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Feasibility of Re-use of Treated Wastewater for Irrigation, Fertilization and Ground-water Recharge in Idaho

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by

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ABSTRACT

The increasing rate of production of industrial and domestic wastewaters has prompted scientists and engineers to investigate methods of renovation which offer alternatives to disposal in surface water bodies. Reuse of effluent for irrigation, fertilization and ground water recharge is among the techniques which have received much attention during the past several years. A large number of studies have demonstrated that vegetation and the proper geologic column are capable of greatly reducing the nutrient content of wastewater. Concomitantly the irrigated crop receives the normal benefit of the wastewater, as well as the benefit of the fertilizer contained therein. The fertilizer value (nitrogen, phosphorous and potassium) of domestic effluent has been estimated at about $18 per acre-foot; however, this figure can vary significantly.

It has been demonstrated also that under appropriate hydrogeologic conditions wastewater renovated by a porous medium can be expected to meet U. S. Public Health Service drinking water standards. Appropriate hydrogeologic conditions include the presence of an unconsolidated porous medium (such as sand) through which the wastewater can move an appreciable distance (which will vary with geologic conditions) before entering a water supply; the absence of surficial, jointed rocks through which the wastewater might move without appreciable adsorption of dissolved solids by the porous medium; and a water table depth of at least five feet. Hydrogeologic conditions less than optimal will result in less than optimal renovation of the wastewater, in which case care must be taken during application if water supply sources are located near the disposal area. Only rarely will a given hydrogeologic environment not renovate wastewater to the equivalent of secondary (biological) treatment. In many cases renovation of wastewater by vegetation and the geologic column can be substituted for tertiary treatment. Terrestrial disposal has also been used in lieu of secondary treatment.

Intermittent application consisting of three days of spray irrigation followed by seven days of rest has yielded best results. The application of 1 to 4 inches of wastewater per week, depending on infiltration and evapotranspiration rate, has been recommended by most investigators. Wastewater can be removed from lagoons, from secondary treatment facilities or from storage tanks.

In Idaho the major sources of nutrient rich wastewaters are located within the Snake River Basin above Brownlee Dam. Above this point only one-third of the total flow from the Snake River Basin must be relied upon to assimilate the nutrients produced by 75% of Idaho's population. It is in this portion of the basin that primary emphasis should be placed on the implementation of irrigation with wastewater.

Included among those communities in southern Idaho which appear to have potential for successful reuse of wastewater are Idaho Falls, Weiser, Rupert, and Nampa. The wastewater from the communities of Buhl, Mountain Home, and Jerome already are reused on a part-time basis. This list does not imply that wastewater reuse is not adaptable to other communities; however, the potential

for reuse in other communities needs additional investigation. Boise, for instance, may be able to introduce its effluent into the Farmers Union Canal, through which it can be transported to areas not experiencing the near-surface water table problems of the area nearer the city. Neither does this list include a number of food processing plants which should investigate the potential for reuse of their own wastes. The Green Giant Company near Buhl currently spreads sweet corn processing wastes on its own cultivated land. The company recently received the Pacific Northwest Pollution Control Association pollution control award for their operation.

In northern Idaho, Coeur d'Alene, Lewiston and Moscow offer potential for reuse of effluent. The Moscow treatment plant is ideally located for reuse of its effluent by irrigation of the University of Idaho golf course and nearby farm land. Although some of the Moscow wastewater is already being reused, there is potential for expansion. The South Fork of the Palouse River, into which the Moscow effluent eventually flows, has been designated a pollution problem area by the Federal Water Pollution Control Administration. The Palouse Loess which covers most of Pullman-Moscow Basin should be an ideal effluent renovation medium.

Reuse of effluent for irrigation of certain portions of the sloping valley wall above Lewiston may be feasible; however, additional hydrogeologic and economic investigation are also needed in this area.

Consideration should be given to transporting the wastewater from Coeur d'Alene treatment plant down river to the irrigated land on Rathdrum Prairie. Irrigation water for this land currently is withdrawn from the Spokane River.

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INTRODUCTION

The Snake River in southern Idaho probably is the major natural resource of that portion of the state. Though the stream is put to many uses, irrigated agriculture receives maximum benefits from it. In the broad basin of the Snake and its tributaries almost 3.4 million acres of agricultural land are irrigated with surface water withdrawn largely from the main stem of the Snake. With an average diversion rate of some 4 feet of water per acre, the total demand is between 15 and 20 million acre-feet per agricultural season. This figure incorporates an estimate of irrigation water lost via inefficient transfer systems, and includes some anticipated additional developments of irrigated acreage.

Ground water in the Snake basin supplies over 70% of the water needs of some 200 individual municipal water supply systems and approximately 100 industrial plants; furthermore, industrial and domestic demands on surface water and ground water can be expected to grow. At present over 360 million gallons of water a day are required for the forementioned users. It is projected that by the year 2020 the joint municipal-industrial requirement will increase to 1,140 mgd (USDI, 1968). In addition, the water users in the basin are becoming increasingly concentrated in the major service areas of the basin.

The river is also an important resource for the generation of hydroelectric power and for navigation. Development of impoundments for storage, power production, and navigation has resulted in a highly regulated river basin. There were 80 storage structures either existing, under construction, or authorized as of 1968. Total existing storage is 9,664,000 acre-feet, with 11, 619, 200 acre-feet of storage available upon completion of structures under construction or authorized for construction in 1968. The existing capacity of the power structures presently operating is a total of 1,894,300 kilowatts. The total power capacity, including dams under construction or authorized, is 3,689,300 kilowatts (USDI, 1968). Some 20 power and multi-purpose dams are presently operating, under construction, or authorized for construction. Of these, 4 will be utilized to provide slack-water navigation for barge traffic to the Lewiston-Clarkston complex, linking these cities with ports on the lower Columbia River.

The Snake is also a significantfisheries resource. In the Columbia River system some 61% of the anadromous fish passing McNary Dam on the Columbia River enter the Snake system each year (See Figure 1). Hydroelectric projects have precluded the entry of these fish into the upper reaches of the Snake.

Recreation in the Snake River Basin is an important source of income to Idaho business. For the State as a whole in 1968, tourism was the third leading income producer, ranking behind agriculture and manufacturing. Estimated recreation days spent by both in-state and out-of-state recreationists or tourists averaged 1.6 million on publicly adminstered reservoirs which offer boating and swimming opportunities. The U. S. Fish and Wildlife Service has estimated that the anadromous fishery resource of the lower basin is primarily responsible for approximately 2.7 million angler days of sport fishing (USDI, 1968). Another important source of recreation is the migratory waterfowl hunting available in season in the basin.

Several agencies, both public and private, estimate that tourism and recreation expenditures may outrank both agriculture and manufacturing as the major income producing activity for the residents of Idaho by 1985 (Howe, 1969). Tourism

Figure 1. ESTIMATED MAXIMUM RUNS OF SALMON AND STEELHEAD TO THE SNAKE RIVER SYSTEM *(after USDI, 1968)

Species	Columbia River Past McNary Dam	Snake River	% of Columbia
Fall Chinook	97,500	66,300	68
Spring Chinook	222,100	122,200	55
Steelhead	172,600	114,800	66.5
Total	492,200	303,300	61.6

* Data Source: U. S. Fish and Wildlife Service

income is growing between 9 and 12% each year, while manufacturing is increasing by 5% annually and agriculture by less than 5%. Idaho's water resources figure prominently in the total tourism and recreation picture. These figures lend emphasis to the importance of maintaining this valuable resource for the continued profit and pleasure of its beneficiaries.

It is possible to extrapolate from this discussion in order to draw conclusions relative to the value of other water bodies located within the State of Idaho. As in southern Idaho, northern Idaho's lakes and streams are important resources of recreation and tourism, for power generation, and, to a lesser extent, for agriculture.

This brief summary of the utilization of Idaho's water as a multipurpose resource is intended to illustrate the value of that resource to the State. It is the purpose of this publication to document the effect of waste disposal practices on the continued use of certain of Idaho's water bodies and to examine alternative means of disposal of these wastes in order that their negative effect on water quality and utility can be minimized. The approach taken will be to demonstrate the problem by a discussion of other areas, more developed than Idaho, where the consequences of unsatisfactory waste disposal practices have become critical. A discussion of the problem as directly related to Idaho will follow. Subsequent sections will treat wastewater reuse for fertilization and irrigation as an alternative to disposal in streams. Evidence which has been gathered in other areas will be presented which demonstrates that such disposal practices are safe, beneficial and feasible under appropriate hydrogeologic and engineering conditions. Finally, a discussion will be presented of localities in Idaho where wastewater reuse systems might be most easily implemented in order to minimize water quality deterioration in Idaho. For reasons stated above, particular attention will be given to the Snake and its tributaries.

DISCUSSION OF PROBLEM

Stream and Lake Pollution

Malodorous rivers, encumbered with drifting islands of blue-green algae and slime, oily, rainbow-hued water surfaces, and waste and litter are conditions that man must face for today and even more so for tomorrow if present waste disposal practices are continued. Only man can produce the huge quantities of synthetic materials that resist natural decay. If the resulting alteration of man's environment is to be corrected, the carefully balanced forces of nature must be restored in order to allow the efficient decay processes of nature to catch up to the pollution load supplied by man. The increased demands being placed upon our water resources by the expansion of population and industry, and the increased problems of waste disposal and water pollution, have made the philosophy of earlier years that "the solution of pollution is dilution", unworkable for much of today's complex society.

An important factor in the pollution of our lakes and streams is the quantity of domestic fertilizer equivalent emptied into the water bodies. This fertilization results in dramatic changes in the biologic character of the water body affected. In the natural aging process, a water body passes through the three stages of oligotrophy, eutrophy and dystrophy. One of the criteria for determining whether a lake is oligotrophic or eutrophic is the biological character of the lake. In the initial or oligotrophic stage, a lake is high in dissolved oxygen, low in organics, and supports a clean water plant-animal community consisting of diatoms, dinoflagellates, and desirable fish species such as trout and whitefish. In the eutrophic stage the oxygen content is reduced by the dead and decaying vegetable matter; several species of algae appear, including species of blue-green algae, such as Oscillatoria rubenscens (a species that forms nuisance blooms); and the fish population consists only of species such as carp and pike which can tolerate the low oxygen environment. In the dystrophic stage the lake supports few or no desirable forms.

This aging process normally encompasses thousands of years. However, there is abundant evidence that man accelerates the process many fold. Researchers have reported on the growing pollution of lakes and streams in many countries, including Austria, England, Finland, Germany, Italy, New Zealand, Switzerland, and the United States. Hasler (1947) has reported on eutrophication of Lake Zurich, in Switzerland. The lake consists of two basins. The city of Zurich is bisected by the Limmat River flowing out of the lower, larger basin. Zurich contributes no wastes to the lake. But the buildup of communities around this lower basin has resulted in a dramatic increase in the input of domestic waste. The upper basin still has a relatively sparse population around its shores. The lower lake has lost all trout and whitefish, which are replaced now by perch. northern pike, and trash fish. The upper basin lake continues to support commercial fishing for trout and whitefish. Less than a hundred years ago both basins were clear, clean, and supported a commercial crop of trout and whitefish. Since the turn of the century, algal scums in the lower lake have created a malodorous nuisance, turning the larger part of Lake Zurich and the water of the Limmat to a copper-red color as it flows through the city. Expensive filtering and purifying equipment for the city's water supply is now required. Hasler also reports that the blue-green algae bloom has exploded in Lake Zurich. He cites similar explosions of Oscillatoria rubescens in Lake Windermere, the largest lake in England. Cores taken from the bottom of Lake

Windemere show little apparent change in the character of the sedimentary deposits from the end of the Ice Age to comparatively recent times. But in these recent times the change has been dramatic. This change was accelerated with the great increase in the tourist population in the 1840's, to the point that the sediment now reflects a much more rapid filling of the lake, with an increasing composition of dead and partially decayed organic matter replacing inorganic sediments.

Reid (1966) reports that Lake Maraetai, a hydroelectric impoundment in New Zealand, has experienced wastewater pollution and cultural enrichment. Cases of disease in a town drawing its water supply from the lake are attributed to viruses carried in the surface water of the lake polluted by the same town's wastewater. Plankton in the town's water supply results from cultural development of the river basin, impoundment in the reservoirs, and cultural enrichment.

Lackey and Sawyer (1945), Rohlich (1949), and Fitzgerald (1960) have reported on the pollution of a chain of four lakes near Madison, Wisconsin. In a span of 30 to 40 years these lakes have changed from an oligotrophic condition to an eutrophic state. The source of nutrients was determined by Lackey and Sawyer to be predominately urban. Of the fertilizer value being fed into the lakes in 1945, 76.9% of inorganic nitrogen and 89.2% of inorganic phosphorus in the nutrients were contributed by Madison's effluent. The agricultural sector of the pollution contributors was insignificant in this case.

Beeton (1965) has classified Lake Erie as eutrophic on the basis of its biologic character. Several changes commonly associated with eutrophication in small lakes have been observed in the Great Lakes. These changes reflect accelerated eutrophication in the Great Lakes due to man's activity. Chemical data compiled from a number of sources, dating as early as 1854, indicate a progressive increase in the concentration of various major ions and total dissolved solids in all of the lakes except Lake Superior. The plankton has changed somewhat in Lake Michigan and the plant and animal populations of Lake Erie are greatly different today from those of the past. These changes are remarkable for such large lakes. Man's activities clearly have accelerated the rate of eutrophication. This rate has been greatest in Lakes Erie, Ontario, and Michigan and these lakes have had the largest population growth within their drainage areas.

Edmonson, _et al_, (1956) report that Lake Washington in Seattle shows definite evidence of having rather suddenly increased in nutrient content. The oxygen deficit in 1955 was 1.8 times that in 1952, and 2.7 times the deficit in 1933. The biological character of the lake has changed recently in that the former dominance of diatoms and dinoflagellates in the population has been replaced by that of the blue-green algae. These changes have coincided with the rapid increase in population buildup around the lake; so Lake Washington seems to be fitting the pattern of abrupt change similar to other lakes which have been studied limnologically before pollution became serious.

Other studies in the literature include Palmer's work (Palmer, 1960) on eutrophication of the rivers of the United States, including the Mississippi, and Ludwig and McGauhey's (1963) work with pollution of Lake Tahoe in California. In all cases the emphasis is on the physical, chemical and biological changes occurring, and on the consequences to man. Some of the consequences of this domestic fertilization of water bodies are: 1) aesthetic deterioration resulting from scums of algae, and the unpleasant odors accompanying its decomposition; 2) loss of recreational uses such as boating and swimming, arising from the growth of larger aquatic plants and the accumulation of slime and algae; (3) the depreciation of riparian property values; 4) the increased costs of filtration and deodorization of domestic water; and 5) the hastened extinction of the water body. Hastened lake or reservoir extinction if a genuine problem. Hasler (1947) states that artificial fertilization of reservoirs and lakes raises the rates of production of organic matter and its subsequent sedimentation. This matter accumulates without decomposing completely, forming a growing mat of dead vegetation. Hasler states that a eutrophic water body is filling by sedimentation of organic material at a greater rate than the rate of sedimentation via inorganic substances such as silts and clays. Thus lake extinction is hastened when the lake is fertilized by domestic and industrial wastewater. This problem of organic sedimentation is especially serious because presently there is no practical method of reversing the process. It is on this premise that the frequently heard statement, "a lake is effectively dead", is based.

Oswald and Golueke (1966) have assessed the potential impact of a population in the acceleration of eutrophication. The problem arises from the fact that man, in inhabiting a drainage basin, does not rely solely upon the resources of that basin for his sources of energy. Instead, man frequently imports large quantities of these components for his food, power, and industry. It is this importation of additional nutrients into the drainage basin that precipitates the watershed problem. In many bodies of water the ability of the stream to foster decay processes exceeds by several times the natural capacity of the drainage basin and the stream to produce decayable material. Oswald and Golueke state that under natural conditions a lake may assimilate its own synthate and that of a watershed 50 times its own size. But 1 person contributes nutrients equivalent to 5,000 to 25,000 square meters of natural watershed, so it takes only a few people and improper treatment of their wastes to extend the equivalent watershed area far beyond the assimilative capacity of the receiving water body. Eutrophication is a threat to all of our inhabited major river basins and to many of our most desirable lakes and reservoirs. This threat is a consequence of development and the concentration of larger and larger populations in the vicinity of many of our most valuable water resources. Oswald and Golueke estimate that the rate of eutrophication will double in the next 25 years and redouble near the end of the century.

It is not difficult to extrapolate from the national and international scene to realize a similar future for much of Idaho's water resources. The most dramatic example of eutrophication of Idaho streams and reservoirs is the Snake River. Along its entire length in Idaho, with few exceptions, the problem of stream pollution is increasing.

The United States Department of the Interior's Federal Water Pollution Control Administration (FWPCA) has published a booklet entitled Water Quality Control and Mangement, Snake River Basin (1968). This publication is concerned with documentation of stream pollution for the Snake River Basin. The following discussion on water quality problems is extracted from the report (USDI, 1968, pp. 32-39):

> "Water quality problems exist in the Snake River system in the form of impaired uses of water or of potential uses lost because of degraded water quality. The most dramatic problem has been the loss to the fishery. Fish kills have occurred at Milner Reservoir

in 1960, 1961, 1962, and 1966; at American Falls Reservoir; and in the Portneuf and lower Boise Rivers. In each case the cause has been a combination of inadequately treated toxic or oxygen-demanding wastes and low stream-flows. The fishery has also been affected by occasional high water temperatures in the lower Snake, preventing the migration of salmon up the system for several weeks.

Other problems have been less intensive but have also resulted in impaired water use. For example, the City of Twin Falls was forced to abandon its Snake River water supply as a result of tastes and odors associated with decay of aquatic growths and other waste loads in Milner Reservoir. Bacterial contamination has also made water-contact recreation undesirable in several stretches of the river.

The most chronic problem in the Snake River is the damage caused by aquatic growths which break loose from the rocks or shallow stream beds and float downstream in rafts or sink in deep, slow-moving pools to create bottom oxygen demand. Irrigators have suffered increased costs and inconvenience when these dense masses of aquatic vegetation have interfered with water transmission; recreationlists have abandoned certain areas because of the disagreeable appearance of aquatic growths, and the fishery in American Falls Reservoir has been adversely affected by heavy algal blooms.

Water quality problems in the Snake are best described in terms of the water quality standards which prescribed the criteria for each use and serve as a guide in defining problem areas."

Dissolved Oxygen Depletion

"Dissolved oxygen (oxygen held in solution in a given amount of water) provides the basic respiratory supply for most living aquatic organisms, including not only fish and other higher life forms but also the bacteria which consume organic matter. When oxygen levels are depleted, fish and other desirable organisms are inhibited or killed and the stream or reservoir can be converted into an odor-producing nuisance.

Instances of low dissolved oxygen occur intermittently in the South Fork Teton River and Henrys Fork below the Teton River; in the Boise River; and in American Falls, Milner, and Brownlee Reservoirs. A generalized dissolved oxygen profile of the main stem Snake under summer and winter conditions shows severe depressions occurring at Borwnlee and Milner Reservoirs. The levels of oxygen are at times substandard (below 5 mg/liter) in other reaches of the lower river. Levels in irrigation drains and in the lower Boise River have approached zero. Fish kills have occurred in Milner and American Falls Reservoirs and in the lower Boise River because of depleted oxygen levels.

The principal causes of dissolved oxygen problems are the extreme low flows caused by the operation of storage reservoirs, by irrigation withdrawals, and by untreated or inadequately treated wastes. Because organic wastes also use up oxygen when they decompose, the small quantity of oxygen which exists under low flow conditions is quickly depleted; even with a high degree of waste treatment, enough water must be available to assimilate residual loadings to the stream. The principal source of organic wastes causing dissolved oxygen depletion is potato and sugar processing, but inadequately treated municipal wastes contribute to the problem, as do decomposing aquatic growths."

Aquatic Growths

"Perhaps the most characteristic water quality problem of the Snake River Basin is the excessive aquatic growths which detract from the beauty of the streams, clog irrigation canals, and eventually die, creating sludge deposits and oxygen demands. Thick blooms of algae make the waters of the upper and central basins a characteristic opaque green. Floating rafts of algae are prevalent on the surface of the Snake and form clinging slimes where they adhere to rocks and banks. As these growths die and decay, they release nutrients for new growths and become a principal source of oxygen demand in the basin. They cause a noticeable fluctuation in dissolved oxygen levels during night and day as the plants' respiration and transpiration processes alternate. An August 1967 fish kill in American Falls Reservoir was attributed to algal oxygen demand."

These excessive aquatic growths are related to the high concentrations of basic nutrients--nitrogen and phosphorus--in the Snake system. Phosphate concentrations rise steadily through the upper basin, then increase abruptly at the head of American Falls Reservoir, where the Portneuf River, carrying wastes from the phosphate mining and processing operations joins the Snake. In addition, natural phosphate levels, irrigation return flows, municipal wastes, animal wastes, and the decay of aquatic biota all contribute to the nutrient balance which stimulates aquatic growth.

"Another factor compounding the problem is the system of impoundments on the Snake River. When a free-flowing stream is changed into a series of pools, the aquatic environment becomes more susceptible to algae and other plant productivity. Temperature, stratification and detention time all serve to increase biological productivity."

Bacterial Pollution

"The coliform group of bacteria is used to measure the bacterial deterioration of water quality because these bacteria occur in the fecal matter of all warm-blooded animals, including man. Although these may also be found in plants or in the soil, their presence in a body of water is usually considered evidence of fecal contamination. Such contamination is an indication of a possible health hazard from accompanying pathogenic bacteria and viruses and restricts the use of that water for water-contact recreation or drinking water supplies."

Generally, coliform levels above 1000 organisms per 100 milliliters are considered too high for water contact recreation. This level is exceeded below most population centers in the Snake Basin, especially in the Burley, Idaho Falls, Shelley areas and below the mouth of the Boise River.

"The cause of bacterial pollution in the Snake Basin poses a difficult problem of evaluation. Discharges of sanitary sewage are unquestionably responsible for many of the problems, particularly below population concentrations."

However, a significant portion of the problem results from the large number of livestock concentrated near the Snake and Boise Rivers in areas laced with irrigation drains which transport a portion of the animal wastes along with the other runoff from the heavily irrigated agricultural basin.

"Animal populations are concentrated to the extent that their wastes exert a distinct effect on water quality in several stream reaches. Half of the basin's cattle are found within twenty miles of either side of the Snake and Boise Rivers in three areas: (1) along the Snake River between Lake Walcott Reservoir and the mouth of the Big Wood (Malad) River, (2) in the lower Boise River Valley, and (3) in the central basin between Adrian and the head of Brownlee Pool. In these three areas about 800,000 cattle- and significant numbers of other farm animals-- are clustered in about 5,300 square miles. The relative closeness to the rivers in areas laced with irrigation drains ensures that the wastes of these animals constitute a significant source of bacteria."

Thermal Pollution

"Water temperature is critical to the anadromous and resident fisheries of the Snake Basin and to the aesthetic quality of many of the system's streams. Anadromous fish require relatively low temperatures to migrate, spawn, and develop; higher temperatures delay migration, accelerate disease, and generally reduce the survival rate of young fish. In addition, high temperatures stimulate the productivity of aquatic plants, act as a catalyst to algal blooms, and reduce the dissolved oxygen resource of the stream."

"The cause of temperature problems is related to the impoundment of the free-flowing stream and the use of the system for irrigation. Flow depletion due to storage and diversion of the surface return of irrigation waters warmed on fields combine with solar radiation to increase temperature levels."

Suspended Solids

"Sediment and suspended solids result in turbid conditions which hamper fish spawning, recreation, and the aesthetic beauty of the river. In the spring, turbidity is particularly noticeable in the main stem in the lower basin and in lower basin tributaries such as the Palouse, Tucannon, and Asotin Rivers. During periods of high runoff, sediment concentrations reach objectionable levels throughout the basin. In addition, irrigation returns are a summer source of localized turbidity."

