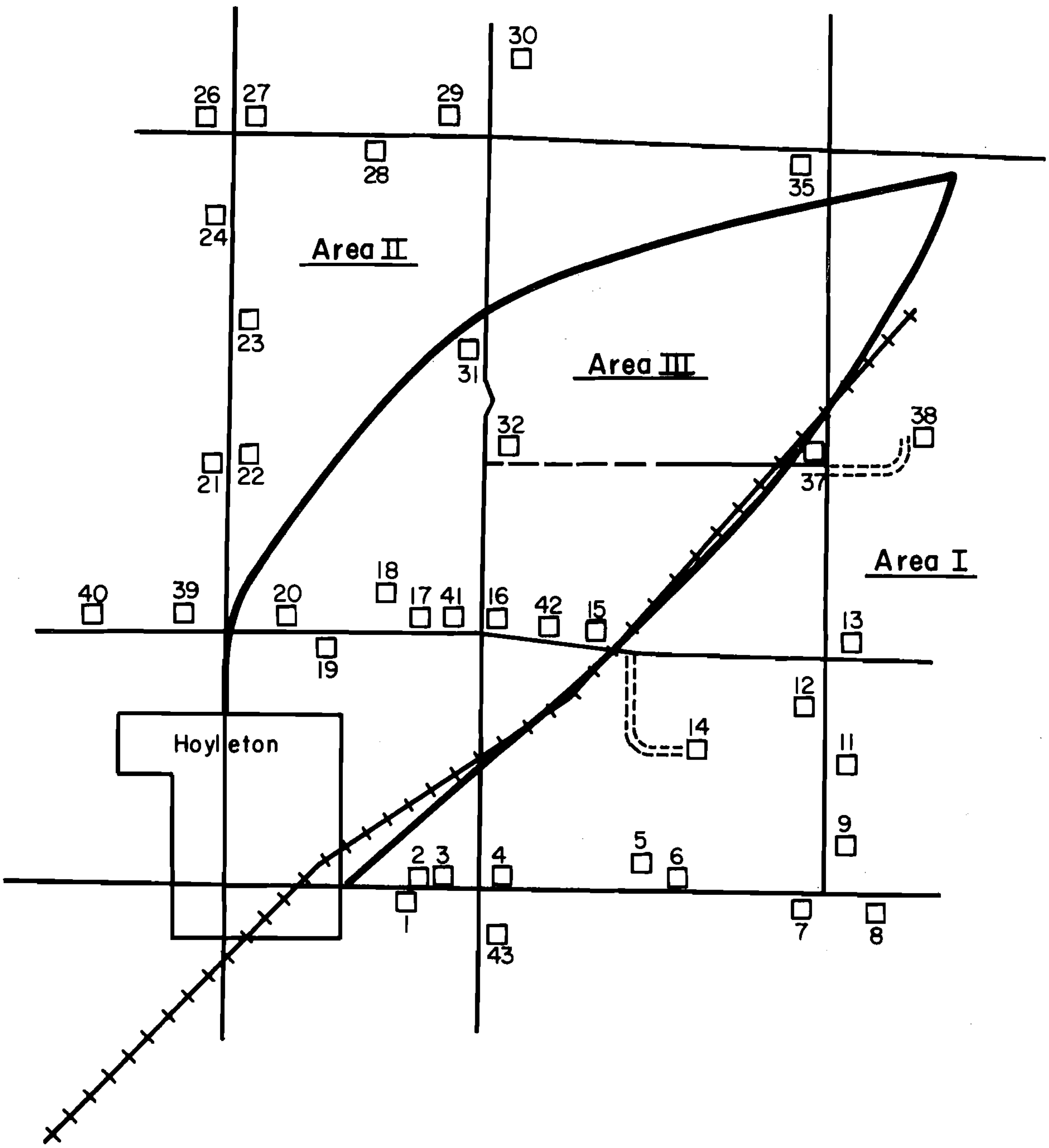

FIG. 3 LOCATION OF RESIDENCES WITHIN THE STUDY AREA

Table 5 - Amount and Percent of Water Hauled to Each Subarea

	Total Hauled To Study Area		Subarea I		Subarea II		Subarea III	
	Gallons	Percent	Gallons	Percent	Gallons	Percent	Gallons	Percent
Nov. 1970	17,900	100.0	15,900	88.8	2,000	11.2	0	0.0
Dec. 1970	43,900	100.0	36,100	82.2	7,800	17.8	0	0.0
Jan. 1971	46,700	100.0	25,700	55.0	21,000	45.0	0	0.0
Feb. 1971	21,900	100.0	13,800	63.0	4,500	20.6	3,600	16.4
Mar. 1971	10,100	100.0	9,100	90.1	1,000	9.9	0	0.0
Apr. 1971	13,100	100.0	12,100	92.4	1,000	7.6	0	0.0
May 1971	15,125	100.0	11,200	74.0	3,925	26.0	0	0.0
June 1971	24,775	100.0	15,400	62.2	9,375	37.8	0	0.0
July 1971	12,000	100.0	10,000	83.3	2,000	16.7	0	0.0
Aug. 1971	24,900	100.0	20,000	80.3	4,900	19.7	0	0.0
Sept. 1971	48,525	100.0	42,200	87.0	5,325	11.0	1,000	2.0
Oct. 1971	72,000	100.0	69,500	96.5	2,500	3.5	0	0.0
Column Mean	29,244	100.0	23,417	79.6	5,444	18.9	384	1.5

IV. WATER REQUIREMENTS IN THE STUDY AREA

One of the primary reasons for interviewing each of the residents in the study area was to determine their water requirements. This was accomplished by determining the number of persons living at each residence and the maximum numbers of livestock that were on each farm at any one time during the year. The maximum number of livestock was desired rather than the present amount because livestock population may have been at an unusually low level due to recent sales or other reasons. The numbers of persons and livestock were then multiplied by their respective daily requirements to arrive at a total daily requirement for each residence. A summary of the water requirements for the whole study area is presented in Table 6. The residents were asked if they would expand their present operation or initiate a new enterprise if they had all the water they desired. Of those interviewed, seven said they would expand or start new enterprises. If the expansion (or initiation of new operations) were to take place the area water requirement would increase by 8,980 gallons per day or to a total of 60,960 gallons per day.

From the interviews, it was apparent that most of the water use was located in two different segments of the study area; one east and one north of the Village of Hoyleton.

Because of this, and the physical location of the residents within the study area, it seemed appropriate to divide the area into three subareas, designated I, II, and III (see Figure 3, page 27), and to examine the alternative sources in terms of these three subareas. The

Table 6 - Study Area Daily Water Requirements in Gallons Per Day

Species	Number in Study Area	Average[a] Daily Requirement	Total Requirement
Human	126	50	6,300
Dairy (NP)[b]	265	20	5,300
Dairy (P)[c]	535	35	18,725
Beef	330	12	3,960
Hogs	3,185	5	15,925
Horses	24	10	240
Chickens	15,300	10/100	1,530
TOTAL	--	--	51,980

a/ Source of average daily requirements is "Guide for Engineers in the Design of Rural Community Water Systems in Illinois," FHA, PN418, January 20, 1970.
b/ Dairy Cattle not in production.
c/ Dairy Cattle in production. 15 gallons per cow per day is used for flushing stables and washing utensils.

human and maximum livestock populations and their respective water requirements are shown in Table 6. If those who wished to expand their present operation did so, the ranking of the areas in terms of water requirement would remain the same, however, the percentages would change as seen in Table 7. The increase in Subarea I would result entirely from an anticipated increase in the dairy cattle by 140 head. The average of the two daily requirements (for those in production and those not in production) was used as the factor to determine the increase in subarea total requirement. Approximately two-thirds of the increase in Subarea II would result from an anticipated increase

Table 7 - Daily Water Requirements by Subarea Designation[a/]

Species	Subarea I Number	Subarea I Daily Requirement (in gallons)	Subarea II Number	Subarea II Daily Requirement (in gallons)	Subarea III Number	Subarea III Daily Requirement (in gallons)	Total Area Number	Total Area Daily Requirement (in gallons)
Human	56	2,800	37	1,850	33	1,650	126	6,300
Dairy (NP)	160	3,200	40	800	65	1,300	265	5,300
Dairy (P)	460	16,100	45	1,575	30	1,050	535	18,725
Beef	75	900	250	3,000	5	60	330	3,960
Hogs	240	1,200	2,745	13,725	200	1,000	3,185	15,925
Horses	17	170	5	50	2	20	24	240
Chickens (100)	12	120	132.5	1,325	8.5	85	153	1,530
Total		24,490		22,325		5,165		51,980
% of Total		47.11		42.95		9.94		100.00
Expanded Total		28,270		27,525		5,165		60,960
% of Expanded Total		46.38		45.15		8.47		100.00

a/ See footnotes to Table 5

in the poultry population of 34,500 birds. The remaining one-third of the increase would be due to an increase of the swine population. Residents in Subarea III reported no desire to expand their present operations or initiate any new ones. Desired changes that would increase the water usage, but that are not expansions of a livestock operation and cannot be easily estimated are such changes as acquiring automatic washers, dishwashers, and other water-using conveniences in the house, sprinkling systems for swine barns, and automatic preparation stalls for dairy cattle. All of these changes were reported by respondents as desirable if they could acquire sufficient water at a reasonable price. Thus, the expanded totals in Table 7 are underestimated to some extent.