Toxins have caused some water quality problems at several points in the basin. Examples include acid waste discharges to the Portneuf River and pesticide concentrations high enough to injure or kill fish in the Boise River, C. J. Strike Reservoir (1964) and American Falls Reservoir (1966).

Ralph Hanson, writer for the Blackfoot News, has authored a series of articles on the Snake River in southern Idaho (Hanson, 1969). In these articles he has enumerated various abuses and cited several sources and types of pollution of this stream. In general Hanson writes of those symbols of pollution which have become visible: The buildup of silt from organic deposition in the reservoirs, the abundance of water-borne bacteria "feeding on the proteins, carbohydrates and fats dumped by the potato processors", which have accumulated in "slimy, fibrous clumps". He has also commented on the destruction of spawning beds for game fish, the growing bacterial pollution "from inadequately treated municipal sewage water", and the "rising level of chemical residues in the rivers and reservoirs" as a consequence of increased use of agricultural pesticides. The visibility of these effects of pollution is enhanced as a consequence of impoundment, and diversion during the summer, of the Snake River. The impoundment and diversion produce low flow rates, reduced recreational value, and a reduced capacity of the river to dilute waste inputs, all occurring during the season of maximum demand for fishing and recreation.

Hanson poses the question of whether or not the Snake River is worth saving. The costs involved in providing primary and secondary treatment for domestic and industrial waste water are nearly prohibitive. But by 1972, Federal statutes established under the Federal Water Pollution Act of 1965 will force cities to comply with water quality standards advocated by the Federal Water Pollution Control Administration. Mr. Hanson feels that the costs of complying with these standards are worth the benefits which will be realized. He emphasized, however, that just meeting the water quality standards of the FWPCA may not be sufficient. The rapid expansion of population and of industry, particularly that of the food processing industry, may require a third stage of treatment to augment the first two stages, because the nutrient content of the large volumes of secondary effluent may create nuisance growths of aquatic plants even in the absence of other water quality problems.

An alternative to the costs embodied in such a three-stage treatment process would be to follow practices many eastern cities and states have been forced to adopt, that of writing off the Snake River as a multiple-use stream, allowing it to degenerate to the status of a sewage canal, and concentrating on saving the still unpolluted rivers of Idaho. Hanson feels that this drastic step is not necessary yet, and he justifies paying the costs of avoiding such a circumstance, by citing the increasing emphasis Americans are placing on the recreational and esthetic value of waterways.

The pollution problem in the Snake River Basin is a consequence of several factors working together to complement one another. An example is that of the depletion of dissolved oxygen. Adding biochemical oxygen demand (BOD) to the stream from industrial and domestic wastewater is a serious matter from the standpoint of pollution and depletion of dissolved oxygen. But the impact of impoundments such as Milner and American Falls Dams upon the nutrient load carried by the stream is that such impoundment produces septic conditions and oxygen demand that are many times more serious than that which would have existed in a free-flowing stream. The impoundment permits the accumulation and sedimentation of this partially decomposed organic material and the corresponding hastened extinction of the reservoir. The increased growth of algae and other aquatic biota are a consequence of the warming of the relatively still reservoir water from solar heating. The concentration of slime and other aesthetically unpleasant matter on the surface and along the shores of the reservoir is another by-product. Under free-flowing conditions the river would enjoy a greater self-regenerating or self-cleansing action, especially during the period of annual high-water. This regeneration would facilitate the more efficient removal of the nutrient load by the current, thus prohibiting the compounding of the pollutants.

The entire solution to aesthetic and recreational deterioration of such a resource will require measures much broader than that simply of controlling the sources of nutrient enrichment of this water body. For example, the control of nutrient input will not significantly aid in effecting a solution to the problem of thermal pollution arising from impoundment. In addition, controlling the input of nutrients from domestic and industrial sources will do little to alleviate the pollution problem of turbidity or of agricultural contributions to the river. But this problem of domestic and industrial nutrient enrichment (eutrophication) and its control is still one of the most important goals we must strive to achieve before multipurpose uses become limited.

Nutrient input is also the major pollution problem for northern Idaho streams and lakes. Although the problem is identified, too little research has been conducted to date to properly certify the severity of pollution.

Persons having riparian rights along northern Idaho streams and lakes have complained to several State agencies regarding offensive conditions and pollution of these waterways. The major pollution problem has been the appearance of algae blooms, unsightly masses of aquatic plants, and an increase in bacteria count to levels endangering the continued use of the affected water bodies for contact recreational activities such as swimming. These problems have appeared in companion with the growth of resident and seasonal population along the shores of lakes and streams. It is generally agreed that the primary source of nutrients essential to support the aesthetically offensive appearance of this undesired biota, and the primary source of the contaminant bacteria, is domestic wastewater.

Examples of this enrichment of northern lakes in Idaho is Cocolalla Lake and Coeur d'Alene Lake. Cocolalla Lake has experienced a rapid increase in urban buildup around its shoreline, and for the past several years, seasonal algal blooms have occurred during the summer months.

The primary species of algae involved is Aphanizomenon flosaquae, a species of blue-green algae that is associated with taste and odor problems. Also, as a consequence of the increase in dead and decaying vegetable matter in the lake, the dissolved oxygen has been rapidly depleted during the months of the "bloom." Fish kills have also occurred. Algal problems in Coeur d'Alene Lake probably are related to the entry of phosphate via the Coeur d'Alene River (Williams, 1969).

Another example of pollution in northern Idaho is the South Fork of the Palouse River. Wastewater inflow from Moscow, Idaho and Pullman, Washington, contributes a significant portion of the dry weather flow of the stream. The Federal Water Pollution Control Administration has declared the stream one of the eleven sites in the Snake River Basin which is the scene of very serious pollution requiring immediate remedial action to return the stream to full utility for all users.

In some cases the addition of nutrients to a water body is beneficial. Payette Lake has experienced an increase in the inflow of nutrients from the population buildup around its shores (Olson, 1969, personal communication). Some have hypothesized that this fertilization may be increasing the productivity of the lake as a fishery. But fertilization of a lake via the input of domestic wastewater must be viewed as a delicate proposition. The balance required to guarantee that the water body does not progressively enter the road to eutrophication, and then to hastened extinction, is such that fertilization by wastes must be carefully studied and monitored if it is to be assured that the process does not get out of hand. Failure to monitor such a system is likely to produce undesirable results and the limiting of the water body for some users.

Proposal of Renovation by Soil Systems as a Corrective Measure

The need for control of sources of domestic and industrial pollution are well recognized. However, the costs for such control via customary means of waste processing and treatment are substantial. It is the purpose of this text to examine a supplement, and in some cases and alternative to a portion of primary, secondary, and tertiary treatment processes. The alternative solution which may provide this needed control is the irrigation and fertilization of agricultural crops with domestic and industrial wastewater, or the surface application of domestic and industrial wastewater for renovation by a soil system.

It is hypothesized that such irrigation or surface application of wastewater where hydrogeologic conditions permit will yield a level of treatment or renovation equivalent to that obtainable with the tertiary treatment processes currently available. Surface application may provide an economical method of treatment which is less costly than extensive advanced treatment of domestic and industrial wastewater. Irrigation with wastewater will result in increased crop production, an increase in the supply of irrigation water available for agricultural irrigation, and will renovate the wastewater by lowering nutrient content, by reducing biochemical oxygen demand (BOD), by removal of some of the dissolved solids from industrial waste water, and by removal of bacteria from the wastewater. In addition, such irrigation or surface spreading onto a soil system normally will result in recharge to ground water of a portion of the effluent, with minimum threat to the continued quality of that valuable resource. The early recognition and elimination of undesirable results can be assured by the installation of appropriate monitoring devices.

DOMESTIC AND INDUSTRIAL WASTEWATER REUSE IN OTHER AREAS

Examples of Cities Reusing Effluent

Today more than 400 cities in the United States are utilizing their treated effluent for agricultural irrigation. Sewage farming (the agricultural utilization of a sewage) involves the use of domestic and/or industrial effluent for the production of crops and the raising of animals.

Merz (1956) reported on the status of several sewage farming operations. At that time Fresno, California, was utilizing the effluent from a primary treatment plant for the production of crops and cattle feed. Over 22 million gallons per day of primary effluent were being used for the irrigation of corn, grain, alfalfa, and grasses. The farming utilization took the place of secondary treatment that would have been needed to provide an effluent renovated to the degree that it could have been discharged to a stream or canal. In addition, the irrigation water that percolated through the soil and into the ground water was purified to the extent that it had no harmful effects upon the quality of the ground water. In Bakersfield, California, primary effluent has been used for the irrigation of pasture, cotton, alfalfa, grasses, and the pre-irrigation of potatoes (Merz, 1956). In the California cities of Pomona and Tulare, domestic effluent was being used, in 1956, to irrigate alfalfa, citrus fruit, grain, grasses, sunflowers, and the watering of cattle.

In Texas,irrigation with sewage effluent is in operation at Abilene, where by 1956 approximately five mgd (million gallons per day) of raw sewage lagoon effluent were being used for the irrigation of grain, grasses, and maize; at Kingsville, where 1.0 mgd of raw sewage lagoon effluent were being used for the irrigation of similar crops; and at Lubbock, where six mgd of filter plant effluent were used for the irrigation of barley, cotton, sorghum and wheat; and at San Antonio, where 23 mgd of activated sludge effluent were used for the irrigation of alfalfa, corn, and grasses and for the watering of cattle and horses (Merz, 1956).

Bauer (1961), reported that the Air Force Academy sewage treatment system, employing two-stage trickling filters, was designed to collect all of the settled final effluent for utilization in a landscape irrigation system. Only during periods of high rainfall does any effluent escape to the receiving stream.

The cities mentioned here do not comprise a complete list of communities utilizing their waste effluent for agricultural purposes. Furthermore, it is significant that this practice is not something relatively new to the United States. For example, the cities of Upland and Ontario, California, have been irrigating with their domestic sewage effluent for more than 50 years, using such methods of application as flooding, furrows, and sprinkling. In Europe this logical utilization of nutrient enriched city wastewater has been accepted for several hundred years. Berlin has disposed of its effluent in this manner since the sixteenth century. The principal investigator has observed several cities in Mexico which have used the technique for decades.

Fertilizer in Domestic Effluent

In addition to efficient and sanitary disposal of wastewater and the economical treatment of this same wastewater, the cities realize an economic return from the fertilizer value of the effluent. The nutrients contained in this water add to crop yields. Hershkovitz (1967) estimates that the percapita annual contribution of nutrients to domestic sewage is equal to 5.5 to 6.6 pounds of nitrogen, 1.7 to

2.2 pounds of phosphorus (P_2O_5), 2.9 to 3.5 pounds of potassium (K_2O) and 22 to 26.4 pounds of organic matter. He points out the value of organic matter in sewage by noting that organic matter improves soil structure by aggregating the soil particles, thus forming a more granular soil having better physical characteristics. Other estimates of per capita contribution of nutrients show some variance with Hershkovitz. Fair, Geyer and Okun (1968) report per capita annual contributions ranging from 6 to 7 pounds of nitrogen, 1.2 pounds of phosphorus, 2 pounds of potassium (K_2O) and as much as 110 to 120 pounds of organic matter. In Israel, the addition of such organic matter to the sand dune soil of the Holon sewage irrigation farm resulted in the stabilization of the sand dunes and their resulting conversion to productive agricultural land (Hershkovitz and Feinmesser, 1967). Dye (1958) has also reported on the beneficial results realized in utilizing organic matter in sewage effluent for agriculture irrigation. He states that an average suspended solids content of 30 ppm is equivalent to spreading 81 pounds of organic material on an acre with every acre-foot of the effluent used.

The average per capita contributions of nutrients described above have been converted to more usable statistics by several authors. Day and Tucker (1959), in Arizona, report that effluent from the activated sludge complete sewage treatment plant in Tucson contains about 65 pounds of nitrogen, 50 pounds of phosphate (P_2O_5), and 32 pounds of potash (K_2O) per acre-foot. In Ruston, Louisiana, chemical analysis of effluents from two sewage treatment plants handling Ruston's domestic wastes showed the following concentration of nutrients: Nitrogen, 16-20 ppm; phosphorus, 7-10 ppm; potassium, 35-40 ppm; and calcium, 100 ppm; with a pH of 7.2-7.4 (Thomas and Law, 1968). The researchers calculated that the value of the ferilizer elements in the Ruston effluent was approximately $17.50 per acre-foot of effluent.

Many other researchers have contributed estimates of the ferilizer value in treated sewage effluent, and the values vary with the study, with the type of treatment given to the sewage effluent, and with the source of the effluent. It is appropriate to include two other research findings to further illustrate this point. Schreiber (1957) reports that the amount of the principal fertilizer elements nitrogen, potassium, and phosphorus in sewage effluents from 15 California cities studied is 60 to 100 pounds of nitrogen chiefly in the form of ammonia; 20 to 40 pounds of potassium occurring as potassium; and 60 to 100 pounds of phosphate occurring as phosphate, per acre-foot of effluent. Schreiber does not assign a dollar value to the fertilizer contained in an acre-foot of effluent; however, Hirsch (1969, p. 60) states that the 1969 value of the nitrogen, phosphorus and potassium fertilizer in an acre-foot of a typical San Diego wastewater is $18. Hirsch goes on to say that, "There would be no need for the application of additional chemicals when utilizing this reclaimed water for landscape-horticulture except for the use of supplemental nitrogen to turf areas during seasons of rain (if reclaimed water is not used for a period of two months or longer)." A Pennsylvania State University research experiment (Parizek, et al., 1967) attempted to relate effluent derived agricultural nutrients to equivalent commercial fertilization rate. In this case the investigators determined that with an application rate of two inches of effluent per week for periods varying from 24 to 33 weeks of irrigation in three years of study (1963-1965), fertilizer application to crops and wooded plots was equal to 100 to 280 pounds of nitrogen, 180 to 300 pounds of available phosphorus, and 120 to 320 pounds of water- soluble potash per acre.

Crop Response

The most meaningful product of fertilization by sewage effluent is crop yield. In other words, how does the crop yield of crops irrigated with sewage effluent differ from the yield of crops not irrigated with the effluent, or irrigated with ordinary irrigation water? Day and Tucker (1959) have conducted one of the more extensive studies along this line. In eight experiments conducted over a two-year period (1957-58) at Cortaro, Arizona the pasture forage production of small grains irrigated with sewage effluent was compared with the pasture forage production obtained when small grains were irrigated with regular irrigation water. In part of the experiments commercial fertilizer was added to the normal irrigation water in amounts equivalent to the fertilizer content of the effluent. The following results were observed (as reported by the authors): Winter pasture forage yields equivalent to 11.14 tons per acre were obtained from barley irrigated with sewage effluent. Barley produced 112% more forage on plots treated with sewage effluent alone than was produced on the control plots that received normal irrigation water with no additional fertilizer. Wheat growth with normal irrigation water with no additional fertilizer produced 3.50 tons of forage per acre. Wheat plots that received sewage effluent produced 263% more pasture forage than check plots that received normal irrigation water with no additional fertilizer. In general, as the amount of nitrogen fertilizer was increased in normal irrigation water, the average wheat forage yield also was increased. Plots of oats produced 3.13 tons of pasture forage per acre when irrigated with pump water with no additional fertilizer. When oat plots were irrigated with sewage effluent they produced 249% more forage than plots that received only pump water.

Normal irrigation water fortified with commercial fertilizer in amounts equivalent to the fertilizer content of the effluent showed no significant improvement in crop yields of oats and wheat over the yields realized using sewage effluent on these crops. With the exception of barley the normal irrigation water fortified with commercial fertilizer was significantly superior to effluent for stimulating crop yields. This was interpreted to indicate that for barley the negative effects of some semi-toxic trace elements in the effluent overcame part of the positive growth effects of the nutrients in the effluent.

In the Pennsylvania State University study mentioned earlier (Parizek, et al., 1967), the application of sewage effluent resulted in an approximate 300% increase in hay yields, 50% increase for corn grain, 103 to 136% increase in yield for corn stover, and from 17 to 51% increase in oats. There was little increase in wheat yields, but the nitrogen content of the wheat was increased by 19 to 30%. In a third study in Florida domestic sewage effluent increased yields amounting to 240% for both Napier grass and Japanese cane when compared with the unirrigated crops or with the same crops irrigated with well water (Stokes, et al., 1930).

From the additional volumes of research concerning the effects of sewage farming on crop yields, it is evident that most crops produce much higher yields when irrigated with effluent than when not irrigated or when irrigated with ordinary water but not commercially fertilized. In several cases the actual equivalent amount of fertilizer applied by irrigating with sewage effluent was in excess of the amounts recommended by agricultural experts.

Response by Wooded Areas

Sewage effluent also has been used for the irrigation of forested plots and plots planted to tree seedlings. Because pertinent variables differ from location to location, results have varied among experiments. A significant factor in some of these experiments has been that the objective of many programs has not necessarily been that of maximizing yield, but rather that of maximizing the volume of effluent applied to a limited acreage. Typical of the latter is the Seabrook Farms operation in Seabrook, New Jersey (Little, et al., 1959, Mather, 1953). By 1959 the Seabrook cannery had sprayed cannery waste under high pressure onto forested plots for seven consecutive years. After sprinkling at high pressure over a 120 foot radius over this period, it is reported that 59% of the trees within a radius of 37-$\frac{1}{4}$ feet died. It is estimated that all trees within 100 feet of the nozzles will die eventually. The growth of water-tolerant shrubs and herbs was luxuriant, covering 75% of the surface, with a height of 4.3 feet (the height of the spray). In general, when high-pressure irrigation with high-rate application is planned, tree species will suffer and shrubbery and herbaceous cover will flourish. This damage is due primarily to too much water applied under too great a pressure. If the application rate is reduced to two to four inches per week per acre (depending on soil permeability), an appreciable gain in both tree and forest-floor vegetative growth can be realized. In addition, some types of trees can tolerate, and indeed demand, more water than others. Rudolph (1957) reports that boxelder, black willow, hybrid willow, cottonwood and balsam poplar were planted, than checked after three years of irrigation with the cannery waste water. The black willow showed the highest survival and most rapid height growth. In the irrigated area the black willow averaged 9 feet in height, and the stand was rapidly reaching closed conditions. In the unsprayed check plot, the average height of the black willow was 1$\frac{1}{2}$ feet.

Except for the cottonwood, survival of the other species was higher in the irrigated plantings than in the unsprayed check area. The cottonwood showed a higher survival in the unirrigated planting. Surviving trees of all species showed a markedly greater height growth in the irrigated area than in the check plantings. It should be pointed out that all these trees are phreatophytes (water loving) and that the cottonwood is the least demanding of water.

A successful program of spray irrigation of trees has been reported in the Pennsylvania State University study (Parizek, et al., 1967). Results of the first year (1964) of the growth study indicated that irrigation with sewage effluent had no significant effect on the annual diameter growth of the hardwoods or red pine; but there was a significant increase in the height growth of the red pine and white spruce. The growth of dry herbaceous cover showed the greatest difference with respect to irrigation versus non-irrigation. In 1963 the pounds per acre of dry matter produced on the irrigated plot was 3381, as compared to 1470 pounds per acre on the control plot. In 1964 the ratio was 7607 pounds to 1763 pounds of dry matter for the irrigated plot and the control plot respectively. Sufficient data have been accumulated to show that forest irrigation is feasible and productive if conducted with tree yield as the major goal, and not merely disposal at the greatest rate possible.

In summary, the studies discussed here have demonstrated that nutrient valuesobtained from sewage farming are appreciable, though quite variable, yielding as much as $70.00 in fertilizer value per acre with irrigation rates of one to four inches of effluent per acre per week for the duration of the irrigation season. In addition, high-rate application of wastewater is practical on forested plots, and significantly greater yields in tree growth can be realized with the proper program of application. Many additional studies which provide similar evidence have been reported in the literature.

DISTRIBUTION SYSTEMS EMPLOYED

There are four basic system designs for surface application of treated or untreated wastewater. In most cases these designs lend themselves to high rates of application and have been adopted largely by industrial operations seeking economical means for disposing of wastewater resulting from manufacturing and processing operations. But these designs also lend themselves to utilization by cities, and in most cases to agricultural enterprises. The four systems are: 1) infiltration basins, 2) ridge-and-furrow, 3) spray-irrigation, and 4) spray-runoff.

Infiltration Basins

Infiltration basins generally are small, diked areas in relatively permeable soils, rocks or sediments. They have been used successfully as the final step in the comprehensive treatment of wastewater for direct reuse. The Los Angeles County Flood Control District conducted three years of testing to develop prototype facilities for reclaiming treated effluent which would make the effluent pure enough for direct injection into a recharge well (Laverty, *et al.*, 1961). Infiltration basins were constructed as a final polishing step prior to injection into the recharge well. Two half-acre spreading basins were constructed at the test site. Each was located at the top of a 13-foot thick section of well-sorted highly uniform dune sand having an effective average grain diameter of 0.5 millimeters. The spreading areas were equipped with under-drains. Under the dune sand a more impervious soil was treated with dry cement and bentonite to make it watertight, and side dikes were formed similarly to give a freeboard of 3.5 feet.

The objective of the study was to obtain 0.5 cubic feet per second (cfs) of continuous flow for the recharge well test. Each half-acre basin was divided into eight sub-basin areas. One foot of wastewater was pumped into each sub-basin daily during a half-hour period; the remainder of the daily operating cycle was used for drying and aeration to preserve the spreading basin percolation characteristics. This method was entirely successful. At no time did the plant experience slime buildup on the beds of the basins (which would have impeded infiltration), nor did the drainage capacity of the basin soils diminish during the 11 months of operation. The percolated waters obtained were clear, odor-free, and of superior quality as compared to those derived from areas where continuous spreading was practiced. The study established that itermittent application was the only feasible operating plan.

Core samples from the test spreading basins indicated that there was no sulfide content in the underlying sand, and the sand had a natural color and appearance. In addition, analysis of core samples showed no significant change in the mechanical properties of the basin soils. On completion of all wastewater percolation tests, the permeability characteristics of the spreading basins were found to be essentially unchanged. It was concluded that it is feasible to reclaim high-rate activated sludge effluent containing suspended solids and BOD as high as 87 parts per million (ppm) and 59 ppm, respectively, by means of intermittent surface spreading in small basins at an average of 0.5 cfs equivalent continuous flow.

Ridge-and-Furrow

Ridge-and-furrow irrigation consists of channeling the waste water into furrows at least several inches below the height of the ridges. Vegetation is commonly grown atop the ridges. Wastes permeate the ridges laterally and are carried by capillary action above the line of saturation. Corrugate irrigation as practiced in Idaho row-crop agriculture is a form of ridge-and-furrow irrigation.

The system referred to here differs from corrugate irrigation in that the furrows are generally 6 to 15 feet apart, 1 to 2 feet deep, and 1 to 3 feet wide. Corrugates are much smaller and much closer together as a rule. Increasing the furrow depth has some advantage in that the water level in the ditches for a particular plot can be varied over a wider range, thereby providing protection during freezing weather. The deeper the water in the ditch, the less trouble experienced with freezing or icing. The fields constructed for ridge-and-furrow application are commonly diked to prevent surface runoff from other areas from flowing to the irrigated area, and to hold any overflow of effluent.

This technique was used for cannery waste disposal as early as 1913 in Illinois (Monson, 1953). Monson (1953) reported on irrigation disposal of wastes from Green Giant Company operations. Green Giant's first ridge-and-furrow installation was at Watertown, Minnesota, in 1948. During a 30-day season an average of 2.15 inches or 58,200 gallons per day per acre (gpd/acre) of wastewater was applied. In 1949 a single area received 4.9 inches per day (in/day) or 133,000 gpd/acre. At Lanark, Illinois, ridge-and-furrow irrigation was used on 38 acres of a heavy soil; the average application rate for the entire field was maintained at 57,000 gpd/acre with no problems. Monson reports that results always improve when vegetation becomes established. Ridge-and-furrow installations at Watertown, Minnesota, and Belvedere, Illinois, continue to operate satisfactorily, with no decrease in the ability of the lands to handle wastes.

There are a number of examples of studies of ridge-and-furrow irrigation for the disposal of milk wastes. Schraufnagel (1962) has summarized the operations of several milk processing plants and their effluent disposal. In 1950 a creamery in Minnesota installed a ridge-and-furrow system for the disposal of effluent resulting from the processing of slightly more than 40,000 pounds per day (lb/day) of milk. The BOD of the effluent discharged was approximately 210 mg/l (milligrams per liter or parts per million). The plant utilized a 2.8-acre field which was drained via tile laid at a depth of approximately three feet beneath the surface. The field was also divided into 3 sections for intermittent application. At the time of Schraufnagel's report (1962) the system had operated with minimum maintenance and with no development of offensive conditions. Samples at the tile outlet have shown the percolate BOD to be about 3 mg/l, which is approximately a 98.5% reduction in BOD from the effluent discharged onto the field. One of the key advantages of this operation was its economy. Schraufnagel reports that the total cost of the system, exclusive of land, was about $800. Pumping was not required, and the only additional expense of maintenance was reditching of one-third of the furrows in 1956 at a cost of $350.

A similar operation, patterned upon the system just described in Minnesota, was installed in Wisconsin by the Mindoro Cooperative Creamery in 1954. Schraufnagel reports that this system was also about the same size, utilizing three acres. After addition of the costs of land ($2,000) and the costs for pumping required at this site, total costs amounted to $8,000. The average milk intake was about 50,000 lb/day, with a wastewater output of about 30,000 gpd with a BOD of 300 mg/l. The three-acre installation provides sufficient capacity so that as of 1962 no more than one-half of the system was ever needed in the handling of wastewater. The loadings reported are 23,300 gallons and 58 pounds BOD, both on a per acre per day basis. The field is underlain with two lines of drain tile in order to prevent the zone of saturation from reaching the surface in the low permeability glacial till. At times a flow estimated at less than 5 gpm was produced in the drain tile, with a maximum BOD of 49 mg/l. This flow from the tile drains represented less than 10% of the effluent flow applied to the field. It is estimated that the overall effectiveness of the field for BOD removal has been greater than 95%.

Schraufnagel (1962) also reported on the use of ridge-and-furrow irrigation in the disposal of domestic waste effluent in two Wisconsin cities. The city of Westby, Wisconsin, installed a 3.7-acre ridge-and-furrow field to complement their two-stage high-rate filter for treatment of domestic and industrial waste. The ridge-and-furrow system has disposed of all wastes since that time. During 1960 the average flow ranged from 89,000 to 267,000 gpd, averaging 133,000 gpd. The field is divided into four sections; discharge is alternated weekly into two sections at a time. The volumetric loading based on the total area averages 37,000 gpd/acre with a BOD load of about 8 lb/acre. The soil is a deep silt loam underlain by sand. There has been no odor or overflow problem.

In Sauk City, Wisconsin, primary treated sewage from Sauk City and Prairie du Sac is also used for irrigation from May 1 to October 1 annually in lieu of providing chlorination or secondary treatment during this period. The area has been enlarged progressively from 3½ acres to 7½ acres and then up to 11 acres by 1961. In 1961 the disposal area was able to handle all wastes without difficulty; at this time the estimated average flow was 0.55 mgd.

Schraufnagel (1962, p. 1126) has summarized the various research findings on ridge-and-furrow irrigation:

> Discounting the high rates (up to 100,000+ gpd/acre) found at some of the canning plants (they operate for relatively short periods of time), the industrial waste load that can be applied ranges from less than 2,500 gpd/acre to more than 50,000 gpd/acre. It is reported that for land disposal of sewage the daily volume that could be handled per acre ranges from 2,000 gallons to 40,000 gallons, with an average of about 8,000 gallons.

Schraufnagel (1962, p. 1126) reports that the principal factor in waste disposal is the ability of the soil to transmit water.

> If it is expected to get a stabilized water in the soil from an organic waste, aerobic conditions must be maintained in the soil. It may be possible in some loose soils that aeration can be maintained through the ridges, even with continuous waste application. In most cases, however, to prevent water-logging and anaerobic conditions, intermittent operation usually is necessary.

It is possible to achieve high volumetric loadings, even in areas with near-surface water table problems, if tiling is utilized. It is suggested that the tiles be installed at $2\frac{1}{2}$ feet below the furrows, and that the BOD be maintained at less than 1000 mg/l (Schraufnagel, 1962). In addition, the wastes should be applied intermittently. Drainage in a porous soil with a high water table will also aid in removing concentrated soil solutions. If the water table does not permit the installation of tile $2\frac{1}{2}$ feet beneath the furrows, then it is suggested that it may be possible to install the tile under the ridge sections where the wastes would have to infiltrate laterally for several feet.

Spray Irrigation

Spray irrigation, the third system design mentioned, also is highly adaptable to irrigation with cannery wastewater. Monson (1960) has reported on irrigation techniques employed by the Green Giant Company in LeSueur, Minnesota.

The Green Giant Company has irrigated with corn processing waste since 1947. The Company first experimented with ridge-and-furrow, but subsequently switched to spray-irrigation. They experienced increased costs, but they were able to use land with steeper slopes when utilizing spray-irrigation rather than ridge-and-furrow.

At LeSueur, tiling was necessary, and it improved cropping and operation efficiencies in addition to lowering the water table. The irrigated land is planted in grass and alfalfa. Cattle are pastured to some extent, but in some areas cattle traffic resulted in soil compaction. As a consequence most of the crop is utilized as hay instead of pasture.

The wastewater is pumped several miles from the plant, using a low-head trash-type pump to move the effluent from the plant to the irrigated plot. At the disposal farm a high head turbine pump moves the water from a reservoir to spray nozzles. The effluent is screened carefully here, with fiber lengths restricted to 1/8 inch. It is possible to pump directly from the plant to the nozzles and eliminate the reservoir if adequate screening is done at the plant. Solids separation is accomplished successfully with both rotary or vibrating type screens. These screens usually are installed in a pit with elevating conveyers removing the solids to a hopper.

The reservoir at the disposal farm has steeply pitched sides lined with asphalt-impregnated fiber board. This design facilitates flushing the reservoir clean each day, thereby preventing septic conditions and odor problems.

The H. J. Heinz Company also utilizes spray irrigation in their operations in New Jersey and Pennsylvania (Luley, 1963). The New Jersey operation uses 43 acres, divided into three sections. The sections are irrigated alternately every third day. The company applies a maximum of 1.5 million gallons per day (mgd); the average is 0.65 mgd. The industrial waste, channeled in a separate system from other waste, passes through a 1 inch square mesh stationary screen before entering a wet well at the plant. From the wet well the waste is pumped by suspended, submerged trash pumps into a steel main that crosses under a navigable river and extends across a swamp area approximately 2,500 feet to the spray field pumping station. At this location the waste enters a wood tank wet well from which it is pumped to the spray field. The pump utilized here is a horizontal, split-case, centrifugal pump driven by a diesel engine which is controlled automatically by a float.

The waste is metered with a propeller-type flow meter after which it goes to one of the three sections of the spray field. The sprinklers used are of the agricultural type with a $2\frac{1}{2}$ inch inlet and a 7/8 inch nozzle. To prevent plugging of the secondary nozzle and the driving nozzle, the firm has plugged the driving nozzle and replaced the secondary nozzle with a piece of standard 3/4 inch pipe bent slightly so as to activate the circular motion of the sprinkler head.

The firm utilizes a 15-foot deep wooden tank as a wet wall in place of the lagoon used originally, because they had experienced odor problems with the lagoon due to the long holding time. The tank is baffled to help keep solids from the pump suction; a float attached to an automatic diesel starting device controls the on-and-off functions of the pump. The arrangement permits the waste to be pumped to the sprinklers and applied to the spray field in a fresh condition, thus reducing odor considerably.

In the spray field the firm uses permanently placed sprinklers. They have experienced corrosion problems with the galvanized, portable variety of pipe. The permanent pipe is an arrangement of standard steel pipe with welded joints.

Seabrook Farms in Seabrook, New Jersey, has spray irrigated as much as 10 mgd from April through November (Little, et al., 1959). Their effluent is screened to remove most of the suspended solids, after which it is moved via gravity flow in a canal, 9000 feet to the fields. The canal allows additional settling of solids, some evaporation, and a small amount of seepage.

Once the effluent reaches the fields, three pumping stations force it through 8 inch and 6 inch portable irrigation pipe onto wooded slopes, where 7 lines having 6 to 13 nozzles apiece are utilized to spread the wastewater. The effluent is sprayed through large nozzles into the woodland. The sprinklers are operated for 8 hour periods, with a three to four day rest between applications. The sprinklers have a nozzle stream radius of 120 feet, with the wastewater being sprayed at a pressure of 55 to 65 pounds per square inch. This delivers 21,000 gallons per hour, or 0.8 inches per hour per acre, giving a total of 400 to 600 inches of wastewater applied per acre during an 8 month period. The soils are of a coastal plain variety, with sand predominant. The maximum depth to the water table is 38 feet.

Gerber Products Company in Michigan, has reported significant success with a year-round spray program of cannery waste on both cropped and wooded land (Dietz and Frodey, 1960). Both Gerbers and Seabrook Farms in the previous example, have found that wooded areas demonstrate far more capacity for absorbing water than do open fields. Gerbers has run saturation tests in which water was applied continuously until the ground was saturated and runoff occurred. The clay soil in their test plots accepted $2\frac{1}{2}$ inches of water; the grass on sand accepted 9 inches of water, the sand in the woods accepted 29 inches. On cropped plots they found that a good thick cover crop gave much better results than that obtained with grains such as wheat and oats. They reported that alfalfa thrived under conditions of constant irrigation.

The firm's installation for forest and crop irrigation is on 140 acres of Ottawa fine sand. The site is $3\frac{1}{2}$ miles from the plant, requiring 17,000 feet of 10 inch pipe, buried 40 inches beneath the ground, to deliver the wastewater. Two 40-horsepower pumps force the water from the plant to the irrigation site. At the plant the effluent is first passed over shaker screens to remove coarse solids and then is collected in a 30,000 gallon underground tank. The pumps start automatically when the tank is full. Two pumps of 700 gpm and 1,000 gpm capacity, withdraw effluent from a 3,000 gallon collection tank at the end of the Transite pipe from the factory.

The distribution system on the farm consists of an 8 inch galvanized steel main with openings of 4 inch aluminum irrigation laterals at 130 foot intervals. Each lateral is equipped with 5 risers at 120 foot intervals. The sprinkler heads used are Buckner No. 692 Super Irrigators that have a nozzle opening of 9/16 inch. Each sprinkler will cover a circular area 210 feet in diameter and will deliver 81 gpm at 60 pounds pressure. Under these conditions 42 hours of irrigation are required for 1 inch of precipitation equivalent.

The wastewaters contain from 200 to 3,000 ppm of suspended solids and from 800 to 3,000 ppm of BOD. The pH is neutral except for short periods of cleanup, during which it may go as high as 11.0.

Spraying in the winter time has been successful, but it requires carefully controlled spraying over a small area. The water is taken directly from the plant via the pipeline, bypassing the 3,000 gallon collection tank, and sprayed onto the irrigated plots. Some runoff is diverted into a storage lagoon when excessive precipitation occurs or when below zero temperatures occur. However, the latter two conditions usually do not persist and the company is able to spray without any runoff or ice buildup for most of the winter.

The author of the Gerber project report concludes with the remark that "perhaps the most amzing part of the whole system is that nobody thought of it sooner than 1947."

According to Westernhouse (1963) an added benefit of spray irrigation is the cooling effect on heated effluents. Pulp and paper waste effluent was cooled from 150° F at the nozzle outlet to 80° F at the ground surface by raising the nozzle angle 3° higher than normal. 840,000 gpd (gallons per day) were disposed of on 60 acres of alta fescue clover pasture by applying $\frac{1}{2}$ inch/acre-day to 9.5 acres per day on a rotation basis. The average water table was 18 inches below the ground surface. From 80 to 100 head of prelactal and postlactal dairy cattle grazed the 60 acres.

Spray-Runoff

The Pennsylvania operations of the H. J. Heinz Company is an example of the application of spray-runoff (Luley, 1963). The soil at the Pennsylvania site is clay and shale, with slopes of 2% to 12%. Layers of shale lie 1 foot to 2 feet below the surface, and are covered with a silty clay mixed with shale, so that very little water infiltrates, making the depth of the water table inconsequential. This site is completely undesirable from the standpoint of site qualities customarily prescribed in the literature.

Empirical observations at the site led scientists with the company to believe that adequate treatment and chemical oxygen demand (COD) reduction would be obtained simply by contact of the cannery effluent with vegetation and ground surface spreading operation. The decision was made to treat the industrial waste by spraying it on the surface of the ground, which sloped down to a small stream. Caution was essential to keep the wastewater moving slowly over the ground so as to prevent erosion and not to exceed the dilution capacity of the stream. The treatment has been likened to that of a trickling filter in a standard sewage treatment plant. To keep the effluent moving slowly, the areas of steepest slope were contour plowed to obtain ridges along the slope. The ridges were planted to honeysuckle and reed canary grass. There was in addition a natural growth of weeds and grass.

The company utilizes 52 acres for a program of spray-runoff waste disposal the year round. During the winter months the waste flow is much less than it is during the operations in the fall. Winter icing occurs, with slightly lower BOD reduction, but still there is no problem with low dissolved oxygen (DO), as the receiving stream concentration has never fallen below 5 mg/l.

Two spray laterals are used in the fall. Design capacity is 1.73 mgd, and the two main laterals are stationary rather than portable. The force main from the pumping station at the factory site to the spray field consists of 2,300 feet of standard weight steel pipe plus a main spray field header of 1,000 feet--also standard weight steel pipe. Eight main laterals and one minor lateral take off perpendicular to each of the two main headers diverted from the 1,000 foot main. These eight smaller laterals are galvanized portable irrigation pipe.

At least two days rest between each 24 hour application is used, and the author notes that this period is considerably less than the 4 to 8 hour application and 6 day rest recommended in the literature. The average BOD of the raw waste from the plant is 1095 mg/l, or 2196 lb/day. The average BOD of the runoff is 80 mg/l or 60 lb/day. Therefore the average BOD reduction amounts to 97.3%. In addition, the pH of the raw waste ranges from 4.3 to 10.0, while that of the runoff averages 6.4 to 7.7. The average suspended solids of the runoff is 27 mg/l, or 20 lb/day. During the year the runoff flow averages 37% of the raw waste flow. But during periods of heavy rain, runoff will exceed raw waste flow.

At the factory the waste is pumped over 20-mesh vibrating screens. With this degree of filtering of raw wastes the firm still encountered problems with nozzle plugging at the field. The firm experimented initially with spray nozzles ranging from 9/64 inch to 3/16 inch in diameter. However, they experienced problems with clogged nozzles and turned to larger nozzles with fewer sets. The larger nozzles are 3/8 inch in diameter, and deliver 32 gpm per nozzle over a 135 foot diameter circle. The total spray area covered by these nozzles is about 860,000 square feet. The area not covered by the large nozzles is covered by some of the smaller nozzle sets.

Problems with Spray Irrigation

Some of the specific problems associated with spray irrigation are plugging of sprinkler nozzles, pipe corrosion, irregularity of wastewater flow and/or utilization, and the problem of disposing of toxic wastes.

With effluent from primary and secondary treatment plants, there should be no problem with nozzle plugging. It is in spray-irrigation with industrial waste that difficulty is often encountered. Here is has been determined that keeping fibers down to 1/8 inch or less will eliminate the problem. Many canneries utilize chopping and shredding machinery to accomplish reduction of particle size. One preventive measure to forestall the eventuality of nozzle-plugging is to use a sprinkler system with larger diameter nozzles. Dye (1958) reports that no sprinkler nozzle plugging will occur with sewage given secondary treatment. He states that a spray-irrigation system can handle effluent with a suspended solids load of 800 ppm to 1200 ppm with no excessive problem of nozzle plugging. Wallace (1969) states that secondary treatment will yield effluent with a range of 10 to 40 ppm suspended solids, which is well under the limits set by Dye above. Therefore domestic effluent should present no problem with nozzle plugging in spray-irrigation.

Corrosion should not be a problem when irrigating with domestic wastewater. As early as 1939, Hutchins (1939) had determined that stable, reliably disinfected sewage effluent could be irrigated through portable aluminum pipe with as little corrosion problem as one would anticipate with ordinary irrigation water from wells or natural streams. But some researchers have noted some potential for corrosion problems if certain compounds are present. According to a study by Huberty (1957), the ammonium compounds present in fertilizers tend to damage aluminum pipe. Corrosion is aided when dissolved salts are in solution with admixtures of metals. The chloride anion in solution tends to keep the protective coating (oxide) from forming on aluminum pipe. Huberty feels therefore, that there may be some problem in using effluent with aluminum piping. But manufacturers have worked on reducing the corrosive and decomposition potentials of aluminum pipe to solve just such problems. Day and Tucker (1960) report that with today's irrigation pipe one can handle sewage that has received standard activated sludge treatment in the same manner as normal irrigation water. They say that there is no reason to believe that sewage effluent receiving standard activated sludge treatment cannot be applied by sprinkler irrigation systems in areas where other systems can be used. Therefore, corrosion problems connected with sewage effluent should be minimal. If problems should develop, plastic pipe can be utilized.

A third problem encountered with the use of sewage effluent for irrigation is that of daily fluctuation in both output rate and utilization rate in agriculture. In some instances storage reservoirs may be needed to make full use of the supply of effluent. Small storage reservoirs could be used to store effluent discharged during night hours, or during non-irrigation periods. This system would increase the amount of effluent available for irrigation and will stabilize the supply of effluent. A storage reservoir would act essentially as an oxidation pond for the effluent, therefore, a further reduction of pathogenic organisms would be obtained. Algae in storage ponds might increase the amount of organic matter applied to the soil through irrigation. Dye (1958) has analyzed the pros and cons of storage reservoirs, and reports that there would be no appreciable loss of fertilizer elements during storage in the reservoir.

A farmer who invests money in an irrigation system needs a dependable water supply. The quantity of water from domestic sources normally is continuous even when other sources are low. There is a tendency for maximum sewage production to occur during the maximum crop consumption period. Approximately 75% of the total daily discharge of domestic wastes occurs during the daylight hours. Therefore, maximum sewage effluent discharges should closely parallel maximum irrigation demand. It is possible, therefore, for many systems to operate without the aid of a storage reservoir, but many large volume systems have shown that money allocated to such a facility is well spent.

The fourth problem--that if disposing of toxic wastes-- usually can be handled by the systems discussed. Pre-irrigation with toxic wastes is one possibility. Merz (1956) relates that the Exchange Orange Products Company Farm in Ontario, California, disposes of 1000 ppm BOD waste which is toxic to plant growth, by pre-irrigation of the fields. About 60 acres of land are treated for a 3 or 4 month period, after which the land is planted to crops. Once the crop is planted, well water is used for irrigation. Other authors have reported that pre-irrigation with effluent or untreated sewage is permissible for vegetables that can be eaten raw. The soil should be rested prior to planting to insure the destruction of organisms in untreated sewage applied to the surface. After this period (which varies according to the different authors from several hours to several weeks), one can plant the crop and commence irrigation with ordinary irrigation water from streams or wells.

Irrigation with Pulp and Paper Processing Wastewater

Pulp and papermill wastewaters deserve discussion with respect to system design. These plants have encountered very serious pollution problems in disposal of wastewater from their processing operations. Irrigation with pulp and papermill waste has proved increasingly feasible as successive studies have demonstrated the savings in costs realized over that of construction and operation of conventional waste disposal facilities. A summary of 18 pulp and papermill land disposal operations as of 1958 is presented in Table 1.

Blosser and Gellman (1961) report that operating costs for systems installed for several of the Kraft mills included in the table have shown that the effluent can be distributed for approximately $.06 per ton, and the system can be installed for $85.00 per ton of design capacity, excluding varying costs for acquisition of land. The authors report that such effluents have been used for the irrigation of hay crops, turnips, corn, and peanuts. Loadings have varied from 1,500 gpd/acre to 14,000 gpd/acre. Optimum land requirements have not been established, but the authors above report that the median requirement is approximately 1 to 1.5 acres per ton of daily pulp capacity. As in the case of other effluents, the use of storage ponds aids in removing nozzle-plugging particles and in providing flexibility for irrigation requirements.

Malo (1967) reports that 40 to 50 acres per mgd of effluent are required for irrigation of pulping wastes. This amount would be equivalent to a load of 20,000 to 25,000 gallons per acre per day. Malo believes that BOD loading generally should be limited to 200 lb/day/acre in order that aerobic soil conditions might be maintained. In any event, it has been demonstrated in field tests, as reported in the literature, that all methods of land disposal are feasible for the disposal of pulp and papermill waste effluent. Various mills have explored these terrestrial disposal systems with considerable success.

There have also been studies with a fifth means of disposal of wastes, that of utilizing truck-mounted spray rigs to transport the effluent to the irrigation sites and to spread the effluent upon the surface. Malo reports that estimates of operating costs for irrigation disposal with a truck-mounted spray unit utilized by a groundwood and sulfite mill in Wisconsin were $1.39

TABLE 1
SUMMARY OF LAND DISPOSAL DATA FROM 18 PULP AND PAPER MILLS
1958 SURVEY (AFTER BLOSSER AND GELLMAN, 1961)

Mill	No.	Operation	Type	Acres	Gal per Acre/day	Cycle Inches	Cycle Acres	Ton Produc
Paperboard	1	Pilot	Crops	1.3	11,000	3H/5D	2.1	1.0
	2	Pilot	Crops	?	50,000	4H/day	1.9	0.2
Hardboard	1	Full Scale	Crops	100	6,000	18H/10D	3.4	1.2
	2	Full Scale	Crops	300	3,500	18H/10D	2	1.7
Semichemical	1	Full Scale	Filtration	5	285,000	3Wk/3Yr	10.5	0.5
	2	Full Scale	Filtration	8	72,000	12H/36H	4	0.15
Groundwood	1	Full Scale	Filtration	7	215,000	Contin.	8	0.1
Strawboard	1	Pilot	Crops	1.5	13,500	6H/3D	1.5	0.45
Sulfite	1	Full Scale	Filtration	40	8,000	Contin.	0.3	0.4
	2	Full Scale	Filtration	160	1,500	Contin.	0.06	1.5
	3	Full Scale	Filtration	7	40,000	Contin.	1.5	0.05
	4	Full Scale	Filtration	80	1,200	Contin.	0.04	1
	5	Pilot	Crops	1	300	1D/Month	0.03	10

per ton of yearly production or $5.56 per ton of production during the irrigation season. This cost compares favorably with those of other methods of secondary treatment and may represent a substantial saving in capital investment. Costs for trickling filters with stone or plastic media for partial pre-treatment, as of 1965, have been estimated to add about $2.25 per ton to the costs of finished paper from a 200 ton per day sulfite mill. Malo states that capital costs based on 1965 estimates are also high, ranging from $80,000 to $100,000/mgd capacity. Expenditure depends on the size of the mill and is exclusive of suspended solids removal systems.

In summary, it can be said that of the four system designs for surface application, only two are considered as being applicable to a very broad range of disposal and agricultural requirements. These two are ridge-and-furrow and spray-irrigation. In comparing the spray technique to the ridge-and-furrow method, the spray method is superior in many respects. In general, spray irrigation systems have a lower original cost; there is less danger of a nuisance; no preparation of land is required; it is easy to expand and easier to crop; woodland and moderate slopes pose no special problem; the equipment has some salvage value; and better control and distribution are possible. Advantages of ridge-and-furrow systems are that they usually require less land, they are cheaper to operate and maintain, there is less difficulty with winter operations, removal of gross solids is not as critical, and pumping may not be necessary.