A factor closely related to the uses of water is the quality of the water. Often only one distinction is made concerning the quality of water; that is, water is either safe for human consumption or it is not. These two qualities will be designated as quality I and quality II, respectively. This dichotomy is not mutually exclusive; water that is safe for human consumption, quality I, can be used for other uses, such as household uses other than consumption, watering livestock, etc., but water that may be suitable for watering livestock, quality II, may not always be safe for human consumption. This difference in the quality of water is very apparent to the dairy farmer since all water that is used for washing transmission lines, holding tanks, and other milking equipment must be safe for drinking. This is enforced by periodic checking of milking equipment and water supplies by milk inspectors. It is rather obvious that water used for human consumption, dishwashing, etc., should be of quality I standard, however, there is presently no means of enforcing such a requirement in private residences. In other words, public health regulations protect people from use of public water supplies containing waterborne diseases, but there are no regulations that protect people from their own private sources which may be contaminated. Thus, little can be legally done if people knowingly continue to consume unsafe water on their own property.

Of the 38 residences in the study, 10 reported no livestock at all. Three more reported that the only type of livestock on the farm was 2, 5, and 9 pleasure horses each. Two additional respondents reported that their only livestock was 200 and 600 chickens, respectively. Consequently, 23 of the residents in the area own a majority of the livestock. From another examination of Table 7, one sees that the large water requirements in each subarea are a result of large numbers of dairy, especially in Subarea I, or hogs and beef, in Subarea II. Thus, there seems to be three natural classifications or types of farmers in the area. One type is designated "rural resident." Persons in this classification are those whose primary demand for water is for household uses with only minor demands for livestock purposes. This group was made up of the ten respondents who reported no livestock as well as the five that had only a small amount. These people could be grain farmers or only rural residents who work in a nearby city or village. The second classification can be designated as "primarily dairy." As the name implies farmers in this category have more than 25 cows in production. There are seven farmers in this classification with milking herds ranging from 30 to 150 head. Farmers in this category have large requirements for quality I water for use in the milkhouse in addition to that used in the household. Their requirement for quality II water is also relatively large since dairy cattle are large consumers of water. The third classification is "general livestock" farmers. This group is made up of those farmers with 25 or fewer dairy cows in production and/or large swine herds, beef herds, and/or poultry operations. This group has less demand for quality I water than the "primarily dairy" group, however, their requirement for quality II water is almost the same.

For the purpose of this study, the mean and the range of requirements for each of the three classifications of farmers were determined by quality of water required. It was assumed that if an abundant, reliable source of quality I water were available, it would be used for all uses in the household. Thus, the requirement of 50 gallons per day per capita is assumed to be all quality I water. A summary of the mean water requirements is presented in Table 8.

Table 8 - Water Requirement by Category of Farmer by Quality of Water in Gallons per Day

Category	Quality I Mean	Quality I Range	Quality II Mean	Quality II Range
Rural Resident	150 gpd	50-300 gpd	13 gpd	0-90 gpd
Primarily Dairy	1165 gpd	600-2,500 gpd	1,722 gpd	900-3,500 gpd
General Livestock	240 gpd	100-625 gpd	1,492 gpd	60-7,400 gpd

V. COST ANALYSIS OF WATER SOURCES

The present sources of water for the residents in the study area are (1) individual farm wells (with exception of one, all are large diameter, shallow type), (2) cisterns and (3) ponds. In addition to these three on-farm sources any shortages are presently being made up by hauling from an off-the-farm source, usually the Village of Hoyleton. In addition to the present on-farm sources, possible alternative sources include: (1) a central well that would serve several farmers, (2) a central reservoir that would serve several farmers, and (3) connection to a municipal source. A discussion of each of these six sources and their costs follows.

The net-present-value method is used to compare the costs of alternative water sources [4 and 5]. This method requires the discounting of costs to their present values. Recognizing that different alternatives have different lengths of life, different timing of major repairs, etc., the time horizon (i.e., the total length of time over which the alternatives are to be considered), the expected useful life of each alternative, and the discount rate selection are of major importance. For this study, the total length of time over which the alternatives are to be considered is 40 years. Although most of the analysis assumes a discount rate of 7 1/2 percent, the effect of varying the interest rate on relative costs of alternative sources is also studied. The expected useful life of individual sources as well as timing of major repair and replacement items will be discussed in connection with each alternative source.

I. On-Farm Wells

The type of well most suitable for the type of geological conditions found in this area is the large diameter (36 inches or more) shallow well. This type of well is used in areas where clay formations are predominant and the bored hole will stand open until a length of casing can be installed. The casing usually consists of three or four sections of large diameter concrete pipe stacked one upon another. The upper 10 feet of the well should be sealed to prevent contamination from seepage into the well by water containing contaminants from privies, cesspools, septic tanks, and sewers. In the study area most of the wells are not sealed and are of the old style construction using brick for the casing. The yields of these wells are not large (generally less than five gpm). Reliance is placed on the storage and seepage capabilities of these wells to satisfy peak demands. It has been suggested by personnel at the Illinois State Water Survey that yields of this type of well in this particular area of the state would probably be closer to one to two gpm rather than to five gpm. The storage capacity of a 36 inch diameter well is 53 gallons of water per foot of depth[23]. Effective storage capacity is limited by height of the water table and the depth of the well. As an example, consider a shallow well 25 feet deep with the water table 7 feet below the surface. Suppose that it was desired not to draw the level of water below 5 feet from the bottom. Thus, the storage capacity is (25'-7'-5') x 53 gallons per foot or 689 gallons. Naturally, as the water table fluctuates, this capacity will also vary.

In some parts of the state, two or more wells of this type may be required to furnish an adequate domestic supply. In the study area there are several people who have more than one well on their property. Some are not presently being used either because the farmers have switched to less intensive livestock operations or they have retired and no longer have any livestock. Thus, their need for large quantities of water has diminished.

James P. Gibb of the Illinois State Water Survey has provided cost information for private home ground water supply systems in Illinois [10]. Data developed in Gibb's study are used for estimating well costs. The well cost resulting from the use of Gibb's procedure was increased by 5 percent to bring the cost to a 1971 price level.

Gibb also collected costs of approximately 200 domestic pumping systems installed during 1967, 1968, and 1969[10]. These data included the installed costs of the pump, pitless adapter unit, pressure tank, and all associated piping and wiring. The pump capacities ranged from 1 to over 20 gpm. These costs were also adjusted to a 1971 price level.

The mean and the median costs of the systems considered by Gibb were about $585 and $510, respectively, with over 50 percent in the range $400 to $680. For this study a cost of $520 (1969 dollars) was chosen which when increased 5 percent to reflect 1971 values results in a pumping system cost of $546.

Based on Gibb's estimates the median service lives of domestic wells and pumps were assumed to be 20 and 10 years, respectively. Since the time horizon was specified as 40 years, the well will need to be replaced after 20 years and the pumping system at 10 year intervals, i.e., in year 10, 20, and 30. Knowing the discount rate, the length of useful life, and the time horizon, the cost of the shallow well alternative can be determined. Costs other than for the construction of the well and pumping system that need be considered in the associated cost stream are the annual maintenance and power or operating costs, estimated to be $10 per year.

All costs associated with the shallow well alternative will be identical for all three of the subareas with the exception of the well construction cost which is dependent upon depth of the well. The depths are assumed to be 26, 25, and 30 feet in Subareas I, II, and III, respectively. Using Gibb's equation the construction costs, including the 5 percent increase to adjust to 1971 costs, are $346.00 in Subarea I, $333.90 in Subarea II, and $394.38 in Subarea III. The details of the costs incurred during the life of the investment appear in Moore[21 and 22]. The present values of costs (40-year service period) for shallow wells are as follows: Area I, $1555, Area II, $1540, and Area III, $1615.

2. Cisterns

Since the cistern is used so widely in this area, consideration must be given to this source of water supply. There are only 5 of the 38 residents in the study area that do not have a cistern. Only one of the residents uses a cistern as the single source of water, while several use a cistern as the single source of water for household and drinking purposes. Two residents indicated that each had two cisterns.

The Illinois Department of Public Health suggests that, "A cistern can be made a reasonably satisfactory source of drinking water, but should be used only after efforts at producing other sources of water have failed.... Cistern water cannot be considered assuredly safe unless it is boiled or disinfected with a chemical; therefore, a cistern should not be built for a drinking water source unless every reasonable means for ground water development has been exhausted."[7]

About half of the 38 residents in the study area use cisterns for their drinking water while the remaining half use wells. Because there is no good ground water source in this area and that which does exist is of questionable quality, some people elect to use cistern water for drinking and to supplement other water supplies. Even with this widespread use of cistern water for drinking, there is not one cistern in the study area that has a continuous chlorination process in the system. Also, during the interview that was conducted of each resident in the study area, no one indicated that they practiced any kind of systematic batch or shock chlorination treatment. The general response concerning treatment was, "yes, I throw some chlorox in the cistern every now and then." This sporadic dose of chlorox definitely is not a satisfactory method of "purifying" the source of drinking water.

During the interview, respondents were asked the capacity of any existing water storage. Of the 23 that responded, nearly everyone cited their cisterns as the available storage, with an estimate of its capacity. This question was asked only of those 26 who answered all of the questions on the interview schedule.* The average capacity of cisterns reported was approximately 4,000 gallons. If a cistern is to be used for the single source of a family's water supply, it should be of sufficient size to hold a 3 month's supply of water according to recommendations in Private Water Systems[23]. Using the average daily requirements presented in Table 7 and converting them to monthly requirements, it is obvious that a 3-month capacity requirement would result in a cistern capacity of over 150,000 gallons for both the dairy and general livestock farmers. If the cistern were to be used only as the source for quality I water, a 3-month capacity requirement for the rural resident would take a cistern three times larger than the average cistern found in the study area.

*See copy of the interview schedule in the appendix.

Therefore, a cistern with a 4,000 gallon capacity will be used in the estimation of the cost for this alternative, recognizing that the cistern is used only as a supplement to other water sources on all but one residence in the study area.

The items of costs associated with the cistern are very similar to those of a shallow well, i.e., construction, pumping system, and maintenance. The average useful life of a cistern is estimated at 20 years, the same as that of a shallow well. Since the pump and distribution system for a cistern is the same as that for a shallow well, it is assumed for the purpose of this study that the useful life of this system is also the same as that of the shallow well, 10 years.

To acquire a meaningful estimate of the construction costs for cisterns, a concrete products firm in the general locality of the study area was contacted. This firm handled only pre-cast cisterns of various sizes. The largest cistern they handled was a 4,000 gallon, pre-cast cistern which costs $440. This firm charges $100 for installation of this size cistern. Therefore, an initial cost for the cistern is $540. Since the time horizon is 40 years and the average expected life of a cistern is 20 years, the initial cost will again need to be incurred in the twentieth year, t_{20}.

The pumping system, as stated previously, is the same as that for the shallow well. The additional cost incurred for spouting and filter in the cistern system is assumed to be the same as the slightly higher cost of the well casing in the shallow well alternative. Therefore, the cost as developed in the previous section for pumping systems will be used, i.e., $546. This cost will be incurred in years t_0, t_{10}, t_{20}, and t_{30}.

The maintenance required by a cistern system is much greater than a shallow well if the cistern, cistern filter, and spouting are to be properly maintained. Constant attention has to be given the quality of the water and proper steps taken to insure adequate treatment. In addition, extra maintenance is required by this system because of the maintenance on the filter and spouting, not a part of the shallow well system. Therefore, a realistic maintenance cost is estimated to be $18 annually. A systematic procedure for batch treatment is assumed and is included in the $18 maintenance cost. As with the shallow well system, the electricity to power the pump is assumed to be negligible and is not considered.

All of the costs associated with the cistern system are the same for all three subareas since the costs are not dependent upon any factors unique to any one area. The present value of costs for a 40-year service period for a 4000-gallon pre-cast cistern is $1895.62.

3. Farm Ponds

Over 70 percent of the residents in the study area reported that a pond did exist on their property. However, only 14 farmers indicated that the pond is presently serving as a source of water for some of their livestock. Not one farmer was using the pond as a source of water for domestic use.

Surface water collected in a farm pond should be used in the home and milkhouse only when ground water sources are inadequate or unacceptable. From the discussion of the geological conditions that exist in this area, and the analysis of the water samples taken from the wells in the study area, it can be concluded that the ground water sources are in fact both inadequate and unacceptable. Therefore, ponds as a source of both water for livestock only, and as a source of water for livestock, household, and milkhouse will be discussed.

There are two basic kinds of ponds, an embankment or fill type and a pit or dugout type. An embankment pond is made by building an embankment or dam across a stream, water course, or a valley . This type of pond is usually used where slopes range from gentle to steep. An excavated or pit type pond is made by digging a pit or dugout for impoundment of water. This type is more common where slopes are very small or on level surfaces. The cost of the embankment type pond is much less because less excavation is required to construct a sufficiently large "pool" whereas for the pit type a cubic yard of earth will usually yield three cubic yards of water. The Washington County Soil Conservation Service (SCS) reports that nearly two-thirds of the ponds that they have assisted with in the County have been the embankment or fill type.

Knowing the average daily requirements for the three general classifications, it was desired to develop size specifications and cost estimates for a "typical" size and type of pond that could supply the water needed by each type of farmer. Two sizes for each type of farmer were developed, one if only livestock were to use the water, and the second, a larger pond, if it was to supply water for both quality I and II requirements. The size of each of these "typical" ponds was estimated by determining the annual water requirement in each situation. Using the local SCS recommendation that a pond in this area should be designed to hold a two-year supply, this annual amount was doubled. In addition to the water required for use, an annual evaporation loss had to be included in the design capacity. It was estimated that, on the average, one acre-foot (325,851 gallons) of water be lost by evaporation and seepage annually. Together these two water requirements gave the estimated capacity of the pond in gallons. Using SCS specifications, the estimated excavation requirements in cubic yards were determined for both a pit type pond and a fill type pond. Since two-thirds of the ponds in this area are fill type, a weighted average was taken to determine the cubic yards of excavation needed for the typical pond in each situation. Also needed in the design of this typical pond is the appropriate spillway. Again, in cooperation with the local SCS office a spillway cost was determined for the various sizes of ponds described.

The average useful life of the items associated with the pond alternative had to be estimated. To arrive at meaningful estimates of these figures, local construction firms, the soil conservationist, and other personnel were consulted. All agreed that the life of a pond was very dependent on the quality of management of the watershed. If the watershed was under row crop cultivation each year, the pond would not last as long as if the watershed were in forest or grassland. Based on these considerations, the average life of a pond and spillway in this area was estimated to be 20 years. The pumping system for the pond is basically similar to the well and cistern. However, due to the more abrasive nature of pond water, major pump repairs or replacement are estimated to be required every 5 years.