It has been concluded that intermittent operation will prove most successful for all systems (see Foster, 1965). Tiling of fields minimizes shallow water table problems and permits higher volumetric loading. Storage lagoons lend flexibility to the systems.

A Total System Design

As a final consideration, it is appropriate to examine what can be called the "total system design". Up to this point the systems discussed have had as their purposes only the disposal, treatment, and agricultural utilization of effluent. The total system design, as exemplified by the Pomona, California, system, involves the capture of rainwater runoff and the reclamation of industrial and domestic sewage effluents for industrial, recreational, and agricultural uses, as well as for recharge of ground-water reservoirs (Sharp and Wagner, 1967).

This enterprise involves close cooperation between many governmental agencies, and is unique in that it has introduced the concept of a utility which deals in the sale and distribution of the reclaimed effluent to many, varied users. The master plan for this cooperative wastewater conservation program must deal with all phases of water resources utiliztion, including treatment, sales, and distribution, experimentation in agricultural irrigation with effluent, ground-water recharge, additional research in wastewater reclamation, irrigation of public partks and greenbelts, and recreation and beautification via creation of lakes and the irrigation of golf courses and other community facilities. The components of the operation at Pomona may be summarized by the following:

(1) Treatment - The Sanitation District will produce by secondary or tertiary treatment reclaimed Class II utility water, meeting desirable specifications and all health requirements. This supply is expected to exceed 40 million gallons per day by the turn of the century, or an amount of water sufficient to supply a southern California city of 200,000 people.

(2) Sales and Distribution - The City of Pomona, through its municipal water department, will develop a storage and distribution system for Class II water and promote the sale of this utility water to a wide number of agricultural, industrial and recreational users.

(3) Experimenter and User - The California State Polytechnic College of Pomona is the first customer under a joint agreement entered into in October of 1965, whereby the College will use the water for experimental and irrigational purposes on its 800 acre campus.

(4) Underground Recharge - A recharge facility (known as the Pomona Percolation Lakes) will be built for recharging of the 68,000 acre foot Spadra Basin. This recharge facility will be owned and operated by the Los Angeles County Flood Control District, using the reclaimed water not immediately needed for re-use as well as routing rainwater runoff from the San Jose Channel. This channel was designed and built by the U. S. Army Corps of Engineers who cooperated with the Flood Control District in the installation of the outlet works near the recharge basin.

(5) Research - Extensive research in water reclamation financed jointly on a 50-50 basis by the Sanitation District of Los Angeles County and the Federal Water Pollution Control Administration will be carried out. Extensive research is already underway at the plant, including activated carbon adsorption and foam separation.

(6) Irrigation - Large volumes of water will be used to irrigate the landscaping of three major freeways in Pomona Valley by the State Division of Highways.

(7) Recreated and Beautification - Reclaimed wastewater will be extensively used for recreational purposes, including golf courses, proposed lakes and the irrigation of parks, greenbelts and other facilities of the City of Pomona and of Los Angeles County.

(8) Master Plan Execution - A master plan for wastewater reclamation and re-use will be closely adhered to. The original financing of this plan was underwritten by the Pomona Valley Municipal Water District.

Such a program is an obvious answer to problems of water deficiencies in areas such as southern California where demand exceeds supply. The additional benefits realized from such planning and use of effluent points out the practicality of consideration and implementation of such planning even for areas such as Idaho, where the water resource supply is much more generous. With such comprehensive planning, a system design can better meet the criteria for renovation of effluent which is or will be necessary if the growing volume of industrial and domestic wastewater being contributed to Idaho's lakes and streams is to be reduced.

QUALITY OF WASTEWATER REQUIRED FOR IRRIGATION

Chemical Composition

The suitability of domestic wastewater for irrigation depends mainly on the chemical composition of water supplies and how this composition is affected by the use cycle. The common range of total dissolved solids in municipal wastewater is 100 to 450 ppm. If concentrations greater than this range are observed, one should be suspicious that the source of domestic water is high in dissolved solids because the municipal wastewater has been augmented by industrial sources during cycling or for some similar reason. The industrial contributions to the waste carried in a municipal effluent may have a negative impact upon the utility of the wastewater for agriculture or may require a more sophisticated level of treatment prior to use in irrigation. In either case the user should be aware of any additions of industrial wastes to domestic wastes in order that their effects may be anticipated. High total dissolved solids can often be tolerated during irrigation provided toxic elements and certain other elements are not present in high concentrations. Salt content frequently is expressed in terms of electrical conductivity, or micromhos per centimeter, although dissolved solids expressed as parts per million (ppm) can be used. The range of conductivity of most irrigation water is approximately 0 to 5,000 micromhos/cm. These values correspond to about 0 to 3,500 ppm dissolved solids. Water is considered to be low in total dissolved solids when its electrical conductivity is less than 250 micromhos/cm; medium in total dissolved solids when readings are 250 to 750 micromhos/cm; high in total dissolved solids when values are 750 to 2,250 micromhos/cm; and very high in total dissolved solids when readings are above 2,250 micromhos/cm.

Salinity and the ratio of sodium to calcium and magnesium are important factors in judging the suitability of water for irrigation. Municipal water softening by the ion exchange, or "zeolite" process increases the concentration of sodium in domestic effluent. This process is only one example of the multiple factors that can contribute to salinity problems with effluent.

Soils commonly are not adversely affected by saline irrigation waters if the sodium concentration is low in relation to the concentration of calcium and magnesium, but plants have difficulty in extracting water from saline soil solutions. The osmotic pressure of such solutions interferes with the movement of water from the solution into the plant root and, under these conditions, the plants may suffer from incipient drought.

With sodium, a sodium adsorption ration (SAR) has been established which, when known, allows one to anticipate with a good deal of confidence the effect of an irrigation water on the soil. The formula is: $SAR = Na^{+}/\sqrt{(Ca^{++} + Mg^{++})/2}$, where all concentrations are expressed in milliequivalents per liter. Irrigation waters with SAR values of 8 or less are safe for all uses in agricultural crop irrigation. Values of 12 to 15 are marginal and continued use of waters with values much greater than 20 would lead to decreases in permeability. Sodium soils are relatively impermeable to air and water. They are hard when dry, difficult to till, and plastic and sticky when wet. These adverse physical conditions retard or prevent germination and water removal by plants and are generally unfavorable for plant growth.

Boron also may cause agricultural problems. Boron is essential to normal plant growth, but concentrations only a little above the accepted limit are toxic to many plants. Boron is present in all natural waters, usually in the form of non-ionized boric acid (H_3BO_3), and reported in water analyses in parts per million. Permissible limits of boron in irrigation waters are 0.3 to 1.0 ppm for sensitive crops, 1.0 to 2.0 for semi-tolerant crops, and 2.0 to 4.0 for tolerant crops.

Wilcox (1958) summarizes a sample list of crops and their relative salt sensitivity. These tolerances are presented in Table 2. This list should be kept in mind if ordinary municipal effluent is contaminated by industrial effluent to the extent that the SAR or other parameters are sufficiently high to hamper crop growth. Standards for water quality relative to factors in addition to salinity values, are summarized by both the United States Public Health Service (USPHS) and the United States Department of Agriculture (USDA) for drinking water and irrigation water respectively. These standards are listed in Table 3.

Bacterial Content

The USPHS standards for drinking water are included in Table 3 in order that the reader might contrast drinking water standards with irrigation water standards. In most cases drinking water standards are more rigorous than those for irrigation water, but in a few exceptions irrigation water standards will exceed those of drinking water.

Possibly the most significant standard for irrigation water, from the standpoint of public interest, is that for bacterial content. Restrictions on coliform counts, the primary index used for bacterial contamination, are relatively rigorous for irrigation water. These rigorous standards are partly a consequence of demands made by the general public.

Coliform bacteria are found in the intestines of all warm-blooded mammals. In addition, coliform bacteria also exist in the soil system. In testing for coliform counts, public health officials are primarily concerned with fecal coliform, but it is important to realize that the presence of coliform bacteria in wastewater is only an indication of the potential presence of pathogenicity, as coliform bacteria themselves are not pathogenic.

Most of the public reservations concerning the use of treated sewage effluent for irrigation and fertilization stem from the feeling that the effluent is unclean, unaesthetic, and contaminated with disease organisms. Because of this attitude, the current general practice in the United States is to provide at least primary treatment and to utilize treated sewage for irrigation of non-food crops only. Secondary treatment and chlorination greatly improve the quality of sewage, and for aesthetic and safety reasons these conventional wastewater treatment processes are recommended for upgrading municipal wastewaters before irrigation use.

It is difficult to generalize as to the quality of wastewater realized from various means of treatment. Primary sedimentation of municipal sewage may remove 25% to 65% of the suspended solids, whereas good secondary treatment processes may remove over 95% of the suspended solids (Fair, et al., 1968). Highly overloaded secondary systems may provide treatment which is only slightly better than good primary treatment. There is also a broad range of quality of effluent available from any given plant at different times. Quantitative predictions of hazard without extensive evaluation of each individual soil and disease organism are impossible. In this regard it is useful to look at experience in the use of treated wastewaters from irrigation. A survey by Glass and Jenkins (1962) showed that there were 401 treatment plants in the United States whose effluent was applied to land; 361 of these in the 17 western states. Of the 217 million

TABLE 2
SALT SENSITIVITIES OF SELECTED PLANTS (AFTER WILCOX, 1958)

Salt-Sensitive	Medium Tolerance	High Tolerance
Strawberry	Grape	Asparagus
Peach	Cantaloupe	Garden beets
Apricot	Cucumber	Barley
Plum	Squash	Sugar Beets
Prune	Peas	
Apple	Onion	
Pear	Carrot	
Benas	Bell pepper	
Celery	Potato	
Radish	Sweet corn	
Clover	Lettuce	
	Cauliflower	
	Cabbage	
	Broccoli	
	Tomato	
	Oats	
	Wheat	
	Rye	
	Alfalfa	

TABLE 3
WATER QUALITY (AFTER WILCOX, 1958)

ANALYSIS	SUGGESTED LIMITING STANDARDS USPHS Drinking Water	USDA Irrigation Water
Bacterial:		
Coliform (no/ml)	.01*	100**
Organic:		
BOD (ppm)	0.5	
Ether solubles (ppm)	2.0	5
Physical:		
pH	6.8-8.0	6.0-9.0
Turbidity (ppm)	20	
Color (ppm)	30	
Susp. Solids (ppm)	100	
Floating solids	none	
Odor	none	not noxious
Taste	none	
Temperature (°F)	60	
Chemical:		
Total diss. sol (ppm)	1000	1500
Chlorides (ppm)	250	500
Fluorides (ppm)	0.6-1.7	
Phenols (ppm)	0.001	
Boron (ppm)		1 to 3
Nitrates, as NO_3 (ppm)	45	
Na (% of total cations)		75

*The arithmetic mean coliform density of all standard samples examined per month shall not exceed one per 100 ml.

**In the report of the National Technical Advisory Committee on Water Quality Criteria, Federal Water Pollution Control Administration, U. S. Department of the Interior (1968), the Subcommittee for Agricultural Uses recommended the following guide lines for coliform limitation in irrigation water: "The monthly arithmetic average density of the coliform group of bacteria shall not exceed 5,000 per 100 milliliters and the monthly arithmetic average density of fecal coliforms shall not exceed 1,000 per 100 milliliters. Both of these limits shall be an average of at least two consecutive samples examined per month during the irrigation season and any one sample examined in any one month shall not exceed a coliform group density of more than 20,000 per 100 milliliters." The report further states that these limitations are particularly applicable where the tops or roots of the irrigated crop are to be consumed directly by man or livestock.

people served by these plants, 2.6 million were in the western states. The total population served increased from 0.9 million in 1940 to 2.7 million in 1962. A broader survey encompassing the use of treated or untreated effluent for all surface applications for treatment and irrigation reported that as of 1964 about 1,300 soil systems were employed for surface application in the United States (Hill, et al., 1964). Some two-thirds of the systems were being used specifically for wastewater treatment and crop benefits were not an important consideration in these operations. In the remaining one-third of the systems, irrigation of crops was the primary objective. There were as many systems in cool, humid regions as there were in warm, arid regions; the systems were installed in soils ranging in texture from clay to sand. This survey showed that soil systems can be used successfully throughout the United States for wastewater treatment.

It will be shown subsequently that a soil system is a remarkably efficient system for the control and elimination of disease organisms. Wide experience in irrigation with treated effluent indicates that such irrigation is safe provided that at least primary treatment is used in conjunction with chlorination for the destruction of pathogenic microorganisms.

RENOVATION OF WASTEWATER BY SOIL SYSTEMS

Percolation of effluent through the soil mantle may in some cases be substituted for tertiary treatment processes. This has been done by the city of Santee, California (Stoyer, 1967). Santee faced effluent quality requirements in excess of those which can be achieved with primary and secondary treatment These requirements were adopted and enforced by the San Diego Regional Water Pollution Control Board because of thè large volumes of effluent being produced in the area. In order to meet the Board's stringent requirements Santee faced the alternatives of participating in a metropolitan system for the San Diego Metropolitan Area, or of developing a tertiary wastewater treatment system which would produce an effluent much higher in quality than that obtainable by the primary and secondary treatment processes. Either way, the cost would be very high. Fortunately, Santee's existing secondary treatment plant was located at the mouth of a shallow canyon containing 12 feet of alluvial fill of sand and gravel underlain in impervious clay. The city was able to take advantage of this geology by implementing a system of terrestrial renovation of their wastewater. The renovated effluent easily met the standards established by the Control Board. The system consists of pumping wastewater from the secondary treatment plant into an oxidation pond. From the pond the effluent is pumped up-canyon past a series of excavations made by mining operations which had removed portions of the aggregate for use in construction.

The wastewater from the oxidation pond is spread over the surface of the canyon floor one-half mile above the uppermost such excavation; from there it moves down-canyon above the impervious clay layer until intercepted by a trench above the first excavation. The entire canyon has now been revamped into a series of five recreation lakes, each 10 to 15 acres in surface area. These lakes provide not only picnicking and boating, but also fishing and swimming facilities for better than 125,000 people who use the area for recreation.

The importance of this example is the fact that a terrestrial means of disposal has provided an effluent of such quality that it has been judged suitable for such intimate contact use as that of swimming. In addition, the wastewater eventually is used to irrigate agricultural crops, two golf courses, a high school and a college campus, and an extensive green belt recreation area adjacent to the city. All of this has been accomplished at a cost that is equal to or less than that anticipated had the city joined in the previously mentioned Metropolitan System and pumped its highly treated effluent directly into the Pacific Ocean.

The City of Santee was able to exploit the geological advantages of the location of their wastewater treatment plant, and turn their effluent to beneficial use in a multi-purpose plan of recycling of their valuable domestic water. Other studies have demonstrated that renovation via terrestrial means is feasible by taking advantage of a wide range of soil, geological, biological, and climatic conditions.

In an operation similar to that conducted at Santee, the country of Israel has experimented with renovation of wastewater using terrestrial disposal. In the Israeli study, Amramy (1968) reports that domestic wastewater was subjected to a series of anaerobic and aerobic treatment lagoons, and then spread into three percolation basins for infiltration and percolation into the groundwater. The study sought to determine the infiltrative capactiy of the percolation basins, the rate of clogging, and the methods of operation required to prevent clogging and to restore the infiltrative capacity of the basins. The study also sought to determine changes in the chemical and bacteriological characteristics of the effluent applied to the spreading basins as it percolated through the soil of the basins down into the aquifer below.

It was observed that an adequate infiltration rate and an absence of problems of clogging of the basin soil by algae and organic matter were realized when the spreading basins were operated in a cyclic period of 2 to 3 days of wetting followed by 7 to 8 days of drying. The entire cycle encompassed a period of ten days. The basin soil was composed largely of dune sand 10 to 23 feet deep, underlain by a relatively impervious layer of clay with additional strata of sand and calcareous sandstone down to the water table approximately 65 feet from the surface. The study showed that this soil solumn remained basically unaltered from the original soil even after $3\frac{1}{2}$ years of continuous use.

The chemical changes in the effluent after passing through the dune sand depended on the length of path through which the effluent traveled. Amramy summarizes:

> After passage of the effluent through the subsoil (but not through the entire soil section) a pronounced mineralization occurred. The BOD was reduced by 90%; the COD by 58% to 80%; the dissolved volatile solids by 34% to 64%; and the organic nitrogen by about 63%. The nitrates increased considerably, whereas in the concentration of ammonia nitrogen there was reduction from 74% to 94%. The total nitrogen content was decreased by 64% to 84%. This phenomenon could be attributed to (1) denitrification; (2) adsorption of ammonia by the soil complex; and (3) the storing of nitrogen in the slimes developing at the surface of the sand. Iron and manganese concentrations were materially increased, but total dissolved salts, chlorides, sulphates, and electrical conductivity remained the same. Boron was reduced by about 40%, evidently due to adsorption by the soil complex. Detergents (ABS) were reduced by about 75%. Calcium content was very markedly increased (by about 130%), indicating ion exchange between the water and the soil. The water was clear and odourless, and without unpleasant taste. Still, it was concluded that in traveling through the dune-sand, the subsoil layer, and the further stratum of sand and calcareous sandstone, until reaching the groundwater, a total distance of some 20 meters, the water did not attâin a potable water standard, such as that of the U. S. Public Health Service, in that dissolved iron and manganese, as well as detergents were present in concentrations higher that recommended (Amramy, 1968, p. 60).

Table 4 (Amramy, 1968) lists the chemical analysis of effluent as applied to the spreading basin, followed by analysis of effluent that had percolated downward 65 feet through the soil section and had percolated laterally 260 feet through the aquifer proper.

The increase in dissolved volatile solids for the percolated effluent was mystifying to the researcher, but he noted that most Israeli waters contain varying but rather high concentrations of dissolved volatile solids.

TABLE 4

EFFLUENT AND WATER QUALITY BEFORE AND AFTER PERCOLATION THROUGH THE SOIL MANTLE (AFTER AMRAMY, 1968)

Average ppm, Except for pH	At the Spreading Basin	262 Feet Into the Aquifer
pH	8.0-8.5	7.3-8.7
Total solids	1,180.0**	1,070.0
Suspended solids	67.0***	
Total dissolved solids	1,095.0	1,040.0
Dissolved volatile solids	138.0	575.0
Dissolved oxygen	0-31.9	1.2
Biochemical oxygen demand	28.4	1.8
Total nitrogen	34.2****	*****
Ammonia	27.7	0.27
Organic	6.5	0.89
Salts:		
Chlorides	349.0	349.0
Sulphates	115.0	9.6
Phosphates	130.0	*
Iron	0.28	0.06
Manganese	0.49	0.02
Calcium	52.6	170.0
Boron	0.60	*
ABS (Detergent)	8.4	0.71

* No data presented
** 83.5% mineral
*** 90% organic
**** Nitrites and nitrates almost nil
***** Nitrates averaged 16.2 mg/l. After one year, alternating high and low concentrations.

After passing through the porous medium (aquifer) a vertical distance of 65 feet and a horizontal distance of about 260 feet the water met all criteria for drinking water except for occasional high nitrates. It is significant that in the study there was no utilization of vegetation as a part of the treatment system. The ultimate aim was to recharge as great a portion of the lagoon effluent as was possible into the water table; consequently the evapotranspiration that would have resulted from agricultural irrigation would have been undesirable. The absence of a decrease in nitrate concentration is probably a consequence of the absence of vegetation in the recharge area.

Other researchers have evaluated the renovation of sewage effluent after percolation through other soil types. Bendixen, et al. (1963) used lysimeters filled with three grades of Ottawa silica sand to investigate the effects of soil material size and depth of the unsaturaturated soil zone on treatment of septic tank effluent. After five months of operation, the sand-filled lysimeters were removing 70% to 80% of the ABS and 90% to 100% of the ammonia nitrogen. Sand size which ranged from 0.1 mm to 0.3 mm had no effect on treatment, but they did find that treatment potential increased with increased depth of the unsaturated soil zone above a water table.

Robeck, et al. (1963) investigated the degradation of ABS in unsaturated sandy soils obtained from Ohio and California. They applied sewage effluent at various rates into four-foot lysimeters filled with these sandy soils. They reported that ABS in septic tank effluent could be degraded from levels of 5 or 35 mg/l to less than 0.5 mg/l if properly applied to certain unsaturated soils. They also concluded that most of the degradation of ABS and other dissolved organics occurred in the microbiologically active aerobic upper soil layers which must be maintained for continued effective treatment.

Gotaas, et al. (1953) reported on an experiment involving the effect of surface treatment such as spading, sand cover, and application of soil stabilizer. Circular spreading basins, 19 feet in diameter, were constructed and equipped so that samples of the percolating liquid could be collected at various depths for bacteriological and chemical analyses. Spreading was studied with three liquids: fresh water; sewage treatment plant final effluent having a BOD of about 10 ppm; and settled sewage with a BOD of about 100 ppm. A number of operating variables were studied to determine the conditions which gave maximum percolation rates and minimum contamination or pollution of the ground water. In addition to surficial and soil condition these variables included (1) nature of liquid, (2) length of spreading period, and (3) length of resting period.

Some of the conclusions of this study were:

1. A bacteriologically safe water can be produced from settled sewage or final effluent if it passes through at least 4 feet of soil.

2. A water of satisfactory chemical quality can be produced providing high concentrations of undesirable industrial wastes are not included in the raw sewage.

3. A highly treated sewage effluent must be used to obtain high rates of percolation.

4. A percolation rate of 0.5 acre-foot per acre per day can be expected when spreading a final effluent on Hanford fine sandy loam.

Greenberg and McGauhey (1955) reported on the spreading of treated sewage effluent in arid and semi-arid regions in California. In these areas the effluent is allowed to percolate down to the ground water. Results of chemical analyses of percolating liquids in four spreading basins in California were tabulated by the writers. Samples were collected and analyzed to a depth of 13 feet. Concentrations of Ca, Mg, Na, and Cl ions remained the same. Potassium decreased by 50%. Ammonia and phosphorus were removed completely within the upper 4 feet. Sulphates and bicarbonates increased by 30% and nitrate by about 200%. Nitrification accounts for the increase in nitrate. It is suggested that these changes are due to biological activity in soil.

Orlob and Butler (1955) investigated the spreading of sewage on five California soils. The infiltration rate for each soil was found to follow the same general pattern: (1) an abrupt decrease in rate attributed to dispersion of soil particles; (2) an increase in rate due to solution of entrapped gases into the percolating liquid; and (3) a decrease due to accumulation of biological slimes in the soil voids. Infiltration rates in the third phase ranged from 30 feet per day for the most permeable soil to 0.6 feet per day for the fine soils.

Infiltration of settled sewage applied to soil lysimeters decreased sharply due to clogging of soil surface by particulate matter. Coliform removals were generally highest in the fine soils. Increases in calcium and magnesium concentrations and decreases in sodium and potassium concentrations in the percolates were observed.

Foster (1965) reported on the use of sprinkler irrigation to dispose of the effluent from the South Tahoe activated sludge plant. The disposal area consisted of 31 acres of an 80 acre hillside, sparsely populated with pine. The slope of the hillside was approximately 10% and contained several marshy spring areas and granite outcrops. The soil was recent alluvium derived from granite rocks and ranged in depth from 3 feet to 40 feet. Topsoil was shallow and the vegetative cover thin. The effluent was applied to about 10 acres at a time until it appeared that all of the applied effluent ran off the surface (usually 2 to 3 days). The saturated area was then rested for about 4 days before it next received an application. At the normal application rate of 40,000 gpad (gallons per acre per day) more than 90% of the applied phosphate and 56% of the applied nitrogen was removed from the effluent. Poor performance was noted whenever the disposal area became saturated or when the hillside became frozen.