The cost of construction was estimated at $0.50 per cubic yard of earth moved. This figure was based on information from several contractors in the vicinity of the study area. The cost of spillway construction was estimated by the local SCS personnel to be approximately

$325 for the pond of the size required by the rural resident; $400 for the ponds for the general livestock farmer and for the dairy farmer, with water used only for livestock drinking; and $513 for the dairy farmer, with water used for both quality I and II uses. These differences in cost occur because spillway cost is dependent upon the area of the watershed. The maintenance cost for the pond and spillway also varies with size of pond and watershed. The following maintenance costs were determined with assistance of SCS personnel: for the rural resident an annual cost of $40; for the general livestock farmer and dairy farm using pond for quality II water, an annual cost of $50; and for the dairy farmer using pond for both quality I and II, $60.

The pumping system for the ponds was estimated at an initial cost of $625 with major repairs or replacement of parts every 5 years at an estimated cost of $250. After conferring with several farmers in the study area concerning the major repairs or replacement the $250 was determined. Annual maintenance on the pumping system is assumed to be the same as on the well and cistern systems, $10 per year. Using these cost estimates the cost for the pond required to furnish the water necessary for each category of farmer was calculated and is presented in the first column of Table 9 which assumes that the ponds would furnish the quality II requirements.

Table 9 - Present Value of Costs of Water From Ponds, 40-Year Period

	Quality II Requirements	Quality I & II Requirements[a/]
Rural Resident	$2694.68	$ 6474.97
Dairy Farmer	5704.07	12,696.49
General Livestock Farmer	5358.15	9196.76

[a/] Includes cost of treatment.

If the pond is to be used as the source of quality I water, the water must be treated or "purified". Consequently, the costs of treatment must be considered for uses involving Quality I water. Two commercial water treatment companies were contacted to determine the appropriate cost for units needed to deliver the amount of "finished" water required by each type farmer. One of the two companies had several individual farm pond units in operation and was very helpful concerning these cost data.

The general description of the system that was determined to be appropriate in each case is as follows. The pumping system was considered in the initial construction of the pond in the previous section. Therefore, it will not be considered here. The treatment unit for the rural resident consists of two chemical feeders which are placed in the line prior to the pressure tank. One injects a coagulating chemical, usually alum, and the other, the disinfectant, chlorine. The injectors are automatic and precalibrated to inject the correct amount of chemical each time the pump starts. After the chemical feeders is a pressure tank and also several retention tanks, the number depending upon the desired amount of water to be delivered. The greater the amount of water required, the more retention tanks required to provide adequate contact time for proper chlorination of the water. After the pressure and retention tanks is a carbon or charcoal filter to remove some of the excess chlorine residual.

For the rural resident class of farmer, it was assumed that, since only 13 gallons per day was needed for quality II requirements, all the water would be treated regardless of its intended use. The chemical feeders are of the type that is operated automatically by the pump; when the pump is running the injector deposits an appropriate amount of chemical in the line. This type of chemical feeder is used since all of the water is assumed to be treated. If all of the water is not treated, as will be the case for the dairy farmer and general livestock farmer, a different type feeder will be used. For the rural resident it is recommended that two retention tanks be used based on the low average flow requirement.

The general livestock and dairy farmers have a somewhat more difficult arrangement. The water for livestock drinking does not need to be treated while the water used in the house and/or milkhouse does. Therefore, there are two lines leaving the pressure tank, one line with water to the quality II uses directly as it comes from the pond, and the second line with water to the treatment unit. The "branch" in the line occurs after the pressure tank. This type of system needs chemical feeders of the type that are operated by water flow rather than by the pump. In this system if the injector operated, chemicals would be injected into the treatment line each time the pump was started due to large livestock consumption. Thus, a flow injector is needed so that chemicals are injected only when a pre-calibrated amount of water passes through the chemical feeder. Based on the amount of flow required by the dairy farmer and general livestock farmers, two retention tanks were recommended for the general livestock farmer and six for the dairy farmer. The dairy farmer needs a larger number of tanks because of the large quality I requirement for milkhouse purposes.

The expected useful life of this type of treatment system is estimated as 10 years. Every five years major repair to the chemical injectors can be anticipated.

The initial cost of the system for a rural resident would be two automatic chemical feeders at $325 each or $650, two retention tanks at $150 each or $300, and a carbon filter at $325. With installation, this system is estimated at $1,400. The cost of the system for the dairy farmer would be two water meter chemical feeders at $395 each or $790, six retention tanks at $150 each or $900, and a $325 carbon filter. The estimated installed cost for this system is $2,400. The cost of the system for the general livestock farmer would be two water meter chemical feeders at $395 each or $790, two retention tanks at $150 each or $300, and a carbon filter at $325. The estimated installed cost is $1,550. The major repairs that can be anticipated every five years are estimated to cost $200. The annual maintenance cost for both the rural resident and general livestock systems is estimated at $40. The dairy farmer unit is estimated to have a maintenance cost of $55 annually. The present values of the cost of pond water treatment for the 40-year period are as follows: Rural resident, $3328.13, dairy farmer, $5351.86 and livestock farmer, $3543.35. These costs must be added to the pond costs in developing total cost estimates for the use of water from ponds. The sum of the treatment costs and the pond construction maintenance costs are in the second column of Table 10. These estimates assume that both quality I and quality II requirements would be met with pond water, but that only quality I water would be treated.

4. Central Well and Central Reservoirs Serving Several Farmers as an Alternative Rural Water Source

As mentioned earlier, it is difficult to locate productive sand and gravel deposits in this area which yield enough water to meet individual farmer's daily requirements via shallow wells. Nearly all 38 residents reported that more than one source was necessary to meet their requirements. Of the 38 residents only one reported that he was using a deep, drilled well. Good water-yielding bedrock formations are generally absent in the area and consequently it is very difficult to locate a satisfactory deep well. Also, from an examination of the water and oil well drillers logs for the study area, it was found that water-yielding strata in this area were generally absent. Thus, a central well as a source of water for several farmers is a very unrealistic alternative and hence was not considered in the cost analysis.

Consideration of a central reservoir which would serve as a source of water for a number of farmers in the study area was also deleted from the final analysis for several reasons. A report by Dawes and Terstriep[9] indicates that there are no potential reservoir sites in or near the Hoyleton area. Also, due to the topography of the area, such a reservoir would require a very large pool area and would be of a very shallow average depth. Consequently, considerable water would be lost due to evaporation. Therefore, this source of water was deleted from the list of meaningful alternative water sources for residents in the study area.

5. Hauling as an Alternative and Supplemental Source of Water

At the time of the study two farmers were hauling all of the water required for the quality I uses, i.e., for human consumption and for use in the milkhouse. Several others were hauling several thousand gallons each month either as the supplemental source of quality I water or to make up the deficit in their total water supply. Thus, it was obvious that hauling was a very real alternative for the residents in the study area.

Water hauled in the study area is generally purchased at the Village of Hoyleton for $1.60 per thousand gallons. This water is from the

Nashville reservoir, and because it has gone through the Nashville treatment plant, it can be used for either quality I or quality II purposes.

Delivery of hauled water can be by two methods: the farmer hauls his own, or a commercial milk hauler delivers the water. If the farmer hauls the water, his cash operating expense is estimated to be $1.60 per thousand gallons for the water from the Village. If he has a hauler deliver the water, it is usually $5.00 per thousand gallons. It is assumed that if the farmer considered his labor and machinery costs plus the $1.60, his actual cost would also be approximately $5.00 per thousand. Therefore, $5.00 was used in calculations concerning hauling.

The present value of the costs accruing from hauling (1) all of the farmer's quality I water and (2) hauling all the water used for both quality I and II purposes were calculated for each of the three classes of farmers over a 40-year period. The total present value amounts are shown in Table 10.

Table 10 - Present Value of Costs of Hauling Water for Each Classification of Farmer, 40-Year Period

	Quality I Only	Quality I and II
Rural Resident	$3,447.72	$ 3,746.59
Primarily Dairy	26,777.35	66,457.18
General Livestock	5,516.35	39,878.69

6. Connection with a Municipal System as an Alternative Source of Water

Buying water from a municipality has several advantages over developing one's own domestic source. The primary advantage is that the quality of the water in the municipal system is maintained at a safe level. The quality is insured by a system of regular checks and analysis by public health authorities who have the power to demand compliance with standards. When using a public source, the user is, to some extent, legally protected in terms of water quality. Private, domestic water systems have no motivating force, other than the desire of the owner, to maintain a high quality water. The municipal treatment plant by virtue of size and available equipment is better able to treat the water than private units.