Rohde (1962) has noted the effects of trace elements on the exhaustion of sewage-irrigated land. At the Berlin sewage farm some of the soil had shown signs of exhaustion, and crop yields had fallen. Samples of exhausted soil and soil on which healthy plants were growing were compared, particularly for trace elements. The results were compared with analyses of similar samples from a sewage farm in Paris where signs of exhaustion had also been observed. The soil at the Berlin farm was sandy and acidic, while that at the Paris farm was rich in lime. The results of the analyses revealed that the main cause of exhaustion at both Berlin and Paris was the presence of high concentrations of copper and zinc. This factor should be a consideration when evaluating the possible consequences of utilizing domestic effluent in areas where there is an appreciable concentration of heavy metals industries.

In all of the studies cited so far in this discussion, vegetation did not play a part in the renovation cycle of treating wastewater via a soil system. Similarly the manner by which degredation of non-conservative substances in ground water occurs has received no elaboration. Conservative substances are those substances which pass through the soil with little or no physical, chemical, or biochemical change. Non-conservative substances are those substances which can be removed or altered markedly in their passage through the soil. The degradation of non-conservative substances in ground water may be realized through physical, chemical, and/or biochemical phenomena such as oxidation or reduction, adsorption or desorption, ion exchange, precipitation or dissolution, aerobic or anaerobic decomposition, and antibiosis or symbiosis. It is important to recognize the existence of these two different classes of substances, especially when one is attempting to estimate the anticipated concentrations of pollutants in ground water.

The next consideration will be the renovation of wastewater when applied to a soil system which incorporates vegetation in the renovation cycle. The vegetation may vary from that of woodlot to pasture to cropped land. Woodlot renovation of effluent has been examined by Sopper (1967) in the Pennsylvania State University study. After three years of irrigation at rates of 1 and 2 inches of application per week during the periods of irrigation, the concentrations of ABS after percolation through the upper 24 inches of soil were reduced 93% to 99%, and concentrations of ABS in all of the percolate samples collected from various soil depths were less than the 0.5 mg/l limit established by the U. S. PublicHealth Service for drinking water.

The concentrations of nitrogen and phosphorus were also considerably reduced. The reductions in organic-nitrogen varied with depth in the soil. At the 48 inch depth the organic-nitrogen was reduced by 50% or more. The removal of nitrate-nitrogen was much more variable. When the effluent was applied at the rate of 1 inch per week in hardwood and red pine plots, the concentration of nitrate-nitrogen was reduced by 71% to 100%. But when the effluent was applied at the rate of 2 inches per week, at the 48 inch depth the concentration was reduced only by 49% in the red pine plots, and no removal occurred in a white spruce-old field plot. Even with these variable results, the concentrations of nitrogen were still below the allowable maximum of 45 mg/l for drinking water for adults. Phosphorus was reduced by 87% or more after passage through only 24 inches of soil. The degree or amount of renovation on forested plots showed a slight decrease with the third year of operation. It was concluded that this decrease was attributable to recycling of nutrients via annual leaf fall, possibly up to a point where the build-up of nutrients in the soil exceeds the limits of utilization by the biological system. Table 5 presents a summary of the percentage reduction of various components in the wastewater percolate. The average concentrations of all constituents in the percolate were well below the maximum permissible levels for drinking water.

There have been a number of studies conducted to determine the renovation of wastewater applied to plots with a cover crop of grasses or legumes. Bendixen, et al. (1968) report on the biochemical oxidation of organic constituents in a recent study of ridge-and-furrow treatment in Wisconsin. The system handles the flow from a high-rate trickling filter at an average rate of 140,000 gpd. Reed Canary grass is grown on the four basins which operate in pairs alternating on a weekly basis. Soil percolate samples were collected at 1-foot and 3-foot depths. Removals at the 3-foot depth were found to be 88% of the BOD, 70% of total nitrogen content, and 93% of the phosphate. The results show that a vegetated soil treatment

TABLE 5

AVERAGE CONCENTRATION OF CONSTITUENTS IN THE EFFLUENT AND THE PERCOLATE AND PERCENT RENOVATION AT VARIOUS SOIL DEPTHS ON PLOTS WHICH RECEIVED APPLICATION RATES OF 1 AND 2 INCHES PER WEEK (AFTER SOPPER, 1967)

Cover Type, Application, and Soil Depth	Apparent ABS Conc (mg/l)	Apparent ABS Ren (%)	Nitrate N Conc (mg/l)	Nitrate N Ren (%)	Organic N Conc (mg/l)	Organic N Ren (%)	P Conc (mg/l)	P Ren (%)	K Conc (mg/l)	K Ren (%)	Ca Conc (mg/l)	Ca Ren (%)	Mg Conc (mg/l)	Mg Ren (%)
Effluent Quality	1.61		7.6		2.7		10.4		16.3		29.5		14.8	
Hardwood - 1 inch														
Forest Floor	0.19	88	13.5	*	3.5	*	5.1	51	16.8	*	22.0	25	8.6	42
12 inches	0.22	86	6.0	21	2.6	3.7	1.9	82	9.8	40	7.0	76	4.1	72
24 inches	0.02	99	0.2	97	3.0	*	1.1	89	9.8	40	21.1	29	11.6	22
48 inches	0.01	99	0.0	100	**	**	0.4	96	6.3	61	12.2	59	11.2	24
Red pine - 1 inch														
Forest Floor	0.27	83	10.8	*	4.7	*	12.8	*	16.4	*	30.6	*	8.4	43
6 inches	0.14	91	4.3	43	2.3	15	0.9	91	10.3	37	2.0	93	1.3	91
24 inches	0.03	98	0.4	95	1.5	44	1.0	90	6.3	61	9.1	69	3.8	74
48 inches	0.03	98	2.2	71	1.3	52	0.9	91	7.2	56	8.5	71	4.5	70
Red pine - 2 inches														
Forest Floor	0.55	66	14.6	*	3.1	*	6.9	34	17.9	*	26.5	10	14.4	3
12 inches	0.09	94	12.2	*	1.1	59	1.4	86	11.2	31	10.6	64	3.0	80
24 inches	0.04	97	10.7	*	0.8	70	1.3	87	7.2	56	13.3	55	5.1	66
48 inches	0.05	97	3.9	49	1.4	48	0.8	92	5.8	64	4.8	84	1.7	89
Old field - 2 inches														
12 inches	0.21	87	8.3	*	1.8	33	2.6	75	9.9	39	12.6	57	5.1	66
24 inches	0.12	93	8.4	*	0.7	74	0.8	92	8.7	47	13.0	56	3.4	77
48 inches	0.06	96	8.0	*	0.8	70	1.1	89	8.7	47	3.8	87	3.4	77

*Average concentration in percolate was higher than average concentration in applied effluent

**Insufficient sample for complete chemical analyses system provides a high degree of nutrient removal and that a reuse system can be operated satisfactorily in northern latitudes.

Parizek, et al. (1967) report that applying effluent to crops results in additional renovation over the long run, because the cropping removes a significant amount of the nutrients applied in the wastewater. In the study, the crops removed only 20% to 60% of the applied phosphorous. This key element obviously was removed in large part by some mechanism other than the roots of crops. This additional mechanism must be related to the phosphorous fixation ability of clay minerals in soils.

Numerous researchers have reported on the phosphorus-fixing capacities of most soils. Toth and Bear (1947) have reported that soils in New Jersey demonstrated a capacity for fixing as much as 93 tons of 20% super-phosphate per acre furrow slice (2,000,000 pounds). Murphy (1939) determined that California Aiken clay loam was capable of fixing 8,000 lb of phosphorus per million pounds of soil. In the Pennsylvania State University study maximum phosphorus-fixing capacities of the soil were established to be 1,000 pounds of phosphorus per million lb of soil, or 20,000 pounds of phosphorus per acre to a depth of five feet (Parizek, et al., 1967).

The renovation efficiency of crops is determined by computing the ratio of the weight of nutrient removal in the harvested crop to the weight of the same nutrient applied in the effluent. In the Pennsylvania State University study a renovation efficiency was computed for crops irrigated at both 1 and 2 inches per week with domestic effluent. The average amounts of nutrients applied at these levels of irrigation are presented in Table 6.

TABLE 6
AVERAGE AMOUNTS OF NUTRIENTS IN SEWAGE EFFLUENT APPLIED TO AGRICULTURAL CROPS IN 1963 (AFTER PARIZEK, ET AL., 1967)

Nutrient	Amount Applied (Pounds per Acre) 1 inch	2 inches
Phosphorus	52.8	105.6
Nitrate-nitrogen	31.7	63.4
Organic-nitrogen	37.7	75.4
Potassium	94.1	188.2
Calcium	171.4	342.8
Magnesium	101.2	202.4

The renovation efficiency of the crops, computed from tables 6 and 7 is illustrated in Table 8.

The Pennsylvania State research has established the contribution that crops can make towards the renovation of effluent. To realize the maximum benefit from agricultural crops with respect to the removal of nutrients from wastewater, the study illustrates the importance of proper selection of crops. The selection of nitrogen-fixing crops such as red clover and alfalfa will contribute little to the total removal of nitrogen. But either corn or wheat will function admirably in this respect. On the other hand, red clover and alfalfa performed best in the removal of potassium from the effluent. All crops studied above functioned relatively well in removing phosphorus.

In summary, the studies cited herein have demonstrated that terrestrial treatment of effluent will yield a remarkably high quality percolate. Using a soil system which does not incorporate biota into its design, it is possible to produce percolate of sufficient quality that it can be used for drinking water, save for some problems with nitrates. But when the biota are introduced into the design, the resulting percolate can be expected to meet public health standards for drinking water.

Additional support for the efficiency of the soil as a renovation medium is inherent in the common practice of disposing of rural domestic waste via septic tanks. Commonly individual household wells for domestic supplies of water are located near septic tanks. One can conclude that the soil system functions remarkably efficiently because contamination of these domestic wells is seldom experienced.

TABLE 7
POUNDS OF NUTRIENTS REMOVED PER ACRE IN HARVESTED CROPS AT VARIOUS LEVELS OF EFFLUENT APPLICATION IN 1963 (AFTER PARIZEK, ET AL., 1967)

	Red Clover (Inches)			Alfalfa (Inches)			Corn* (Inches)			Wheat* (Inches)		
Nutrient	0	1	2	0	1	2	0	1	2	0	1	2
N	92.4	216.8	210.7	76.3	143.2	191.7	66.2	88.3	90.2	57.2	63.8	82.7
P	10.8	26.0	24.4	10.7	23.0	32.0	15.8	19.9	23.7	14.5	16.1	20.4
K	103.4	264.1	243.5	85.0	167.9	234.0	13.7	16.8	24.8	13.4	11.7	11.9
Ca	52.6	127.0	119.2	28.2	50.0	45.3	0.26	0.26	0.27	1.4	1.3	1.8
Mg	8.0	22.3	21.7	5.3	11.4	14.5	5.3	5.6	6.9	3.7	4.0	5.3

*Grain only

TABLE 8
RENOVATION EFFICIENCY (%) OF CROPS IN 1963 AT 1 AND 2 INCH PER WEEK APPLICATIONS
(AFTER PARIZEK, ET AL., 1967)

	Red Clover		Alfalfa		Wheat*		Corn*	
Nutrient	1 inch	2 inch	1 inch	2 inch	1 inch	2 inch	1 inch	2 inch
N	- -	- -	- -	- -	91.9	59.6	127.2	65.0
P	49.2	23.1	43.6	30.3	30.5	19.3	37.7	22.4
K	280.7	129.4	178.4	124.3	12.4	6.3	17.9	13.2
Ca	74.1	34.8	29.2	13.2	.76	.53	.15	.08
Mg	22.0	10.7	11.3	10.7	4.0	2.6	5.5	3.4

*Grain only

AREAS OF MAXIMUM POTENTIAL FOR WASTEWATER REUSE IN IDAHO

State-Wide Summary of Distribution of Volumes of Wastewater Produced and Sewage Treatment Practices

Approximately 86% of Idaho's total population lives on the drainage of the Snake River; more importantly, 72% of Idaho's total population lives on that portion of the basin above Brownlee Dam. At Brownlee Dam only 1/3 of the total flow of the Snake River at its mouth has entered the main stem of the stream. Therefore, above Brownlee Dam only 1/3 of the total flow from the basin is being relied upon to dilute the wastewater contributed to the Snake by 72% of the population of the State. Present data are inadequate to assess the dilution necessitated by industrial contributions and animal feedlots above Brownlee Dam. However, most sources of these two types of wastewater in Idaho are also located in the Snake Basin above this dam. Nine of the 11 sites of pollution problems designated by the FWPCA (USDI, 1968) fall within this portion of the Snake Basin.

Figure 2 presents the distribution of volumes of domestic effluent produced by communities throughout the State. The volumes shown are generated from population data, assuming a per capita average production of 100 gallons of wastewater per day. Data generated from population figures were utilized in Figure 2 because the majority of the smaller communities in Idaho, and especially those utilizing the lagoon treatment process, do not monitor the rate of effluent production by their community. Most of the larger communities in the State are able to provide figures for volume of effluent handled on an average daily basis. The map in Figure 2 shows only the production of domestic effluent, and does not incorporate industrial wastewater.

The production of industrial wastewater in the Snake River Basin is estimated by the FWPCA to have equalled a population equivalent of 6.4 million people in 1967 (USDI, 1968). The FWPCA has estimated that 90% of the discharged load of BOD emptying into the Snake River and its tributaries comes from industrial sources, with half of this total coming from potato processing. This agency also ascertains that 75% of the basin's discharged wastes occur in the Idaho Falls, Burley, Twin Falls, and Lewiston service areas (USDI, 1968). The raw population equivalent figures presented in Table 9 are useful in the evaluation of the impact of industry in augmenting domestic production of BOD and nutrients. The numbers of Table 9 represent wastes produced dn the communities prior to treatment, not the wastes added to the streams.

Table 10, following, is a more specific identification of major waste loading areas in the basin, with the identification of industrial operations incorporated.

Projected output of major manufactured products, and population projections, for the Snake River Basin are presented in Table 13.

It is evident from the data available that much needs to be done toward efforts to control the input of nutrients into the Snake River system. The FWPCA has specified that by 1972 all wastewater emptying into the Snake River be provided a degree of treatment equivalent to secondary processing. Specific FWPCA dates and recommendations for treatment of sources of effluent are presented in Tables 12, 13A and 13B.

Because of these projected growth figures for industry and population, it is possible that even secondary treatment will be inadequate in renovating the growing volumes of effluent discharging into the Snake Basin. As has been expressed earlier, tertiary level of treatment may be necessary if the Snake River Basin is to be reclaimed to a degree of water quality sufficient to meet the criteria of domestic, agricultural, industrial, and recreational users. Renovation by vegetation and the soil column may

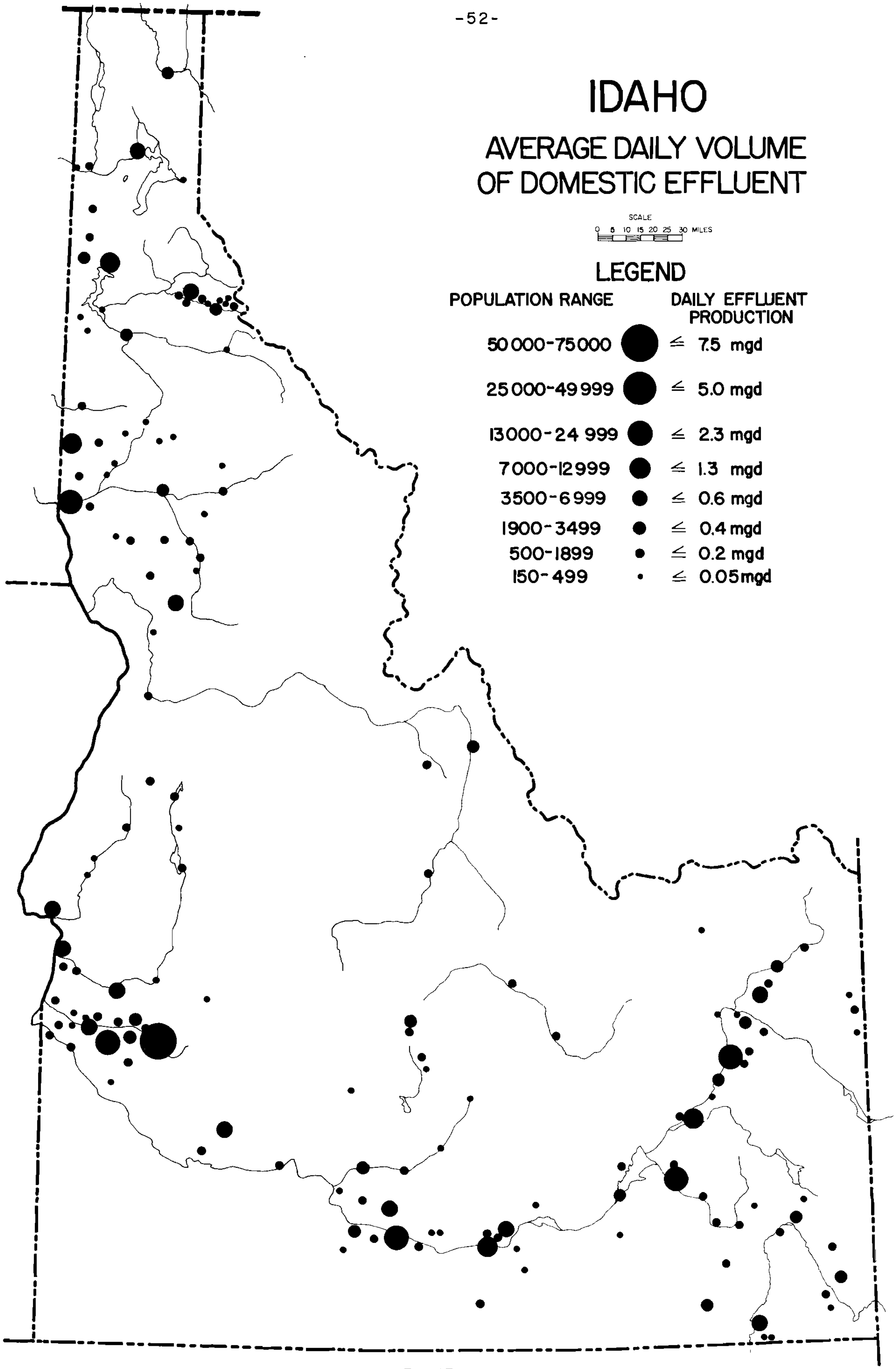

IDAHO
AVERAGE DAILY VOLUME
OF DOMESTIC EFFLUENT
SCALE
0 5 10 15 20 25 30 MILES
LEGEND
POPULATION RANGE
DAILY EFFLUENT PRODUCTION
50000-75000 ≤ 7.5 mgd
25000-49999 ≤ 5.0 mgd
13000-24999 ≤ 2.3 mgd
7000-12999 ≤ 1.3 mgd
3500-6999 ≤ 0.6 mgd
1900-3499 ≤ 0.4 mgd
500-1899 ≤ 0.2 mgd
150-499 ≤ 0.05 mgd

FIGURE 2

TABLE 9
1967 WASTE PRODUCTION (AFTER USDI, 1968)

	Population Equivalents (PE)
Pullman-Moscow	28,000
Lewiston	545,000
Ontraio, Oregon	742,000
Emmett	31,000
Boise	831,000
Twin Falls	795,000
Burley	1,357,000
American Falls	291,000
Pocatello	49,500
Blackfoot	192,000
Idaho Falls	1,300,000
Rigby	53,800
Rexburg	88,600

TABLE 10
MAJOR WASTE LOADING AREAS FOR THE SNAKE RIVER, 1967 (AFTER USDI, 1968)

Service Area	Raw Waste	Discharged Waste	Treatment Efficiency	Percent of Basin Waste Discharge	Percent of Area Waste Discharge
Rexburg	88,600	37,800	57	1.4	
Rogers Bros. Food Prod.		(27,000)			72
St. Anthony Starch Co.		(9,000)			24
Rigby	53,800	37,500	30	1.4	99
Idaho Fresh Pak - Lewisville		(37,000)			
Idaho Falls	1,300,000	442,400	66	16.8	
Rogers Bros. Co.		(110,000)			25
Utah Idaho Sugar Co.		(120,000)			27
R. T. French - Shelley		(85,000)			19
Blackfoot	192,000	82,000	57	3.1	
American Potato Corp.		(72,000			88
Pocatello	49,500	27,700	44	1.1	
Pocatello		(27,000)			98
FMC	Inorganic				
J. R. Simplot	Inorganic				
American Falls	291,000	68,400			
Idaho Potato Growers		(24,000)			35
Lamb & Weston		(25,000)			37
Burley	1,359,000	647,000	52	24.6	
Ore-Ida Foods Corp.		(106,000)			16
J. R. Simplot Co.		(493,000)			76
Twin Falls	795,000	342,000	57	13.0	
Amalgamated Sugar Co.		(200,000)			58
Twin Falls		(70,000)			20
Boise	831,000	167,500	80	6.4	
Boise B		(10,000)			6
Nampa		(30,000)			18
J. R. Simplot - Caldwell		(100,000)			60
Emmett	31,000	1,000	97	0.04	

TABLE 10 (Continued)

Service Area	Raw Waste	Discharged Waste	Treatment Efficiency	Percent of Basin Waste Discharge	Percent of Area Waste Discharge
Ontario	742,000	197,000	74	7.5	
Amalgamated Sugar Co. - Nyssa		(41,000)			21
Ore-Ida Foods - Ontario		(145,000)			74
Baker	12,400	500	96	0.02	
La Grande	13,000	1,300	90	0.05	
Lewiston	545,000	522,000	4.2	20	
Potlatch Forest Industries		(432,000)			83
Pullman	28,000	3,600	87	0.14	
Service Area Total	6,301,000	2,579.000	59	98.1	
BASIN TOTAL	6,430,000	2,633,000	59	--	--

TABLE 11 A

PROJECTED OUTPUT--MAJOR MANUFACTURED PRODUCTS (AFTER USDI, 1968)

Product or Process	Projection Expressed in	1960	1965	1980	2020
Phosphate products	tons/year output	165,000	270,000	390,000	1,020,000
Fertilizer	tons/year output	360,000	700,000	870,000	2,300,000
Wood Pulp	tons/day capacity	650	650	950	2,100
Particle board	tons/day capacity	500	550	750	1,700
Sugar refining	tons/day capacity	18,700	24,600	27,400	55,500
Potato processing	tons/day capacity	5,775	7,225	9,200	20,800
Milk products	million lb/yr output	435	485	670	1,350
Meat	million lb/yr output	150	180	320	520
Misc. canning & freezing	Production index	100	130	235	780

TABLE 11 B

PROJECTED POPULATION--1965-2020 (AFTER USDI, 1968)

	Thousands of Inhabitants		
	1965	1980	2020
SNAKE RIVER BASIN	729.2	934.7	1909.6
Upper Basin	298.7	395.5	855.0
Central Basin	268.7	345.0	705.9
Lower Basin	161.8	194.2	348.7
MAJOR SERVICE AREAS	401.8	586.9	1482.4
Idaho Falls	52.3	83.3	228.0
Pocatello	47.7	74.7	211.0
Burley	24.5	35.6	86.0
Twin Falls	40.5	61.0	150.0
Boise	146.3	203.0	484.5
Ontario (includes Oregon and Idaho combined)	24.6	35.7	88.5
Lewiston	38.1	55.2	148.0
Pullman (includes Moscow)	27.8	38.4	86.4
As % Basin Total	55.1%	62.8%	77.6%
MINOR SERVICE AREAS	81.0	102.5	179.3
Rexburg	15.0	17.4	30.2
Rigby	9.1	11.7	20.3
Blackfoot	15.9	20.2	37.0
American Falls	4.1	4.8	8.0
Mountain Home	12.0	16.4	28.5
Emmett	4.0	5.2	8.9
Baker, Oregon	10.0	13.4	23.2
La Grande, Oregon	10.9	13.4	23.2
As % Basin Total	11.1%	11.0%	9.4%
RURAL	162.0	146.7	108.8
As % Basin Total	22.2%	15.7%	5.7%

TABLE 12
TIME SCHEDULE FOR CURRENT WASTE TREATMENT NEEDS TO MEET ESTABLISHED WATER QUALITY STANDARDS IN SNAKE RIVER BASIN IDAHO (AFTER USDI, 1968)

City or Industry	Secondary (Date)
Rogers Brothers - Rexburg	1970
Idaho Fresh Pak - Lewisville	1970
City of Idaho Falls	1971
U & I Sugar Company - Idaho Falls	1969
Roger Brothers - Idaho Falls	1971
Idaho Potato Growers - Idaho Falls	1971
Idaho Potato Foods - Idaho Falls	1972
RT French - Shelley	1972
Idaho Supreme - Firth	1972
American Potato Company - Blackfoot	1972
City of Blackfoot	1972
Idaho Potato Starch Co. - Blackfoot	1972
St. Anthony Starch Co. - St. Anthony	1972
City of Pocatello	1973
Idaho Potato Growers - Aberdeen	1969
Kraft Foods Company - Aberdeen	1969
City of Rupert	1968**
Kraft Foods Company - Rupert	1968**
Magic Valley Foods - Rupert	1968**
City of Paul	1969
City of Heyburn	1970
J. R. Simplot Company - Heyburn	1970
Ore-Ida Company - Burley	1970
A & P Company - Burley	1970
Amalgamated Sugar Co. - Twin Falls	1969*
Independent Meat Co. - Twin Falls	1968**
Magic Valley Company - Twin Falls	1973
City of Twin Falls	1973
Bertie's Poultry - Twin Falls	1973
City of Aberdeen	1969
Swift & Company - Twin Falls	1973
Young's Dairy - Twin Falls	1973
Idaho Frozen Foods - Twin Falls	1973
City of Jerome	1969
Ida-Gem Dairy - Jerome	1969
King of Spuds - Jerome	1969
City of Glenns Ferry	1968**
City of Wilder	1969
Northwest Boise Sewer District	1969
Swift and Company - Boise	1968**
Star Sewer District	1969
J. R. Simplot - Caldwell	1970
City of Notus	1969

TABLE 12 (Continued)

City or Industry	Secondary (Date)
City of McCall	1968**
City of Connelly	1969
City of Cascade	1968**
Gem Canning - Emmett	1968**
City of Payette	1973
City of Cambridge	1968**
Wells and Davies - Payette	1973
City of Weiser	1973
City of Salmon	1968**
City of Craigmont	1970
City of Orofino	1972
City of Lewiston	1970
Lewiston Orchards - Lewiston	1970
Seabrook Farms, Inc. - Lewiston	1970
Smith Foods, Inc. - Lewiston	1970
Potlatch Forests, Inc. - Lewiston	1968*
Wallowa	1969

*Specified treatment is primary rather than secondary

**Although 1968 deadlines have expired, these cities and industries are included in order that those interested may compare the present situation to that specified in the table. The researchers do not know whether each party above has complied with the directives of the FWPCA within the time period allowed.