Another advantage of the municipal system is the reliability of the water supply. The domestic sources, being of much smaller scale, usually are extremely dependent on weather conditions to supply their water, while the municipal system is usually of a sufficiently large size to "insulate" itself against normal fluctuations in weather conditions.

Some of the people in the study area, especially those people who are hauling several thousand gallons of water to supplement their present on-the-farm sources, are extremely interested in and have suggested a municipal source as a possible alternative source of rural water. Therefore, the possibility of laying pipeline throughout the study area and connecting with a municipal supply was considered. The Village of Hoyleton was the source of water for such a system.

With the assistance of a local engineer, a system of lines going to each of the subareas from the Village was designed. The Illinois Environmental Protection Agency recommended that the system be of sufficient size so as to maintain not less than 20 pounds per square inch (psi) at all points in the line, with an average flow of at least 2 gallons per minute at each domestic dwelling. Using this minimum specification a design was determined for each of the subareas. Upon recommendations of consulting engineers polyvinyl chloride pipe (PVC) was chosen to be used in the design. The PVC pipe was recommended because of its lower cost and its durability. Figures 4, 5 and 6 show schematic drawings of the pipeline system.

Estimates of installed costs of the various size pipe were determined by contacting two engineering firms in the vicinity of the study area, requesting bids on recent jobs involving such size pipe. The cost estimates from these two firms were averaged to arrive at the figure used in this study. The final installed cost per-foot estimates were as follows: $2.37 for 4-inch PVC pipe; $1.68 for 3-inch PVC pipe; and $1.00 for 2-inch PVC pipe.

The cost for the suggested design of pipeline in Subarea I is based on 8,712 feet of 4-inch PVC pipe, 8,052 feet of 3-inch PVC pipe, and 1,056 feet of 2-inch PVC pipe. The costs respectively are $20,647.44, $13,527.36, and $1,056.00 or a total of $35,230.80. The cost of the suggested design in Subarea II is based on 14,784 feet of 4-inch PVC pipe, and 9,900 feet of 2-inch PVC pipe. This pipe costs $35,039.08 and $9,900, respectively. For Subarea III the number of feet of pipe and the respective costs were 1,320 feet of 4-inch PVC at $3,128.40 and 11,616 feet of 3-inch PVC pipe at $19,514.88.

According to Singh in his article, "Economic Design of Central Water Supply Systems for Medium Sized Towns"[25], the average assumed life of a pipeline system such as the one designed is 40 years. The annual operating and maintenance costs on systems such as this, i.e., systems where water is purchased from a central source, was estimated to be $37.81 per user in 1970. This figure is based on an analysis of

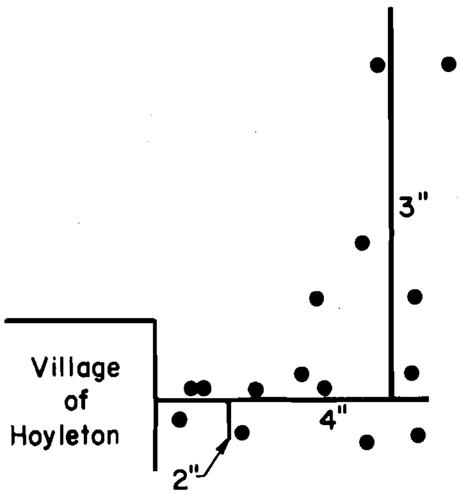

FIG. 4 MUNICIPAL PIPELINE DESIGN FOR SUBAREA I

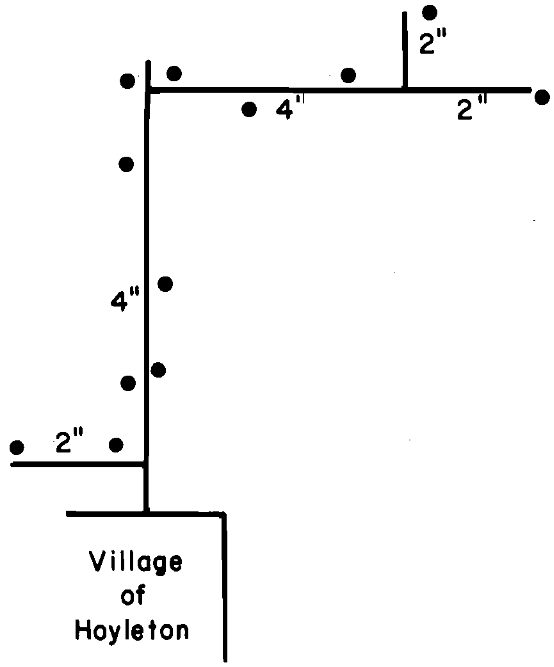

FIG. 5 MUNICIPAL PIPELINE DESIGN FOR SUBAREA II

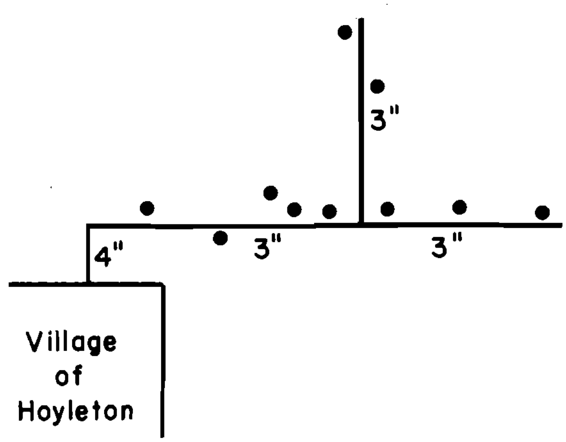

FIG. 6 MUNICIPAL PIPELINE DESIGN FOR SUBAREA III

operating costs for FHA financed community facilities published in "Guide for Engineers in the Design of Rural Community Water Systems in Illinois"[11]. FHA personnel recommended that this figure be increased by approximately 8% to reflect 1971 value. Thus, the cost was set at $40 annually. The variable cost to the farmer is that rate at which he can purchase water from the pipeline. Most rate schedules, according to Afifi and Bassie[2] include both variable costs, i.e., the cost of the water, as well as a portion to be allocated to fixed costs. In this situation, the initial cost of the pipeline system was charged, as indicated below, to the customers so that the appropriate rate would include only the cost of the water used. The only estimate of this figure was the $1.60 per thousand charged as the bulk rate, i.e., there would be no charge to cover cost of the distribution system since it is assumed to have been paid. Therefore, the variable cost per thousand gallons will be $1.60. It was assumed that each resident would have to pay the full cost of the tap-on fee and the service line from the road to the residence or wherever the water was desired. This cost was estimated to be approximately $125 for the rural resident, $150 for the general livestock farmer, and $175 for the dairy farmer.

Two methods of allocating the initial investment among the residents of the study area were used. One was allocating the cost equally among all residents in the area, assuming that over time everyone would, in fact, become a customer. The pipeline design in this instance is as shown in Figures 4, 5 and 6. The second method was to allocate the full cost among only those residents who indicated a desire to connect to a line during the initial interview (Figures 7 and 8). When the second method was used, the length of line was altered to service only those

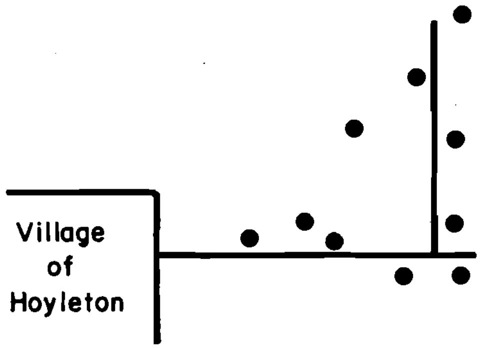

FIG. 7 DESIGN SUBAREA I SHOWING THOSE INTERESTED IN MUNICIPAL LINE

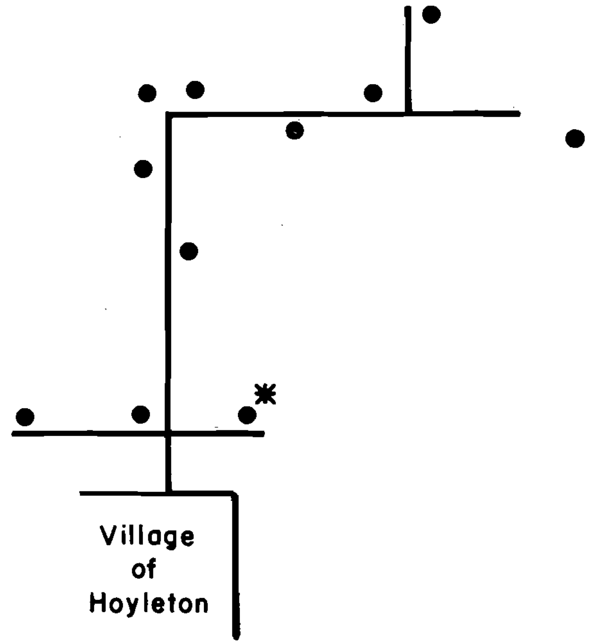

FIG. 8 DESIGN SUBAREA II SHOWING THOSE INTERESTED IN MUNICIPAL LINE

wishing to connect rather than the entire area. These changes would reduce the total cost in Subarea I to $29,739.60 by shortening the length of the 3-inch line by 2,640 feet and deleting the 2-inch line from the system. Only one person (indicated by * in Figure 8) in Subarea III indicated a strong interest in participating in a water line. This farmer was located very near the line in Subarea II, therefore, in the second approach this farmer was added to Area II increasing the cost to $46,786.08. Two residents in Subarea II wished not to hook on, thus, with the addition of the one user from Subarea III there was a net loss of one customer in Subarea II. With the second method there was no line to Subarea III. Figures 7 and 8 illustrate the designs used when only those residents who expressed a strong desire to hook on to a line were considered.

Table 11 shows the present value of costs for the municipal alternative for the rural resident, the dairy farmer, and the general livestock farmer respectively, when the initial cost is allocated equally among all residents in the area: 16 in Subarea I; 12 in Subarea II; and 10 in Subarea III. This table assumes that the user would purchase water to meet his total water requirements from the municipal system. Table 12 shows the present value of costs if the initial cost is allocated only to farmers indicating strong desire to participate in such a municipal system: 10 in Subarea I, 11 in Subarea II; and none in Subarea III. It is assumed that the user will buy water for both quality I and II requirements in this table. Table 13 shows the cost of the municipal line alternative when initial costs are allocated equally to all residents in the area and when only water for quality I purposes is obtained from the line. Table 14 shows the cost of the system when the initial costs are allocated to only those persons expressing interest. Again, Table 14 assumes that only quality I water would be obtained from the line.

From an examination of these tables, it is seen that when the initial costs are allocated to only the interested parties (Tables 12 and 14) there is a significant increase in the cost of this alternative as compared to allocation of costs equally among all residents. Thus, we see why it is very important to have a large percentage of the people in an area participate if such a municipal system is contemplated.

Table II - Present Value of Costs by Type of User and Area. Municipal System. Initial Costs Allocated to All Residents. Use Rate Meets Both Quality I and Quality II Requirements.

	Subarea I	Subarea II	Subarea III
Rural Resident[a]	$ 4,029.57	$ 5,572.48	$ 4,091.97
Dairy Farmer[b]	24,114.89	25,657.80	24,177.29
General Livestock Farmer[c]	15,616.87	17,159.78	15,679.27

a/ Consumption of 163 gallons per day at $1.60 per thousand gallons

b/ Consumption of 2,887 gallons per day at $1.60 per thousand gallons

c/ Consumption of 1,735 gallons per day at $1.60 per thousand gallons

Table 12 - Present Value of Costs by Type of User and Area. Municipal System. Initial Costs Allocated Only to Interested Users. Use Rate Meets Both Quality I and Quality II Requirements.[a]

	Subarea I	Subarea II	Subarea III[b]
Rural Resident	$ 4,801.60	$ 6,080.92	-
Dairy Farmer	24,886.92	30,589.86	-
General Livestock Farmer	16,388.90	17,668.22	-

a/ Daily consumption requirements are the same as for Table II.

b/ No resident in Subarea III expressed an interest in cooperating in a municipal system.

Table 13 - Present Value of Costs by Type of User and Area. Municipal System. Initial Costs Allocated to All Residents. Use Rate Meets Only Quality I Requirements.

	Subarea I	Subarea II	Subarea III
Rural Resident[a]	$ 3,933.98	$ 5,476.89	$ 3,996.38
Dairy Farmer[b]	11,449.44	12,992.35	11,584.11
General Livestock Farmer[c]	4,620.94	6,163.85	4,683.34

a/ Consumption of 150 gallons per day at $1.60 per thousand gallons

b/ Consumption of 1,165 gallons per day at $1.60 per thousand gallons

c/ Consumption of 240 gallons per day at $1.60 per thousand gallons

Table 14 - Present Value of Costs by Type of User And Area. Municipal System. Initial Costs Allocated Only to Interested Users. Use Rate Meets Only Quality I Requirements.[a]

	Subarea I	Subarea II	Subarea III[b]
Rural Resident	$ 4,706.01	$ 5,985.33	-
Dairy Farmer	12,221.47	13,500.79	-
General Livestock Farmer	5,392.97	6,672.29	-

a/ Daily consumption requirements are the same as for Table 13.

b/ No resident in Subarea III expressed an interest in cooperating in a municipal system.

VI. COMPARISON OF COSTS OF ALTERNATIVE WATER SOURCES

Nearly all of the residents in the area reported more than one source of water to meet their daily requirements. Justification for using several sources appears to be the uncertainty of these supplies. Residents in the area are attempting to arrive at some balance between cost of a water source and the probability that a selected source will "go dry" causing them to incur the cost of making up the deficit.

Since the reliability of the individual sources could not be quantitatively determined, a comparison was made of the costs of replacing the different sources that existed presently on the farms in the subareas with the other methods of supplying water to fulfill the residents' requirements. While comparing the alternative sources (or systems of sources), one should keep in mind that the reliability of the different sources of water should be considered, even though we lack good estimates of such reliability.

Using the data presented in Section V of this report the total area costs of replacing the present water sources can be estimated. These costs were calculated by multiplying the present values of the cost for each source by the number of sources in the subarea. The results for the present sources are in the first row of Table 15. Because there was no information on the age or depreciated values of present sources, the investments were based on replacement costs. Thus, the costs overestimate actual costs. However, many of these present on-farm sources are reaching an age where major repairs or replacement will be required.

The next alternative method of supplying water to the subareas that was considered was the construction of an appropriate size pond

Table 15 - Summary of Present Values of Costs Associated With Various Alternative Sources of Water in Each Subarea[a]. 40-Year Period.

System	Subarea I	Subarea II	Subarea III	Total Area
1. Present Sources	$ 92,912.(1)[b]	$ 79,531.(1)	$ 43,992.(1)	$216,434.(1)
2. Pond with Treatment	151,038.(2)	108,417.(2)	73,693.(4)	333,148.(2)
3. Present Sources, Haul Quality I	249,188.(5)	137,430.(3)	90,216.(5)	476.834.(4)
4. Haul All Water	589,791.(6)	432,759.(6)	136,209.(6)	1,158,758.(6)
5. Municipal Line, Both Quality I & II	234,424.(4)	191,241.(5)	72,592.(2)	498,257.(5)
6. Present Sources, Municipal Line, Quality I	169,607.(3)	139,047.(4)	73,062.(3)	381,717.(3)

a/ Interest rate 7.5% and cost of municipal water at a flat rate of $1.60 per thousand gallons.

b/ Alternative source ranking based on costs is shown in parenthesis.

and the installation of a treatment plant for each class of farmer in each subarea. The subarea totals (Table 15, second row) may be compared to the subarea totals from the other methods. The calculation procedure was similar to that for the present sources. The costs of ponds and treatment facilities for each type of resident were multiplied by the number of residents of that type and a total determined for each subarea.

The next alternative source (Table 15, third row) considered was a combination of using the present sources for quality II water and hauling all of the quality I water. All sources designated by the farmer as the source used for quality I water were deleted from the list of present sources. To the remaining costs of present sources was added the cost of hauling all of the quality I water used in the area over the 40-year period discounted to present value.