TABLE 13 A

TREATMENT REQUIREMENTS FOR SOURCES OF POLLUTION IN IDAHO (AFTER USDI, 1968)

	Existing Treatment	WASTE Raw PE*	Discharge PE*	Receiving Stream	Recommended Action
MUNICIPAL (Community)					
Hailey	No system	1200	1200	Big Wood River	Collection & secondary
Ketchum	No system	6000	6000	Big Wood River	Collection & secondary
INDUSTRIAL (Company)					
Armour Meat Co. (Buhl)	Septic tank	4000	3000	Deep Creek	Secondary
B & L Meat Packers (Buhl)	Septic tank	1000	700	Deep Creek	Secondary
Bryants Packing Co. (Burley)	Septic tank	500	300	Snake River	Secondary
Custom Packing Co. (Rupert)	Septic tank	250	200	Main Drain	Secondary
Farrer Meat Co. (Rexburg)	Septic tank	500	400	Snake River	Secondary
Gabriel Packing Co. (Gooding)	Lagoon	7500	5000	Little Wood River	Improved Efficiency
Gibson Bros. Meat Co. (Burley)	Septic tank	500	300		Secondary
Grimes Custom Slaughter House (Nampa)	Septic tank	200	100	Indian Creek	Secondary
H.H. Keim Packing Co. (Nampa)	Septic tank	3200	2400	Indian Creek	Secondary
Hillcrest Packing Co. (Nampa)	X	300	150	Indian Creek	Secondary
Hopkins Packing Co. (Blackfoot)	Lagoon	750	500		Improved efficiency
Idaho Falls Animal Prod. (Idaho Falls)	Septic tank	1000	500	Snake River	To city sewer
Idaho Falls Meat Co. (Idaho Falls)	Septic tank	1250	1000	Snake River	To city sewer
Idaho Hide & Tallow Co. (Twin Falls)	Septic tank	2000	1000	Rock Creek	Secondary
Johnson Bros. Meat Packing (Nampa)	X	400	300	Indian Creek	Secondary
Kraft Cheese Co. (Ririe)	No system	1000	1000	Snake River	Secondary
Kraft Food Co. (Carey)	No system	1000	1000	Little Wood River	Secondary
Liberty Packing Co. (Boise)	No system	800	800	Eagle Drain	Secondary
Mickelsens Packing Co. (Blackfoot)	Lagoon	750	500		Improved efficiency
Nampa Animal Products (Nampa)	Septic tank	500	400	Indian Creek	Secondary
Nampa Packing Co. (Nampa)	Septic tank	300	200	Indian Creek	Secondary
Nankafell Slaughter House (Nampa)	Septic tank	250	150	Indian Creek	Secondary
National Reactor Test Station	Special processes (radio- Radioactive active)	250	150	Indian Creek	Secondary Eliminate deep well injection

TABLE 13A (Continued)

	Existing Treatment	Waste		Receiving Stream	Recommended Action
		Raw PE*	Discharge PE*		
INDUSTRIAL (Company) Continued					
Owyhee Meat Packers (Homedale)	Septic tank	500	400	Snake River	Secondary
Peoples Meat Packing Co. (Rupert)	Septic tank	500	300	Main Drain	Secondary
Seddon Meat Processing (Filer)	Septic tank	500	300	Drainage Ditch	Secondary
Stockmans Meat Packing Co. (Gooding)	Lagoon	10000	6000	Little Wood River	Improved Efficiency
Tiffany Slaughter House (Nampa)	Septic tank	200	100	Indian Creek	Secondary
Vans Packing Plant (Boise)	Septic tank	1500	900	Boise River	Secondary
Wattenbarger Meat Prod. (Shelley)	None	500	500	Snake River	Secondary

*PE means population equivalent

TABLE 13B
TREATMENT REQUIREMENTS FOR SOURCES OF POLLUTION IN IDAHO
(FEDERAL INSTALLATIONS)
(AFTER USDI, 1968)

Installation	Agency	Need
FEDERAL INSTALLATIONS		
Redfish Lake Recreation Area	USFS	Collection system & treatment
Island Park Recreation Area	USFS	Collection system & Treatment
Alturas Lake Recreation Area	USFS	Collection system & treatment
Elk City Ranger Station	USFS	Connect to city
Powell Ranger Station	USFS	Lagoon
Bungalow Ranger Station	USFS	Treatment plant
Musselshell Work Camp	USFS	Treatment plant
Slate Creek Ranger Station	USFS	Chlorination
Mountain Home Air Force Base	USAF	Industrial treatment plant
Anderson Ranch Dam	USBR	Drainfield
Black Canyon Dam	USBR	Drainfield
Black Canyon Dam Power Plant	USBR	Septic tank & drainfield
Cascade Dam	USBR	Drainfield
Deadwood Dam	USBR	Drainfield
Boise River Diversion Dam	USBR	Drainfield
Lucky Peak Dam	USACE	Drainfield
Minidoka Dam & Headworks	USBR	Septic tank & drainfield
Ice Harbor Dam	USACE	Septic tank & drainfield

be the only economically feasible means of accomplishing tertiary treatment.

Figure 2 pinpoints those areas with maximum effluent production in northern Idaho. The Wallace, Kellogg region recently has received attention because of the lack of treatment facilities. However, these communities are fortunate in that they are located on a turbulent stream with good dilution potential. Additional studies are needed in northern Idaho, particularly in the vicinity of lakes which are hydraulically connected to rivers receiving wastewater.

Figure 3 presents the type of treatment facility employed by each community in Idaho. Out of the 161 communities surveyed by the Idaho Department of Health at the end of 1968, only 75 indicated an adequate level of treatment of their domestic wastewater (Idaho Department of Health, 1969). Of these 75, a significant number (approximately 55) used a lagoon design for their treatment system. If rate of effluent production is not great, both Federal and State agencies have accepted lagoons as adequate treatment for domestic waste in lieu of secondary treatment. A large share of industrial operations in Idaho which treat their own wastewater utilize lagoons. For most of Idaho's industrial operations (such as potato processing, sugar beet processing, other food processing operations, phosphate and allied chemical manufacturing) the plan is to eventually combine their wastewater with the domestic wastewater from adjacent city systems into a common treatment system.

The data on distribution of volumes of domestic wastewater produced, the figures on dilution potential of the Snake, and the concentration of industrial and domestic sources of effluent, suggest that maximum benefits can be accrued from wastewater reuse within that portion of the Snake River Basin above Brownlee Dam. Consequently that area will receive primary consideration here. Figure 4 is a summary of those areas in the Snake River Basin where the problems of water pollution are most serious, suggesting those cities which would benefit most from a program of wastewater reuse.

Survey of Communities on the Middle and Upper Snake and the Potential For Reuse of Their Effluent

Before any of the individual sites were evaluated, it was first decided to investigate general agricultural practices in South Idaho in order to determine to what extent the nutrients in wastewater can supplement normal fertilization with commercial fertilizers, and in order to determine what restrictions are necessary in the use of effluent for irrigation of agricultural crops. As a first step, a guide to the application of fertilizer to irrigated field crops was obtained from the Agricultural Extension Service. Tables 14A and 14B contain the Extension Service recommendations for crop fertilization in the two portions of Idaho noted.

Even though these are generalized recommendations, for the crops cited in the Extension Service Bulletin it is evident that the nutrients contained in many wastewaters will easily satisfy the recommended fertilization requirements. Under idealized conditions of application no supplemental commercial fertilizers would be required. This statement is based on the observation by several researchers that an acre foot of domestic effluent contains about 65 pounds of nitrogen, 50 pounds of P_2O_5 and 30 pounds of K_2O. The application of only 3 acre feet of wastewater of this quality would satisfy recommended fertilizer application.

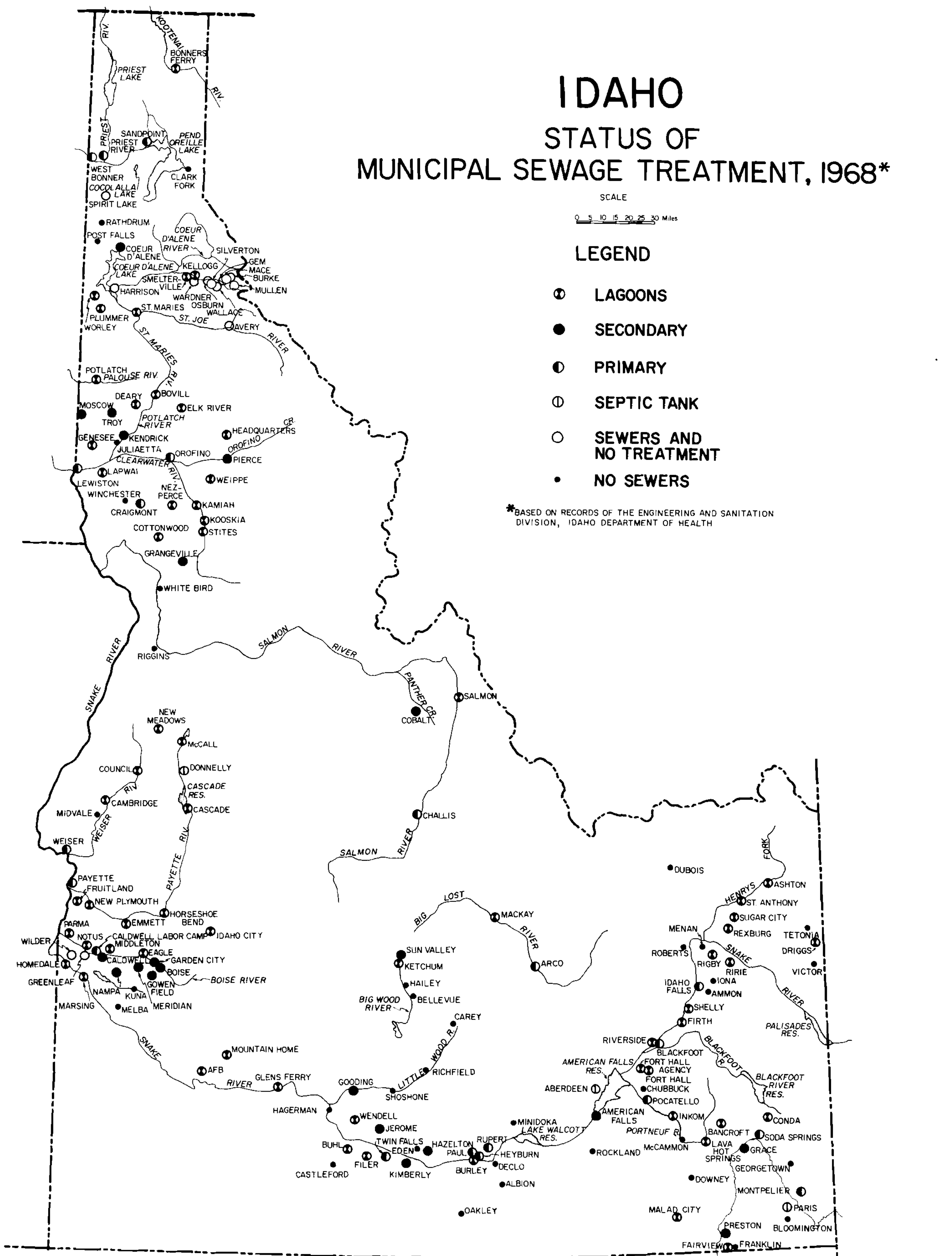
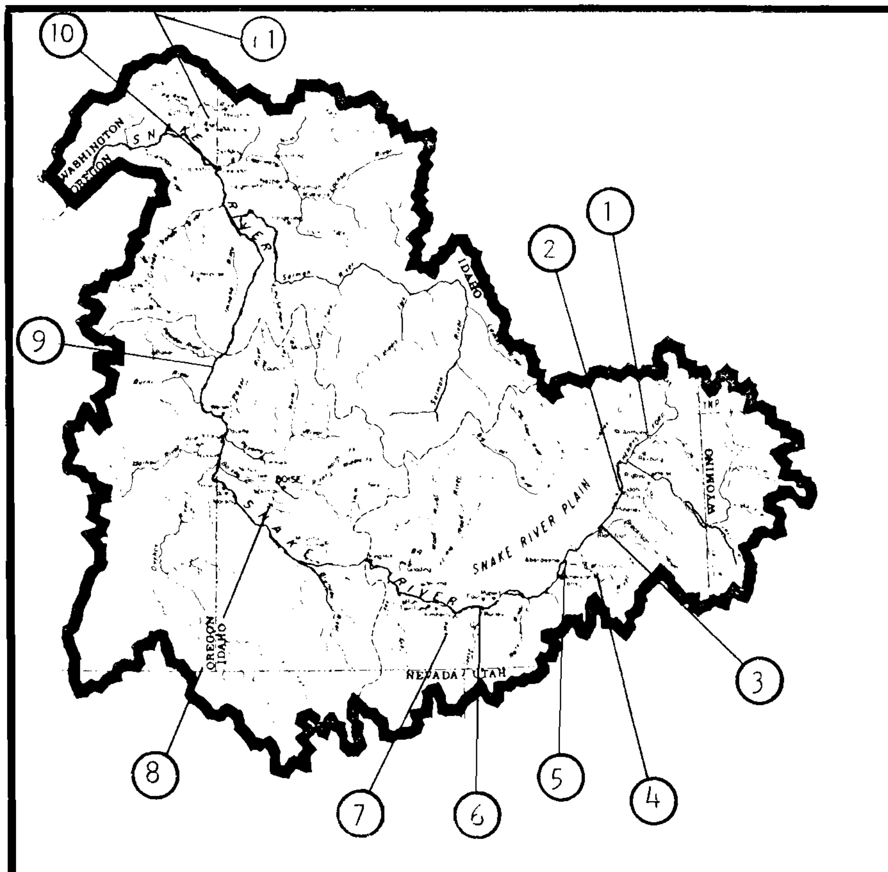

IDAHO
STATUS OF
MUNICIPAL SEWAGE TREATMENT, 1968*
SCALE
0 5 10 15 20 25 30 Miles
LEGEND
LAGOONS
SECONDARY
PRIMARY
SEPTIC TANK
SEWERS AND NO TREATMENT
NO SEWERS
*BASED ON RECORDS OF THE ENGINEERING AND SANITATION DIVISION, IDAHO DEPARTMENT OF HEALTH
BONNERS FERRY
KOOTENAI
RIV.
PRIEST LAKE
PRIEST
SANDPOINT
PRIEST RIVER
PEND OREILLE LAKE
WEST BONNER
CLARK FORK
COCOLALLA LAKE
SPIRIT LAKE
RATHDRUM
POST FALLS
COEUR D'ALENE RIVER
COEUR D'ALENE
COEUR D'ALENE LAKE
KELLOGG
SILVERTON
GEM
MACE
BURKE
MULLEN
SMELTERVILLE
HARRISON
WARDNER
OSBURN
WALLACE
ST. MARIES
PLUMMER
WORLEY
ST. JOE
AVERY
RIVER
ST. MARIES RIV.
POTLATCH
PALOUSE RIV.
DEARY
BOVILL
MOSCOW
TROY
ELK RIVER
POTLATCH RIVER
GENESEE
KENDRICK
HEADQUARTERS
OROFINO CR.
JULIAETTA
OROFINO
PIERCE
CLEARWATER RIV.
LAPWAI
WEIPPE
LEWISTON
WINCHESTER
NEZ-PERCE
CRAIGMONT
KAMIAH
KOOSKIA
COTTONWOOD
STITES
GRANGEVILLE
WHITE BIRD
SNAKE RIVER
RIGGINS
SALMON RIVER
PANTHER CR.
SALMON
COBALT
NEW MEADOWS
McCALL
DONNELLY
COUNCIL
CASCADE RES.
CAMBRIDGE
CASCADE
MIDVALE
WEISER RIV.
WEISER
CHALLIS
PAYETTE RIV.
SALMON RIVER
PAYETTE
FRUITLAND
NEW PLYMOUTH
HORSESHOE BEND
PARMA
EMMETT
NOTUS
CALDWELL LABOR CAMP
IDAHO CITY
WILDER
MIDDLETON
HOMEDALE
EAGLE
CALDWELL
GARDEN CITY
GREENLEAF
BOISE
GOWEN FIELD
BOISE RIVER
NAMPA
KUNA
MERIDIAN
MARSING
MELBA
SUN VALLEY
KETCHUM
HAILEY
BELLEVUE
BIG WOOD RIVER
CAREY
BIG LOST RIVER
MACKAY
ARCO
LITTLE WOOD R.
MOUNTAIN HOME
AFB
RICHFIELD
GLENS FERRY
GOODING
SHOSHONE
HAGERMAN
WENDELL
JEROME
BUHL
TWIN FALLS
EDEN
HAZELTON
PAUL
RUPERT
HEYBURN
DECLO
FILER
KIMBERLY
BURLEY
CASTLEFORD
ALBION
OAKLEY
MINIDOKA
LAKE WALCOTT RES.
DUBOIS
HENRYS FORK
ASHTON
ST. ANTHONY
SUGAR CITY
MENAN
REXBURG
TETONIA
DRIGGS
ROBERTS
RIGBY
RIRIE
VICTOR
SNAKE RIVER
IDAHO FALLS
IONA
AMMON
SHELLY
FIRTH
PALISADES RES.
RIVERSIDE
BLACKFOOT
BLACKFOOT R.
AMERICAN FALLS RES.
FORT HALL AGENCY
FORT HALL
BLACKFOOT RIVER RES.
ABERDEEN
CHUBBUCK
POCATELLO
AMERICAN FALLS
INKOM
CONDA
PORTNEUF R.
BANCROFT
SODA SPRINGS
ROCKLAND
McCAMMON
LAVA HOT SPRINGS
GRACE
GEORGETOWN
DOWNEY
MONTPELIER
PARIS
MALAD CITY
PRESTON
BLOOMINGTON
FAIRVIEW
FRANKLIN

FIGURE 3



Problem Area	Problem Conditions	Causes
1. South Fork Teton R. and Henry's Fork below the Teton R.	Low dissolved oxygen (DO) High bacterial counts	Flow depletion due to irrigation withdrawals. Flow interruption due to diversion structure maintenance Roger's Bros. potato wastes (Rexburg). Rexburg municipal sewage.
2. Snake River below Idaho Falls	Low DO. High bacterial counts	Streambed dried by irrigators withdrawing water prior to discharge from upstream reservoirs. Flow interruption due to diversion structure maintenance Municipal and industrial wastes.
3. Snake River above American Falls Res.	High bacterial counts	Blackfoot municipal wastes.
4. Portneuf River below Pocatello	Low pH, high PO_4, sludge beds & high bacterial counts.	Phosphate processing by J. R. Simplot & FMO Co Septic tank drainage. Untreated dairy waste. Flooded pastures.
5. American Falls Reservoir	Aquatic growths. DO. depression. High pesticide levels High sediment concentrations.	High nutrient levels. Algal decomposition. Agricultural runoff. Residual waste loads
6. Milner Reservoir	Low winter DO. High bacterial counts Aquatic growths.	Municipal wastes—Burley. Heyburn Food processing waste—J. R. Simplot, Ore-Ida Foods. A & P Streamflow depletion due to irrigation storage
7. Rock Creek	Turbidity. High bacterial counts. Odor problems.	Amalgamated Sugar Co., feedlots, municipal wastes
8. Boise River	Low DO. Sludge beds. High pesticide levels High bacterial counts.	Municipal & industrial waste Flow interruption for Lucky Peak Dam maintenance
9. Brownlee-Oxbow Reservoir	Low DO. Aquatic growths Odors.	Algal decomposition. Residual wasteloads
10. Lewiston-Clarkston Area	High bacterial counts	Inadequate municipal & industrial waste treatment
11. South Fork Palouse River	High sediment concentrations High bacterial counts Low DO	Low flows coupled with municipal waste discharge from Moscow and Pullman

Figure 4. Pollution Problem Areas in the Snake River Basin (after USDI, 1968).

With respect to restrictions to be placed upon the use of effluent for irrigation of agricultural crops, it is believed that irrigation with domestic wastewater should be restricted to irrigation of crops not to be eaten directly by man. Therefore, those crops in the list summarized from Extension Service Bulletin 325 that should not be irrigated with wastewater are peas, beans and potatoes. The remainder of the list should be safe recipients of effluent. It is important, however, to discriminate between domestic and industrial wastewater. Effluent from the food processing industry cannot be expected to offer the same bacteriological dangers that are present in domestic effluent; therefore, similar restrictions need not be placed upon the use of this type of effluent. Effluent from the mining and metals industries will need further analysis before it can be determined what restrictions need be placed on the agricultural use of effluent from such operations. The concentrations of individual trace elements are of particular importance here.