For comparison with the other alternatives, the alternative of hauling all of the water that would be used was considered (Table 15, fourth row). This alternative is extremely expensive.

Connecting to a municipal line is one of the alternatives that was to be considered (Table 15, fifth row). Knowing the number of each type of resident in each of the subareas, the total present value of the municipal source was determined for each subarea. These totals were determined assuming that everyone in each of the subareas would connect to the line. The present value of subarea costs include installation of the line, residents' service line, maintenance, and water for both quality I and quality II purposes.

A modification of the municipal system mentioned above involves use of the municipal line for only quality I purposes. Therefore, the same method was used here as was used when residents were considered to haul all quality I while using the present sources of quality II. The calculated costs for each type resident in each subarea are added to the costs of the present on-the-farm quality II sources. The resulting subarea totals for this alternative are presented in the sixth row of Table 15.

An examination of Table 15 indicates that the present-sources alternative is by far the least-cost alternative in all three subareas as well as the total area. However, there are several factors that should be mentioned in conjunction with this finding. First, the quality of water from present sources is, in many cases, unsatisfactory for human consumption. If there were some law that required drinking water from private sources to be of such quality as to meet public health standards, then this present-sources alternative would not qualify for quality I water. Also, the fact that many farmers are presently hauling water from Hoyleton to make up deficits in present supplies from time to time indicates that the present sources are at times unreliable. At the other end of the spectrum, hauling all of the water for both quality I and quality II uses is by far the highest cost alternative.

The pond and treatment alternative ranks second in two of the subareas. Both of these subareas contain farmers with high requirements as compared to the third subarea. Consideration that should be given to this alternative, for which no empirical estimate of cost can be made, is the fact that the farmer must assume the responsibility of a water treatment plant operator. The treatment unit must be checked at regular intervals to insure that the desired quality of water is maintained. Further, a number of farmers expressed an opinion that they did not want to drink pond water even if it were treated.

Another factor that should be considered in the selection of an optimal source of supply is the reliability of the alternative sources. It is apparent that the present sources are rather unreliable from the amount of water that has to be hauled to the study area. Of the six systems presented in Table 15, the present-sources system could be ranked the least reliable. The pond with treatment system would be somewhat more reliable than the present sources because this system is designed to provide a two-year supply. Since this system relies on a larger body of water for its supply, short periods of drought could be endured without resulting in a shortage. However, this system would fail during prolonged periods of drought. Also, depending upon the care taken in the treatment of the water, this source may be unreliable as a source of quality I supply. The remaining four systems can all be considered to be highly reliable, since either part or all of the supply is acquired from off-the-farm sources. For those systems using combinations of on-farm and off-farm sources, shortages in the on-farm portion of the supply can be met by substituting the supply from off-farm sources.

Effect of a Change in Interest Rate and Use of a Graduated Rate Schedule for Municipal Water

In order to determine how sensitive the solution (ranking) was to changes in the interest rate, interest rates both higher and lower than 7 1/2 percent were selected for recalculation. The interest rate was lowered to 2 percent yet the ranking of the total area did not change. The rankings for Subareas I and II remained the same but in Subarea III the two municipal related sources were reversed in rank. Increasing the interest rate to 10 percent also showed no effect on the rankings of the total area. Again, all subarea rankings remained the same, except one pair in Subarea III. The two sources that were switched were the pond with treatment and the municipal source where the existing on-farm sources were used for quality II purposes. It is concluded from the above analysis that the rankings of the alternative sources are relatively insensitive to variations in the interest rate.

In order to determine the effect of a graduated rate schedule (rather than a flat rate schedule) on the overall ranking of the sources, a schedule proposed for a new water district north of Hoyleton was used. The graduated schedule is as follows;

First 3,000 gal./month @ $2.00/1000 ($6.00 minimum)

Next 5,000 gal./month @ $1.60/1000

Next 8,000 gal./month @ $1.40/1000

Next 12,000 gal./month @ $1.15/1000

Next 12,000 gal./month @ $.90/1000

Next 25,000 gal./month @ $.75/1000

All over 65,000 gal./month @ $.55/1000

SOURCE: Henry, Meisenheimer and Gende, Inc., "Revised Report on the Water Supply System for the St. Rose Public Water District, Clinton County, Illinois."

When the above schedule was used in this study, the ranking in subareas and total area were drastically changed. As seen from Table 16, the present-source alternative still is the least cost alternative in the total area, but the second and third ranking alternatives are now the two municipal-related sources. The subarea rankings in Table 16 are also much different than they were in the original ranking in Table 15. As was anticipated, the graduated rate schedule did make the municipal sources more competitive in terms of cost.

Table 16 - Summary of Present Values of Cost Streams Associated with Various Alternative Sources of Water in Each Subarea[a]

	System	Subarea I	Subarea II	Subarea III	Total Area
1.	Present Sources	$ 92,912(1)	$ 79,531(1)	$ 43,992 (2)	$216,434(1)
2.	Pond with Treatment	151,038(4)	108,417(4)	73,693(4)	33,148(4)
3.	Present sources Haul Quality I	249,188(5)	137,430(5)	90,216(5)	476,834(5)
4.	Haul All Water	589,791(6)	432,759(6)	136,209(6)	1,158,758(6)
5.	Municipal Line, Both Quality I & II	120,994(3)	94,972(3)	31,962(1)	247,928(3)
6.	Present Sources, Municipal Line, Quality I	117,048(2)	86,307(2)	43,743(3)	247,098(2)

a/ Interest rate 7 1/2 percent and cost of municipal water is based on a graduated rate schedule.

b/ Alternative source ranking, based on cost, is shown in parenthesis.

VII. CONCLUSIONS

While the present-sources alternative may be the least-cost alter= native, the unreliability and poor quality of these sources make them undesirable. Based on the geological and climatological conditions that characterize this area, the choice of the least-cost alternative should be made from the remaining five alternatives (Tables 15 and 16). A pond and water treatment system could be a very satisfactory source. However, if a prolonged drought occurs this source may become unreliable and the high cost of hauling would have to be incurred to make up the deficit. If alternative six (Tables 15 and 16) were chosen, and a drought would occur, the deficit could be made up conveniently by using additional water from the existing municipal water line. This is essentially stating that the municipal water line would be, in effect, insurance to cover the occurrence of a drought. Other factors than dollar costs should be considered in determining an optimal source of supply. Health considerations should be among the more important factors considered.

When the graduated rate schedule (Table 16) is examined in conjunction with the relative reliability of the sources, alternative six appears to be the best choice for the total area. However, with the flat schedule (Table 15) a more difficult choice is found. In the entire area, the pond and treatment method is somewhat less expensive than the municipal systems, but also less reliable. Given the relative costs, the choice depends on an evaluation of the risk and other factors which differ between these sources.

If a municipal system is chosen, questions of organization arise. The other methods of supplying water depend only on individual actions of the residents in the area. There are several institutional arrangements which are possible for initiation and maintenance of municipal systems such as those discussed earlier. Only a few of these arrangements will be mentioned. It is assumed that the type of arrangement would, in fact, affect the present value of the costs (Tables 15 and 16) very little. The Illinois Revised Statutes, Chapter III 2/3 -- Public Utilities, starting with paragraph 188 concerning public water districts and specifically paragraph 212.1, Annexation of Contiguous Territory -- provides means by which such a system could become part of the Hoyleton-New Minden Water District. After proper petitions and hearings have been held, it requires a two-thirds vote of the board of trustees of the water district to annex such a territory.

Another method would be for persons in the study area, or one of the subareas, to form a cooperative, conforming to the rules and regulations governing such organizations, and as a cooperative purchase water from the Hoyleton system. Technical arrangements regarding the ownership of the pipe once installed, provision of maintenance, personnel to read meters, and other operational duties would have to be negotiated between the Village and the cooperative.

The 1970 Constitution of the State of Illinois also provides a means by which extensions of pipeline into rural areas could be brought into existence. Article VII, Local Government, Section 7, Counties and Municipalities Other Than Home Rule Units states, "Counties and municipalities which are not home rule units shall have only powers granted to them by law and the powers to (1) .... (2) .... (3) .... (4) .... (5) .... and (6) to levy or impose additional taxes upon areas within their boundaries in the manner provided by law for the provision of special services to those areas and for the payment of debt incurred in order to provide those special services."

VIII. PUBLICATIONS RESULTING FROM PROJECT

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APPENDIX

SOUTHWESTERN ILLINOIS WATER RESEARCH SURVEY

Please answer all of the following questions.

1. Indicate the maximum number of each type of livestock that you have on your farm at any one time during the year.

   a. Dairy Cattle ____________
   b. Beef Cattle ____________
   c. Hogs ____________
   d. Horses ____________
   e. Chickens ____________
   f. Other (specify) ______________________________________

2. a. Is the number of livestock listed in question 1 limited because of water supply?

   ☐ YES ☐ NO (skip to 3a)

   b. Was the number limited because of:

   ☐ quality of water

   ☐ quantity of water

   ☐ both quality and quantity

   ☐ other (specify) ______________________________

3. a. If you had access to an unlimited supply of good quality water at a reasonable price, would you expand any of the livestock operations listed in question 1 or initiate new livestock enterprises?

   ☐ YES (go to b) ☐ NO (skip b)

   b. Specify the operations you would expand or initiate and the approximate number of additional livestock involved: (specify expand or initiate)

Operation	Approximate Number

4. How many persons live at this place of residence?____________________

5. What is your present source of water for the following uses? Please check the appropriate column. (Sources 1-5 are assumed to be on your property.)

	Deep Well	Shallow Well Untreated	Pond Untreated	Pond Treated	Haul Municipal
a. Human drinking	____	____	____	____	____
b. Household, other than drinking	____	____	____	____	____
c. Dairy, milkhouse	____	____	____	____	____
d. Dairy drinking	____	____	____	____	____
e. Other livestock	____	____	____	____	____
f. Other, specify	____	____	____	____	____

	Other, Specify
a. Human drinking	____
b. Household, other than drinking	____
c. Dairy, milkhouse	____
d. Dairy drinking	____
e. Other livestock	____
f. Other, specify	____

6. If your present source of water listed in question 5 is a "treated" source, please describe the treatment and why it is necessary, i.e., type of pollutants.

Shallow well: ____

____

Pond: ____

____

Other: ____

____

7. How long have you lived at this address? ____________________

8. a. Have you experienced a shortage of water during the time you have lived at this address?

/ / YES (go to b) / / NO (skip to 9)

b. How many times? ____________

c.

	DATES	DURATION
I.	____________	____________
II.	____________	____________
III.	____________	____________
IV.	____________	____________
V.	____________	____________

d. Reasons for each shortage other than the basic "not enough rain." (Consider quality as well as quantity reasons.)

e. Consequences of each shortage.

f. Indication of seriousness. Use the following scale for each shortage.

	Mild	Moderately Serious	Serious	Very Serious	Severe
I.	______	______	______	______	______
II.	______	______	______	______	______
III.	______	______	______	______	______
IV.	______	______	______	______	______
V.	______	______	______	______	______

g. If you have experienced a water shortage of any kind, how did you alleviate the problem? (Specify particular shortage.)

____

____

____

____

____

9. Are there any potential water sources on your property, that you know of, such as pond sites, dame sites, etc.? Please

____

____

____

10. In your opinion, is the possibility of a water shortage (due to quality as well as quantity reasons) great enough to merit your examination of alternative water sources?

☐ YES ☐ NO

11. Would you be interested in obtaining all or part of your water from a central source such as piping it from a nearby village, cooperatively hauling it from a nearby village, constructing a central treating plant for local ponds, etc. if the cost was not prohibitive?

☐ YES ☐ NO

If you answered YES to question 11, please complete the remainder of the questionnaire. If you answered NO to question 11, skip to the last page and answer questions 27 through 30. Thank you very much for your cooperation.

12. Would you be interested in purchasing water from a nearby municiaplity if the line were financed solely by the municipality on a profit basis and you paid only for water used per month?

☐ YES ☐ NO

13. a. Would you be interested in purchasing water from a nearby municipality if the line had to be financed solely or in part by you and other users in the immediate rural area? (All financial arrangements are between individual farmer and municipality.)

☐ YES (go to part b) ☐ NO (go to part c)

b. How much would you be willing to pay as an initial tap-on fee to help finance the line? (This would be in addition to the monthly water charge.)

0 - $100 ________	$401 - $500 ________
$101 - $200 ________	$500 x $1000 ________
$201 - $300 ________	$1000 or more ________
$301 - $400 ________	

c. Briefly explain why you answered NO.

____

____

____

14. a. Would you be willing to become a member of a formal organization of farmers who would collectively finance the entire construction of the line and collectively buy water from a nearby municipality?

☐ YES (go to part b) ☐ NO (go to part c)

b. How much would you be willing to pay as a member of such an organization to help finance the construction?

0 - $100 ________	$401 - $500 ________
$101 - $200 ________	$500 x $1000 ________
$201 - $300 ________	$1000 or more ________
$301 - $400 ________	

c. Briefly explain why you answered NO.

____

____

15. Do you have a pond on your property?

☐ YES ☐ NO

16. a. Would you be interested in using pond water as a possible source of water for drinking as well as other household uses if it were treated so that it was of comparable quality with municipal water?

☐ YES (skip part b) ☐ NO (go to part b)

b. Briefly explain why you answered NO.

____

____

____

17. a. Would you be willing to become a member of a formal organization of farmers who would establish a treating and distribution system to treat and distribute pond water to the members on some equitable basis?

☐ YES (go to part b) ☐ NO (go to part c)

b. How much would you be willing to pay as a member of such an organization to help finance the treating and distribution facility?

0 - $100 ________ $401 - $500 ________

$101 - $200 ________ $501 x $1000 ________

$201 - $300 ________ $1000 or more ________

$301 - $400 ________

c. Briefly explain why you answered NO.

____

____

____

18. a. Would you be interested in individually buying and hauling water from a nearby municipality on a regular basis?

☐ YES (skip part b) ☐ NO (go to part b)

b. Briefly explain why you answered NO.

____

____

____

19. Do you have access to water hauling equipment?

☐ YES _____ gal. ☐ NO

20. Do you have storage facilities if water were to be hauled to your farm?

☐ YES _____ gal. ☐ NO

21. a. Would you be interested in becoming a member of a formal organization of farmers who would collectively buy and haul water from a nearby municipality and distribute it to the members of the group on a regular basis, i.e., such as farm gasoline is distributed?

☐ YES (skip part b) ☐ NO (go to part b)

b. Briefly explain why you answered NO.

____

____

____

22. Would you be willing to pay a set fee each month in addition to the water bill as your share of the cost of leasing a truck by the group, hiring a driver for the group truck, etc.?

☐ YES ☐ NO

23. Would you be interested in making standing arrangements with a nearby municipality to buy and haul water only in emergencies?

☐ YES ☐ NO

24. Obviously the water supply question has long-run implications, and people adapt themselves to an expected supply, thus, restricting their uses of water to only necessities. If there was a water source, of drinking water quality, off the farm that became available to you, what use(s) would the water be put to? Check the appropriate uses:

a. Drinking only ________
b. Other household (specify) ________________________________

____

c. Dairy drinking ________
d. Dairy, milkhouse ________
e. Other livestock ________
f. Other (specify) ____

____

25. If there was a water source, not of drinking water quality, but safe for other uses, off the farm that became available to you, what use(s) would the water be put to? Check the appropriate uses:

a. Other household (specify) ________________________________

____

b. Dairy drinking ________
c. Dairy, milkhouse ________
d. Other livestock ________
e. Other (specify) ____

____

26. Other comments: ____

THE FOLLOWING QUESTIONS ARE TO BE ANSWERED BY EVERYONE:

27. Name ____

28. Mailing Address ______________________________________

____
Zip

29. Phone number ____

30. a. Do you OWN or RENT your place of residence?

☐ OWN (skip b and c) ☐ RENT (answer parts b and c)

b. What is the name, address, and phone number of your landlord?

Name ____

Address ____

Phone ____

c. Does the landlord:

/ / Maintain the source of water for you

/ / Not provide water for you

/ / Adjust the rent to let you provide your own water

/ / Other arrangement (specify) ______________________

____

____