With these considerations in mind, a field survey of most of the communities in southern Idaho with populations in excess of 3000 was conducted. The purpose of the survey was to accomplish site evaluation of the selected treatment plants for feasibility of incorporating the wastewater from each system into a program of irrigation with domestic and industrial wastewater in Idaho.

The information gathered from the field survey includes data for each city on:

(1) distance from the sewage treatment plant to irrigated cropland,

(2) the type of crop grown in the irrigated acreage adjacent to each plant,

(3) the type of irrigation system used,

(4) the approximate vertical lift necessary to apply the effluent to the same cropland,

(5) the total amount of effluent handled per day in periods of both high and low flow,

(6) the type of treatment (including chlorination) administered to the wastewater,

(7) a list and location of food processing plants and other facilities producing wastewaters which do not go into the city system,

(8) whether the city owns appreciable acreage adjacent to the plant location,

(9) whether devices exist which are convenient for the monitoring of ground water (wells, springs, seeps, streams, etc.) adjacent to potential irrigation sites,

(10) the approximate amount of water per acre applied during the irrigation season to agricultural land adjacent to the treatment plant,

(11) soil thickness and other geologic and hydrologic data of use for purposes of evaluation of the site, and

(12) information on irrigation districts, their canal systems adjacent to the treatment plants, and the costs of water delivered by the irrigation districts.

The information for the cities is presented subsequently in the order in which they were visited (from West to East in a crescent following the Snake River across the State). The individuals from whom the data were obtained are listed in parentheses after the city name.

Weiser. (City data - Charles Stiles, City Engineer, and Alton Prouty, Plant Supervisor. Agricultural data - F. E. Hackler, Washington County Agricultural Extension Service Agent).

TABLE 14A

GUIDE FOR FERTILIZING IRRIGATED FIELD CROPS IN WESTERN AND CENTRAL IDAHO
(FROM EXTENSION BULLETIN 325, SUPPLEMENT, JAN. 1969)

CROP	POUNDS OF PLANT NUTRIENTS TO APPLY PER ACRE			
	$N-P_2O_5-K_2O$ Following a row crop	$N-P_2O_5-K_2O$ Following an alfalfa crop removed	$N-P_2O_5-K_2O$ Following grain--stubble removed	$N-P_2O_5-K_2O$ New land just cleared from sagebrush
Clovers	0-120-0		0-120-0	0-120-0
Peas	0-80-0	0-80-0	60-80-0	60-80-0
Beans	0-80-0	0-80-0	60-80-0	60-80-0
Potatoes	160-120-0	120-120-0	180-120-0	160-120-0
Sugar Beets	160-120-0	120-120-0	180-120-0	160-120-0
Field Corn	140-120-0	100-120-0	140-120-0	140-120-0
Gaines Wheat	120-0-0	100-0-0	140-0-0	140-0-0
Barley	100-0-0	80-0-0	100-0-0	100-0-0
Alfalfa Hay	0-120-0 - Apply annually			
Established Pastures	120-80-0 - Splitting N application between spring and mid-season			

TABLE 14B

GUIDE FOR FERTILIZING IRRIGATED FIELD CROPS IN UPPER SNAKE AND EASTERN IDAHO (FROM EXTENSION BULLETIN 325, SUPPLEMENT, JAN. 1969)

CROP	POUNDS OF PLANT NUTRIENTS TO APPLY PER ACRE			
	N-P_2O_5-K_2O Following a row crop	N-P_2O_5-K_2O Following an alfalfa crop removed	N-P_2O_5-K_2O Following grain--stubble removed	N-P_2O_5-K_2O New land just cleared from sagebrush
Peas	0-60-0	0-60-0	60-60-0	60-60-0
Beans	0-60-0	0-60-0	60-60-0	60-60-0
Potatoes	120-80-0	80-80-0	140-80-0	120-80-0
Sugar Beets	120-80-0	80-80-0	140-80-0	120-80-0
Field Corn	100-80-0	68-80-0	100-80-0	100-80-0
Gaines Wheat	120-0-0	80-0-0	120-0-0	100-0-0
Barley	80-0-0	40-0-0	80-0-0	80-0-0
Established Pasture	100-60-0 - Split nitrogen application between spring and mid-season			
Alfalfa Hay	0-80-0 - Apply annually			

1) Location of treatment: The plant is situated approximately $\frac{1}{4}$ mile west of town and approximately $\frac{1}{4}$ mile north of the Snake River. The plant is approximately 40 feet above the river, and is on a terrace of alluvium which varies in width from 1 to 3 miles. The terrace parallels the river along the north bank of the stream. Above and north of this terrace a series of hills rise from the elevation of the treatment plant (2129 feet above sea level) to approximately 4100 feet. (Kelly Mountain is 4099 feet in elevation.)

2) Distance to irrigated cropland: There is some farming and pasture adjacent to the plant, but it consists of small plots with private residences which are scattered but relatively closely spaced. It is approximately 1 mile to more open farmed area on the terrace. It is approximately $1\frac{1}{2}$ miles to the hillside pasture area situated on the south-facing slopes north of the plant.

3) Type of crop grown and fertilizer amounts applied: Sugar beets, potatoes, onions, sweet corn, and some seed crops are grown in the row-crop agriculture practiced on the terrace. Pasture predominates heavily on the slopes north of the terrace. Approximately 100 lb of P_2O_5 and 100 to 225 lb of nitrogen per acre are applied to these crops.

4) Type of irrigation system used: On the terrace flood and corrugate predominate. On the hillside pastureland to the north sprinkler irrigation is used where irrigation is practiced.

5) Vertical lift necessary: To apply the effluent to the row-crop agriculture of the terrace would require a minimum lift; the plant is situated at approximately the same elevation as the cropped land around it. But to apply the effluent to portions of the hillside pasture would require a lift varying from 50 to 200 feet.

6) Amount of effluent handled per day: The period of high flow occurs in the summer, when the plant must handle up to 4.1 mgd. In February the flow falls to a minimum of approximately .8 mgd. The higher summer flow is largely a consequence of infiltration of irrigation water percolating into the ground water and then into the city sewer lines.

7) Type of treatment: At present the effluent is given primary treatment with chlorination. The plant operator reports that a chlorine residual of 6 ppm is maintained. The cost of chlorination of effluent is $\$.12$ per pound of chlorine used, with approximately 2000 lb of chlorine used per month.

8) Industrial effluent not processed in city system: There is no significant production of industrial wastewater in the Weiser area. A plant which once processed fresh fruit such as strawberries, and miscellaneous vegetables, is no longer operating. This plant was the only food processing operation in the Weiser area.

9) City land adjacent to site of treatment plant: The city owns no appreciable acreage of land other than that used for the plant site.

10) Devices for monitoring of groundwater: Some shallow domestic wells are used in the terrace area, but no springs or seeps or other signs of groundwater discharge were observed or discernable from topographic sheets.

11) Amount of water applied during the irrigation season: Between 3 and 4 acre feet of water per acre are used, and it is reported that there is no shortage of water for irrigation in the row-cropped terrace area. There is a shortage of water in the foothills area, and at the present time a businessman with some acreage in pasture in the foothills immediately north of the treatment plant is pumping water from the Snake River and moving the irrigation water across the terrace and up the slopes to his pasture. He pumps the river water from a point almost immediately adjacent to the outfall line from the treatment plant; his pipeline from the river to the pasture area in the foothills parallels the outfall line from the plant.

12) Irrigation districts: The Weiser Irrigation System presently brings irrigation water to the terrace area west of town from diversion sites on the Weiser River. The Galloway Canal parallels the slope at the bottom of the foothills, and is accessible to the treatment plant only after a traverse of approximately 1 mile. However, there is a minor canal which passes adjacent to the treatment plants, and it may be feasible to transport effluent to potential sites of application via this canal. Current charges for water are approximately $.75 per acre foot.

13) Geologic data: The terrace consists of alluvial deposits of gravel, sand, silt and clay of undetermined depth. The water table lies some distance beneath the surface (more than five feet) and should present no complications with water logging if the wastewater were to be used for irrigation. In the foothills the geology consists principally of poorly consolidated to unconsolidated sediments of the Idaho Formation (river and lacustrine). Similar beds of the Payette Formation also occur at considerable depth in this area. Locally Tenmile Gravels (Savage, 1961, p. 26) of Pleistocene origin mantle the higher foothills. All are interbedded with basalts. The soil depth ranges from 4 to 8 feet in the terrace area, and from 0 to 2½ feet in the foothills with a caliche layer common beneath this foothill soil.

Comments: The Weiser area has good potential for agricultural irrigation with the effluent from the Weiser treatment plant. The means to transport the effluent exist, and the geologic conditions are acceptable with respect to renovation and utilization of nutrients from the wastewater. There is no need for additional supplies of irrigation water in the areas adjacent to the treatment plant, but in the foothills area there is an established need, as demonstrated by the existence of one pumping operation moving water from the Snake River to the area in question. The nutrient value in the effluent which will eventually receive secondary treatment (about $18 per acre foot) should more than compensate for the costs of moving the effluent the distances required. Year round disposal probably is not economically feasible.

<u>Payette</u>. (City data - Larry Monroe, City Engineer and Albert Davey, Plant Supervisor. Agricultural data - Gilbert Matson, Payette County AES Agent)

1) Location of treatment plant: The Payette plant is located adjacent to the east shore of the Payette River, approximately 1 mile above the confluence of the stream with the Snake River. It is situated in low-lying ground which has experienced flooding problems during periods of unusually high spring runoff.

2) Distance to irrigated cropland: Very little irrigated agricultural land is located adjacent to the plant. The City of Payette impinges closely along the banks on the east side of the Payette River where the land is largely flood plain having minimal agricultural value. There is some pasture and cropped land on a large island in the middle of the channel of the river. The island is opposite the plant and it may merit consideration for irrigation with wastewater. An alternative area for the application of effluent for crop irrigation would be the foothills lying east of Payette. By piping the effluent some two miles, and with a lift of approximately 120 to 160 feet, it would be possible to irrigate portions of this foothills area.

3) Type of crop grown and fertilizer amounts applied: Orchards predominate on the foothills, with pasture the dominate crop in the low-lying areas adjacent to the plant. Some grain and potatoes are also raised near the treatment plant. Approximately 20 to 30 lb of nitrogen per acre is applied to orchards. Grain requires 150 lb of nitrogen, and an indeterminate amount of phosphate is applied to each acre of hay crops.

4) Type of irrigation system used: In the foothills area the irrigation is largely by sprinklers, with some corrugate irrigation.

5) Vertical lift necessary: As cited in (2) above, a pumping lift of as much as 120 to 160 feet may be required to irrigate the foothills area with effluent. If the effluent were applied to the island opposite the plant,the lift should not exceed 20 feet.

6) Amount of effluent handled per day: The high flow period occurs in the summer, with as much as 4 mgd being processed at the plant. During the low flow periods in February the volume may be as little as .5 mgd. As was the case for Weiser, the high flow is largely a consequence of groundwater infiltrating into the city sewers as the water table rises with the advent of the irrigation season in the spring and summer.

7) Type of treatment: The City of Payette presently provides primary treatment with chlorination of the effluent. No information was available relative to the amount of residual chlorine available in the outfall, but during the high flow periods approximately 900 lb of chlorine are used each month, at a cost of approximately $.13 a pound.

8) Industrial effluent not processed in city system: Idaho Canning Company and the Wells-Davies packing plant presently do not utilize the city system for the treatment of their wastewater. It has been reported that Idaho Canning Compan experimented with disposal of plant wastewater on cropped fields operated by Mr. Ward Salterbeck, but dropped the practice because of problems with high water table and problems associated with poor infiltration and the development of offensive conditions in the field (Davey, 1969, personal communication).

9) City land adjacent to site of treatment plant: No appreciable city-owned property other than that for the plant site is located in the vicinity of the treatment plant.

10) Devices for monitoring of ground water: The situation is quite poor with respect to location of springs and seeps. Marshy areas do exist on the west

side of the Payette River, opposite Payette. Some domestic wells exist in the area of the plant site. Payette obtains its water from ground water. In the foothills area one can find evidence of groundwater discharge in the form of intermittent streams and some springs. Wells for both domestic and irrigation purposes are also present in the foothills. These wells and the few marshy areas near the river would probably be suitable for monitoring ground water quality if irrigation with wastewater were attempted.

11) Amount of water applied during the irrigation season: Approximately 4 acre-feet of water are applied per acre.

12) Irrigation districts and water charges: The district delivering water in the foothills area is the Lower Payette irrigation district. The Lower Payette Ditch runs along the flank of the foothills, approximately $1\frac{1}{2}$ miles from the treatment plant. Charges to water users are $20 per acre, or approximately $5 per acre-foot.

13) Geologic data: The treatment plant is situated on fluviatile and eolian sediments of gravel, sand, silt, and clay of Recent age. The depth of the material is indeterminate, and soil ranges from a depth of 6 inches to several feet. In the foothills the surface consists of unconsolidated Pliocene Idaho fluviatile sand, silt and clay; locally, this is veneered with Pleistocene Tenmile Gravels, and Caldwell-Nampa Sediments (Savage, 1961, p. 26). Soil depths range from 0 to several feet, often associated with caliche.

Comments: The site is not considered promising for irrigation with effluent at this time. The problem of moving wastewater to the foothills involves the movement of the effluent through a considerable extent of urban residential area within the city. There is a need for additional water in portions of the foothills, and Mr. Gilbert Matsen, Payette County Agent, has estimated that a flow of 3 mgd of effluent could irrigate 240 acres of pasture or orchard with flood irrigation, or 480 acres with spray irrigation (Matsen, 1969). In the more convenient low-lying areas the near surface water table (less than 5 feet) would hinder the efficient operation of wastewater irrigation, especially since much of the area is flood plain.

<u>Emmett.</u> (City data - Glen Wright, Plant Supervisor. Agricultural data - Erling T. Johannesen, Gem County AES Agent)

1) Location of treatment plant: The plant is located adjacent to the south bank of the Payette River, approximately $\frac{1}{2}$ mile from the eastern margins of the town. It is situated upon low-lying ground well within the flood plain of the stream.

2) Distance to irrigated cropland: Pasture and row-crop land are located adjacent to the plant, but there are problems with a high water table, especially in the spring and summer. A canal is situated adjacent to the site, and delivers irrigation water to orchards and other cropped land some distance down-valley, where the water table problem is much less acute.

3) Type of crop grown and fertilizer amounts applied: Pasture, grain and hay predominate among the crops grown. Approximately 30 to 50 pounds of nitrogen are applied per acre to hay, and 60 to 80 pounds of phosphate per acre are applied once every 3 years, with some variations (Johannesen, 1968).

4) Type of irrigation system used: The most common irrigation technique is flood or corrugate (ridge-and-furrow).

5) Vertical lift necessary: If the city were to divert its effluent to the present canal passing adjacent to the final lagoon at the plant site, it is possible that the transfer of water from lagoon to canal could be accomplished with a siphon. Otherwise, the lift necessary would be only a few feet.

6) Amount of effluent handled per day: This information was not available.

7) Type of treatment: The city employs a series of three lagoons, with a total surface area of 40 acres (20-10-10). At the time of observation the effluent contained sediment and was opaque and muddy in appearance.

8) Industrial effluent not processed in city system: The Stokely-Van Camp Corporation operates a food processing plant and provides treatment for their wastewater with a lagoon system. A large lumber mill operates adjacent to the city lagoons, and the mill-pond outflow does not receive any treatment.

9) City land adjacent to site of treatment plant: No additional land other than that for the treatment site is owned by the city adjacent to the plant site.

10) Devices for monitoring of ground water: This information was not determined, but domestic wells are used for rural household water supply near the city. Seeps near the river may offer some potential for monitoring the quality of discharging ground water.

11) Amount of water applied during the irrigation season: This information was not obtained.

12) Irrigation districts and water charges: This information was not obtained.

13) Geologic data: The city is situated upon unconsolidated fluviatile sediments and by Caldwell and Nampa Sediments of fluviatile origin. The thickness of the sediments is undetermined. Adajacent to the Payette River the clay, silt, sand and gravel sediments are of Recent fluviatile and eolian origin.

Comments: There is some possibility that agricultural irrigation with effluent from the lagoons would be feasible in areas removed from the river channel. In areas adjacent to the stream the water table is too close to the surface to permit application without making provisions for darinage, i.e. tiling. The adjacent ditch does offer a possible means of transporting the effluent to agricultural land with promise of fewer problems with water logging. Much of the agricultural data in this area were not obtained because of schedule conflicts between Mr. Johannesen and the field researcher for this project. But personal communication at an earlier period established some of the data presented. The possibilities for conducting the Emmett effluent to irrigated lands via the aforementioned canal need to be further investigated.

Caldwell. (City data - James Easley, Plant Supervisor. Agricultural data - Ralph Hart, Blaine Linford, Max A. Gardner, Canyon County AES Agents)

1) Location of treatment plant: The plant is located approximately $\frac{1}{2}$ mile northwest of the city, and $\frac{1}{2}$ mile southeast of the southern bank of the Boise River. The plant outfall line empties into the Boise River approximately .8

miles from the plant site.

2) Distance to irrigated cropland: It is approximately $\frac{1}{2}$ mile from the plant site to irrigated cropland. Mr. William Richardson owns a large pasture west of the plant site (reported to be approximately 2200 acres). Most of this pasture is located on the flood plain of the Boise River. Additional higher land is located farther from the plant.

3) Type of crop grown and fertilizer amounts applied: In the area of the treatment plant pasture land predominates. Row crops such as hops, corn, wheat, onions, sugar beets, potatoes and pasture predominate in the farmed land more remote from the plant. Up to 200 lb of nitrogen are applied to crops, with varying amounts of phosphate.

4) Type of irrigation system used: Flood or corrugate irrigation are the most common systems employed.

5) Vertical lift necessary: The elevation of the plant is approximately 2355 feet above sea level. The outfall line presently emptying into the Boise River could be diverted to empty into the Riverside Canal. Water is withdrawn from Indian Creek into Riverside Canal at a point downstream from the treatment plant. Thus, there would be no hydraulic lift needed if the effluent were diverted from the Boise River and directed into the Riverside canal. A pipeline or ditch approximately $\frac{1}{4}$ to $\frac{1}{2}$ mile long would be needed to direct the effluent around and over Indian Creek and into the canal.

6) Amount of effluent handled per day: The period of high flow occurs in the summer, when an average of 8 mgd of effluent are processed in July. Low flow occurs during November and December when the average flow drops to 2.6 mgd. In summer about 6 mgd is irrigation water which enters the system by infiltration into city sewer lines as a consequence of a high water table during the irrigation season.

7) Type of treatment: The City of Caldwell provides secondary treatment with chlorination. The amount of chlorine varies, but in 1968 the city used 28 tons of chlorine to treat 1,622.1 mg. The cost of chlorine is $3000 for 30 tons. During May 1968, 1.8 tons of chlorine treated 200 mg of effluent. Chlorine residual is .5 ppm.

8) Industrial effluent not processed in city system: The J. R. Simplot Company's food processing operations in Caldwell at present do not utilize city facilities, nor do the Johnston Meat Packing Company and the Idaho Meat Pack Company. In addition there are several feedlot operations adjacent to Caldwell which feed an unknown number of cattle.

9) City land adjacent to site of treatment plant: The city does not own any additional land adjacent to the treatment plant site.

10) Devices for monitoring of ground water: Domestic wells for rural residences are available in the area, and the city secures its domestic water supply from deep wells, so the potential for monitoring of ground water is good. In addition, topographical maps show the existence of springs and seeps (discharge points for ground water) at various points downstream from the treatment plant.

11) Amount of water applied during the irrigation season: It is not unusual for farmers to use as much as 4 acre-feet of water per acre during the irrigation season. There is no shortage of water for agriculture in areas adjacent to the plant. But in the sloping bench land south and west of the plant some farmers have installed wells to depths of 200 feet for irrigation water. The elevation of this bench land varies from 2450 to 2500 feet, and agricultural land on the bench will be at least 2 miles from the treatment plant site.

12) Irrigation districts and water charges: Three different districts provide irrigation water to users. These districts are Black Canyon, Riverside Canal District, and West Canyon. The representative charge for water per acre is $10, or about $2.50 per acre-foot

13) Geologic data: The plant is located on fluviatile and eolian sediments of clays, silts, sands, and gravel of recently reworked materials. The bench land is unconsolidated Nampa and Caldwell Sediments of Pleistocene age. These are locally veneered with Recent eiolian silts.

Comments: There is potential for irrigation with effluent at Caldwell, but a high water table similar to a marsh in areas adjacent to the plant means that the effluent will have to be transported some distance from the plant site prior to application. This is possible if the Riverside Canal is utilized for transport. There is demand for additional irrigation water in the bench land, but the distance required for horizontal movement across the Boise River floodplain to the bench land is probably prohibitive. The vertical lift from the elevation of the plant to the elevation of the bench is not prohibitive because this difference is only 100 to 150 feet and farmers currently are pumping water from wells at least this deep.

The Simplot operation has experimented with terrestrial disposal on William Richardson's land but has experienced problems with chemicals used in the potato peeling process (Easley, 1969, personal communication. Simplot has also experienced some problems with its effluent overflowing into an irrigation canal adjacent to the canal. Down-gradient users have complained of excessive weed growth in the canal impeding the flow of irrigation water through the canal. The city and Simplot have made efforts to obtain Federal support for the construction of enlarged city facilities (Federal Government to pay 60%, J. R. Simplot Co. to pay 40%) for processing both Simplot's and city wastewater (Easley, 1969). If these wastes can be processed and subsequently transported via the Riverside Canal to an irrigation site which is hydrogeologically appropriate, considerable benefit should be realized by agriculture.

<u>Nampa</u>. (City data - Chet Simpson, Plant Supervisor. Agricultural data - Ralph Hart, Blaine Linford, Max A. Gardner, Canyon County AES Agents)

1) Location of treatment plant: The plant is located $\frac{1}{2}$ mile northwest of the City of Nampa, at a point between the Union Pacific Railroad to the southwest and Indian Creek to the north. It is bounded by the embankment of the railroad and by an embankment constructed for a new interstate freeway to the northwest, leaving a triangular wedge-shaped segment of land opening east toward the city. Within this wedge of land the treatment plant is located. A new city golf course and a large beet-sugar processing plant are located nearby.

2) Distance to irrigated cropland: Because of the embankments created in the laying of rail lines and in the building of the freeway, and as a result of

right-of-way for these transport lines, it is approximately 1 mile from the treatment plant to agricultural land. Pumping would be required to move the effluent across the embankments, but it is only $\frac{1}{4}$ mile to the city golf course which is on the same side of the embankments as the treatment plant.

3) Type of crop grown and fertilizer amounts applied: Row crops such as corn, onions, sugar beets, and potatoes predominate, along with some pasture and some acreage in hops. As much as 200 pounds of nitrogen is applied per acre, with varying amounts of phosphates.

4) Type of irrigation system used: Much of the agricultural land is irrigated via corrugates, with some flood irrigation.

5) Vertical lift necessary: It would be necessary to lift the effluent from the elevation of the outfall line (approximately 2450 feet) some 5 to 10 feet in order to raise it to the level of the city golf course. To get the effluent over the railroad embankment would require an additional lift of 10 feet, after which gravity flow would give access to sufficient agricultural land for irrigation with wastewater.

6) Amount of effluent handled per day: During the high period of flow in summer, the rate can rise to 10 mgd, but averages around 8 mgd. In January and February the flow drops to an average of as little as 2.5 mgd.

7) Type of treatment: Nampa provides secondary treatment with chlorination of its final effluent. This is one of the most complete and efficient plants operating in Idaho, with a BOD removal often averaging 97%. The system handles a population equivalent of 295,000, with a design capacity of 375,000. All industrial wastewater produced in Nampa is processed through the city system for treatment, with the exception of Armour & Co. meat packing operations. The plant attemptsto maintain a .5 ppm chlorine residual in its final effluent.

8) Industrial effluent not processed in city system: Armour & Co. operations provide a 2-cell anaerobic-aerobic waste treatment and odor control facility for disposing of wastes from a packing plant processing an average of 1,450 head of cattle a month. The company recently received an antipollution award (in 1968) from the Pacific Northwest Pollution Control Association for its successful operation of these wastewater treatment facilities.

9) City land adjacent to site of treatment plant: In addition to the municipal golf course, the city owns 15 acres of pasture adjacent to the plant. This pasture is not irrigated at the present time.

10) Devices for monitoring of ground water: The plant itself has a well used for securing plant water for miscellaneous purposes including that of drinking water for plant employees. The well is drilled adjacent to the plant.

11) Amount of water applied during the irrigation season: An average of 4 acre-feet per acre is used in row-crop agriculture.

12) Irrigation districts: Black Canyon, West Canyon, and Riverside Canal District service the agricultural water users for most of the Nampa-Caldwell area.

13) Geologic data: The treatment plant site is upon unconsolidated Pleistocene fluviatal Caldwell-Nampa Sediments and more recent sediments of clay, silt, sand, and gravel. There are outcrops of Snake River basalts in the area of Nampa, and the depth of the Pleistocene sediments over this older basalt is variable and in most places indeterminate. South of the city the Snake River Basalt is exposed at the surface. In addition Indian Creek is located in a shallow valley of Recent fluviatile and eolian sediments consisting of clays, silts, sands, and gravel.

Comments: Nampa has very good potential as a site for terrestrial disposal of wastewater. Several options can be considered: a) irrigate the municipal golf course which is closely adjacent to the plant, b) irrigate the pasture owned by the city, which is also adjacent to the plant, c) develop a program of ground water recharge via high-rate application of effluent into spreading basins or via high-rate application in a ridge-and-furrow system. The latter project might be implemented on the 15 acre plot or on land on the opposite side of the railroad and freeway embankments. The details of economics and efficiencies of such a tertiary system design could be determined at this site. The feasibility of year round terrestrial disposal in the hydrogeologic environment characterized by the Nampa-Caldwell area could also be investigated here. Such a study need use only a portion of the effluent available from the Nampa plant. By using a portion of the effluent the amount of land area required could be restricted to a few acres, thereby limiting the amount of capital investment necessary in the establishment of such a pilot study. The pilot study should include the determination of a system design for year-round terrestrial disposal that would meet the requirements of climatic and geologic conditions present in this portion of the State.

Nampa offers several advantages for such a pilot project. Firstly, the quality of effluent available from the plant is very good. Secondly, the city owns acreage adjacent to the plant site which could be adapted to a pilot study. Thirdly, the geologic conditions are acceptable with unconsolidated sediments of some depth overlying the older Snake River basalts. Satisfactory rates of infiltration and percolation can probably be realized. It is probable that the sediments would renovate the effluent satisfactorily prior to its entry into the basalt aquifer. Indications are that the city is cooperative and very progressive.

Boise. (City data-Bob Griffiths, Commissioner of Public Works, Ross Dake, City Engineer, and Herb Hester, Plant Supervisor. Agricultural data - H. G. Hilfiker, M. B. Calnon, Doran Peterson, Ada County AES Agents)

1) Location of treatment Plant: The treatment plant is located on the north bank of the Boise River, a little over $\frac{1}{2}$ mile west of the Boise City limits.

2) Distance to irrigated cropland: The plant is located adjacent to one of the Boise suburban areas. The Plantation Country Club golf course is located approximately 1 mile downstream from the plant. The golf course is on the north bank of the river. Extensive areas of pasture, including that incorporated into the site of the Ada County Fair Grounds, are located approximately $1\frac{1}{2}$ miles downstream on the south bank of the stream. In addition, the Salvation Army in Boise owns property adjacent to the treatment plant. This property is estimated to be 30 to 40 acres in extent and is in pasture.

3) Type of crop grown and fertilizer amounts applied: In the areas adjacent to the plant or downstream from it and adjacent to the river the land is mostly in

pasture, with some hay, small grains, and silage corn. Fertilizer amounts recommended are based on recommendations published in Extension Bulletin 325 (see Tables 16 A and 16 B).

4) Type of irrigation system used: For most of the area surface water is distributed by canal to users who apply the irrigation water via flooding if the land is flat, and via the use of corrugates of the land is sloping. Farmers Union Canal, a main line canal transporting irrigation water to the vicinity of Dry Creek Valley and beyond, passes within .1 mile of the plant.

5) Vertical lift necessary: Approximately 15 feet of vertical lift would be necessary if the effluent were to be raised from the outfall line to the elevation of the pasture adjacent to the plant, or to raise the effluent to the elevation of the Farmers Union Canal which passes near the plant.

6) Amount of effluent handled per day: In July the high flow averages about 9.5 mgd, while in March the flow can drop to 5 mgd, although 6.5 mgd was the low monthly average for 1966.

7) Type of treatment: The City of Boise provides secondary treatment with chlorination for its effluent. The city utilizes 30 lb of chlorine at a cost of $1.80 to treat each million gallons of effluent, with the city paying $118 per ton for the chlorine.

8) Industrial effluent not processed in city system: Although the list is incomplete, several meat-packing plants presently do not use city facilities, including Davis Packing and Custom Slaughter House.

9) City land adjacent to site of treatment plant: The city owns no additional land beyond that required for the plant site.

10) Devices for monitoring of ground water: There are some private wells in the area of the plant, and some have been monitored for various reasons in the past. The installation of shallow, monitoring piezometers would be inexpensive and simple.

11) Amount of water applied during the irrigation season: The amount of water applied is as high as 5 to 6 acre-feet per acre in areas adjacent to Boise.

12) Irrigation districts and water charges: Farmers Union Canal District serves the agricultural water users of the immediate area. The cost of water is $3 per acre for the season, or around $.50 per acre-foot. This is one of the lowest costs of water in the entire State.

13) Geologic data: The valley area adjacent to Boise River is composed of Recent fluviatile and eilian sediments at the surface, with Pleistocene Caldwell and Nampa sediments and Idaho Formation clay, silt and sand occurring in the benchlands above the valley floor. Bedrock consists of the Snake River Basalt or Pliocene age. It is covered and intercalated by unconsolidated sediments to varying depths. The area experiences water table problems in the summer, and this fact places limitations upon the agricultural reuse of wastewater on the floodplain portions of the river course. On the south side of the stream soil profiles commonly show a caliche layer 12 to 18 inches below the surface, while on the north side of the stream the soil profile is deeper. Along the flat bottom

land soil may be completely absent with the exposure of removed Recent gravels, and these gravel exposures and lack of soil also place limitations upon agriculture.

Comments: The situation in Boise offers some possibility for several means of terrestrial disposal, but the high watertable in the immediate vicinity of the treatment plant limits the potential of effluent reuse by agriculture. There is a possibility of cooperative programs with the Plantation Country Club, with the Ada County Fair Board, and with the Salvation Army, in irrigating some recreational and pasturage areas. But possibly the most promising consideration is the possibility of diverting the effluent via the Farmers Union Canal to areas where hydrogeologic problems such as high water tables are less serious.

Mt. Home and Mt. Home Air Force Base (AFB). (City data - Jim Ross, Plant Supervisor. AFD data - physical plant personnel. Agricultural data - H. M. Edwards, Gem County AES Agent)

1) Location of treatment plants: The city plant is approximately 1 mile southwest of the city; the AFB facility is located on the western boundary of base property.

2) Distance to irrigated cropland: Both plants are adjacent to irrigated cropland.

3) Type of crop grown and fertilizer amounts applied: Potatoes and sugar beets predominate, with some pasture and hay. An average of 160 lb of nitrogen and 160 lb of phosphate are applied during the agricultural season.

4) Type of irrigation system used: Considerable sprinkler irrigation if practiced, with most of the water drawn from wells 400 to 600 feet deep.

5) Vertical lift necessary: Very little lift would be needed to apply the effluent to cultivated land.

6) Amount of effluent handled per day: There is little variability in the flow of wastewater into either facility. The effluent at the AFB varies from .7 to .9 mgd, while that from the City of Mt. Home averages around .7 mgd.

7) Type of treatment: Both facilities consist of a series of lagoons. At Mt. Home treatment is provided by 4 lagoons with a total surface area of 72 acres. The AFB facility consists of 3 lagoons with a total surface area of 64 acres. The effluent outfall from the systems empties into the channels of intermittent streams, whereupon it percolates into the groundwater or evaporates.

8) Industrial effluent not processed in city system: There is no industrial effluent as such. But there is a problem with flight-line wastes at the AFB which include petroleum derivatives and other compounds which are toxic to plant life and unfit for agricultural utilization unless treated. In some cases this flightline effluent may hinder the operation of the lagoons in renovating the wastewater.

9) City land adjacent to site of treatment plant: This topic applies mostly to the City of Mt. Home. The city owns 160 acres adjacent to the plant, which it leases to a nearby farm. The AFB has considerable property within the perimeter of the plant.

10) Devices for monitoring of ground water: There are many wells in the area

of the city plant, and both the city and the base depend upon several wells for their water supply.

11) Amount of water applied during the irrigation season: This is a water-deficit area from the standpoint of storage and distribution. In dry years the farmers who receive water from the canals that exist north of town may be lucky to get as much as 1 acre-foot of water per acre during the agricultural season. In wet years such as 1969 these farmers may get as much as 3 acre-feet per acre for their crops; they can use all the water that is available and would prefer 4 to 6 acre-feet per acre.

12) Irrigation districts: Mountain Home Irrigation District irrigates 4400 acres north and northeast of the city. Hood Corporation is a development company pumping water out of the Snake River southeast of Mt. Home, and there is some private development of land with deep wells and spray irrigation in areas adjacent to the western boundary of the AFB.

13) Geologic data: Both areas have soil ranging in thickness from 15 to 30 inches with a caliche layer in places beneath the soil. The Mt. Home area is situated upon unconsolidated Pleistocene sediments of varying depths, with basalt beneath the sediments. The AFB is situated in an area which does not contain Pleistocene sediments to any significant degree. Here the basalt is much closer to the surface with outcrops occurring frequently.

Comments: Mt. Home is a very promising area for the use of effluent for irrigation. The demand for water is considerable, and there have been attempts made already to utilize city effluent for irrigation on the city acreage which is leased to the nearby farm. The attempts at irrigating with city effluent consisted of the installation of a pump adjacent to the second lagoon in the series and withdrawing the water from the lagoon directly into irrigation ditches for delivery to the fields. When effluent flowing into the lagoons dwindled in the middle summer period the withdrawal of irrigation water had to be stopped because with the withdrawal there was not enough water in the second and third lagoon to prevent the occurrence of odor problems and other offensive conditions from developing. With some changes in the operation of and increases in the size of the lagoon system it might be possible to make a larger quantity of the total effluent available for agricultural irrigation for a longer period in the summer.

Gooding. (City data - J. C. Moore, Plant Supervisor. Agricultural data - Edward Koester, Gooding County AES Agent)

1) Location of treatment plant: The sewage treatment plant is located approximately $\frac{1}{4}$ mile west of town. It is adjacent to the Big Wood Canal, and the final effluent is emptied into the Little Wood River.

2) Distance to irrigated cropland: Cropland is adjacent to the plant.

3) Type of crop grown and fertilizer amounts applied: Alfalfa is the number one crop with respect to total acres planted. Number two use of land is pasture. Grain and corn are other crops in the region. The usual amounts of nitrogen and phosphates applied to grain are 60 to 50 pounds respectively. On corn 100 pounds of nitrogen and 60 pounds of phosphate are applied. For pasture and alfalfa there

is realtively little fertilization practiced.

4) Type of irrigation system used: Most of the agricultural irrigation is by means of corrugate or ridge-and-furrow technique, with little sprinkler irrigation.

5) Vertical lift necessary: There would be negligible lift required to apply the effluent to nearby irrigated acreage.

6) Amount of effluent handled per day: The high inflow of effluent occurs in the summer; the volume averaging about .6 mgd. In January and February the flow results in approximately .3 mgd of effluent.

7) Type of treatment: Gooding provides secondary treatment for its domestic effluent and maintains a chlorine residual of .3 to .5 ppm.

8) Industrial effluent not processed in city system: Magic Valley Meat Packing Company is located some distance outside the city limits of Gooding, and does not utilize city facilities. In addition Gabriel Packing Company provides its own treatment system.

9) City land adjacent to site of treatment plant: The city owns no land other than that for the plant. Gooding County owns approximately 40 acres, with 8 acres in grass at the county fairgrounds $1\frac{1}{2}$ miles north of the treatment plant.

10) Devices for monitoring of ground water: The city water supply consists of wells drilled to approximately 400 feet. There are private domestic wells in the rural area dajacent to the treatment plant. Springs and seeps exist in the vicinity of the Little Wood River which are suitably close to sites of potential for application of effluent to crops.

11) Amount of water applied during the irrigation season: The average volume of water available to irrigation water users is $4\frac{1}{2}$ acre-feet per acre for the growing season. There is an abundant supply of water in most areas, but there are areas of potentially irrigable land close to the plant which do not have water at this time.

12) Irrigation districts: Wendell North Side Canal Company currently charges its users $2.75 per acre-foot for water during the growing season. The Big Wood Canal Company charges $3.90 per acre-foot.

13) Geologic data: The soil cover ranges considerably in thickness. Unconsolidated sediments cover portions of the basalt bedrock. There are numerous basaltic outcrops in the area of Gooding, reflecting the relatively thin veneer of soil and sediments that cover portions of the area.

Comments: There is a need for more water in portions of the agricultural area adjacent to Gooding. A local veterinarian, Dr. Richard Stapp, was reported by the Agricultural County Agent to have purchased recently a quarter-section of land close to the plant, and there is no water right established for this land. There is abundant acreage in pasture and hay cropping adjacent to the plant which offers possibilities for the disposal of wastewater in irrigation. But because of the variable geology and sporadically thin soil, on site investigation needs to be conducted prior to implementation of a wastewater reuse program.

Jerome. (City data - William Odermotte, City Manager. Agricultural data - W. G. Priest, Jerome County AES Agent)

1) Location of treatment plant: The treatment plant is located about .1 mile from the county fairgrounds, on the west side of the Jerome city limits. Its outfall line empties into an irrigation ditch passing just to the west of the plant. This ditch eventually empties into the Snake River.

2) Distance to irrigated cropland: There is irrigated cropland and pasture adjacent to the plant.

3) Type of crop grown and fertilizer amounts applied: Beans , alfalfa, grain, and some pasture are irrigated out of the canal which carries Jerome's effluent.

4) Type of irrigation system used: Since the land is rolling rather than flat and level, corrugate irrigation is practiced almost exclusively.

5) Vertical lift necessary: Since the effluent already empties into a canal for distribution to irrigated agriculture, there is no lift required to distribute the effluent.

6) Amount of effluent handled per day: Jerome has a relatively constant volume of flow, with peak flow occurring in the winter months when 1.2 mgd of effluent are processed. In the summer months the volume may be reduced to .9 mgd. Creamery waste from Ida-Gem Creamery constitutes 57% of the total effluent handled.

7) Type of treatment: The city provides secondary treatment for its effluent with an especially heavy application of chlorine for the final effluent. In the winter when the effluent is not diluted with irrigation water the city adds 45 pounds of chlorine per day to the effluent. In the summer 25 pounds per day are added. The cost of the chlorine is 15.5¢ per pound. The system is presently overloaded during periods of operation for industrial potato processing by King of Spuds Co.

8) Industrial effluent not processed in city system: All industrial sources of effluent within the city limits of Jerome are now processing their wastes in the city treatment plant. In 1964 the city had one special user, Ida-Gem Creamery, contributing a hydraulic loading of .4 mgd and an organic loading of 352 ppm or about 1174 pounds of BOD. Since 1964 the city has accepted another special user, King of Spuds Processing Company. When the King of Spuds is in operation the treatment plant handles an inflow of effluent equivalent to the inflow from a population of 20,000 persons, which is 14,000 above the design capacity of the plant. A bond election was scheduled in July of 1968 to approve the construction of additional facilities to handle this increased volume of wastes. At the time of observation in March of 1969 construction of the needed additional treatment facilities had not been started.

9) City land adjacent to site of treatment plant: There are 1 to 2 acres of land in addition to the acreage included in the plant site, and the additional land will be incorporated into an aerated lagoon and a second filter which are to be added to the present facilities in the next year (1970).

10) Devices for monitoring of ground water: The city water supply is from deep wells drilled an average of 280 feet into the underlying basalt. There are few discharge points such as springs or seeps apparent from study of topographical maps, and the water table is quite far below the surface. This means that monitoring ground water might be difficult. Most farms do have 100 to 200 foot domestic wells.

11) Amount of water applied during the irrigation season: Farmers in the area apply all the water that they can get from the respective irrigation districts to their crops. This usually means an average of 4 to $4\frac{1}{2}$ feet of water per acre.

12) Irrigation districts and water charges: The Northside Canal District serves the water users in the Jerome area, charging $.48 per miner's inch (85 to 90¢ per acre-foot).

13) Geologic data: The geology consists of lava flows of Snake River Basalt which are mantled with alluvial and eolian deposits of gravel, sand and silt to depths of up to 50 feet. In many places adjacent to Jerome the basalt is exposed, and soil depths range from 0 to 15 feet. There is no problem with a high water table in the Jerome area.

Comments: Once the expansion of facilities is accomplished to accommodate special users such as King of Spuds Co., there will be little need to suggest a modification of the city's present system of disposal of effluent. In the summer months the city's wastewater is incorporated into the irrigation water of the canal district and is applied to crops in the area. In the winter the entire flow in the canal consists of effluent from the treatment plant. After heavy chlorination the effluent in the canal is utilized for stock water year round only 100 yards from the outfall line. In 1964 the city experienced odor problems and other offensive conditions along the course of the canal in the winter. This occurred because the canal company in 1964 ceased to divert water through the ditch on a year-round basis and the total flow from the treatment plant was too little in volume. Odor problems occurred as the effluent stagnated in the canal bed and became anaerobic. But in 1967 the city increased its flow of final effluent. This resulting increase in the volume of effluent has subsequently eliminated offensive conditions along the canal course. Very little of this increased flow of effluent reaches the Snake River, as the bulk of it infiltrates to the ground water reservoir through the bed of the canal. The Gem County Agent, Mr. William Priest lives adjacent to the canal, downstream from the city treatment plant. His domestic well is an uncased, 175 foot hole, and has been checked for contamination. The well samples have shown no problems with nitrates or bacteria, even though the well is in the vicinity of the canal.

<u>Buhl</u>. (City data - Lorence Fawcett, Plant Supervisor. Agricultural data - Donald Youtz, Olan Genn, Twin Falls County AES Agents)

1) Location of treatment plant: The Buhl plant is located on the edge of the basalt plain, overlooking the canyon of the Snake River; it is approximately $\frac{1}{4}$ mile northwest of the City of Buhl. The canyon is 750 feet deep (elevation of the plant is 3670 feet and elevation of the river surface is 2920 feet), and the relief consists of a step-like series of hills with small stream channels cutting and disecting the hills. The result is a rugged expanse which stretches away from the plant site for $3\frac{1}{2}$ miles to the Snake River.

2) Distance to irrigated cropland: Pasture is adjacent to the treatment plant site.

3) Type of crop grown: In the areas adjacent to the city but south of the treatment plant site crops consist of hay and grain, sweet corn in the more nearly level areas, with sugar beets and potatoes in lesser quantities. Fertilizer amounts applied vary from 30 to 120 lb of nitrogen for corn and sugar beets and potatoes, and from 30 to 120 pounds of phosphate on the row crops.

4) Type of irrigation system used: When surface water from canals is used, corrugated irrigation predominates. When the irrigation water is pumped from wells the usual means of distribution is via spray-irrigation (sprinklers).

5) Vertical lift necessary: To apply effluent from the treatment plant to pasture requires no lift because pasture land lies at elevations lower than that of the plant.

6) Amount of effluent handled per day: There is evidently no real seasonality in the flow of effluent to the plant, and the average volume is approximately .6 mgd, of which .3 mg is domestic, and .3 mg is wastewater from the Pet Milk plant in Buhl.

7) Type of treatment: The city utilizes a series of aerated lagoons; the area of water surface was inadvertently omitted from the data obtained.

8) Industrial effluent not processed in city system: Green Giant Company near Buhl presently is irrigating with the wastewater from its canning and other food processing operations. Carter Packing Company utilizes a lagoon of limited surface area. Two other meat packing companies utilize septic systems. These companies, in the vicinity of Buhl, are Armour Meat Company and B & L Meat Packers.

9) City land adjacent to site of treatment plant: There is no additional city-owned property adjacent to the site.

10) Devices for monitoring of ground water: There are several deep wells in the area, including city wells down to 1000 feet in the basalt. Each rural residence also has private domestic wells. There are also numerous springs and seeps that will allow the monitoring of ground water.

11) Amount of water applied during the irrigation season: The amount of water applied will vary between 3 to 4 acre-feet per acre, with all the water that is needed generally made available to those agricultural water users located in areas served by canals.

12) Irrigation districts and water charges: Twin Falls Canal Company takes water into their canal system at Murtaugh, from Milner Reservoir. The charge for water is \$2 to \$2.50 per acre for the season, or \$.50 to \$.60 per acre-foot.

13) Geologic data: The basalt plain above the Snake River Canyon consists largely of Upper Pliocene lava flows in sheet-like bodies from the Idaho Group, with Upper Pliocene lake and stream deposits characterized by massive layers of silt, layers of cemented sand, and gravels of miscellaneous origin interbedded

with the basalt. The soil is a shallow phase of the Portneuf Silt Loam of eolian origin, varying in depth from 0 to 20 feet. In the canyon breaks, Pliocene basalts are interbedded with consolidated sedimentary rock of the same age. In the canyon deposits of Mellon Gravel (boulders, cobbles and pebbles of basalt) and alluvial stream deposits also occur.

Comments: The effluent from the Buhl lagoons is utilized presently by Mr. LaVel Lyon to irrigate pasture below the outfall line from the lagoons. Arrangements have been made to cooperate with Mr. Lyon in a program to monitor the renovation of the effluent as it percolates through the soil column of the slope land in pasture. In addition, the Green Giant Company has agreed to a cooperative study program of their irrigation with wastewater from food processing operations at Buhl. The fact that two such programs of application of effluent are functioning at this time provides an ideal opportunity to establish the operating economics of such a system of tertiary reclamation of wastewater. It would be advisable for the other processing companies in the area to look into the possibility of terrestrial renovation.

Twin Falls. (City data - Earl Fullmer, Treatment Plant Superintendent. Agricultural data - Donald Youtz, Olan Genn, Twin Falls County AES Agents)

1) Location of treatment plant: The Twin Falls plant is located at an elevation of 3160 feet, on a bench area at the bottom of the Snake River Canyon approximately 2½ miles northwest of Twin Falls. The elevation of the city if approximately 3700 feet, so the canyon is 540 feet deep to the treatment plant. The Snake River has incised a vertically walled canyon at this point.

2) Distance to irrigated cropland: There is some orchard acreage adjacent to the plant, and downstream from 1½ to 3 miles additional land is in pasture.

3) Type of crop grown and fertilizer amounts applied: Because of the situation of the plant site, it would uneconomical at this time to consider pumping the treated wastewater back up to the top of the canyon rim for application to row crops. The canyon bottom is mostly pasture in addition to the aforementioned orchard. The amounts of fertilizer applied are not known at this time.

4) Type of irrigation system used: This information for the limited area of agricultural land in the canyon bottom is not known.

5) Vertical lift necessary: There is a possibility that if it were determined feasible to transport the wastewater via canal or pipe downstream to agricultural land mentioned previously, that gravity flow would be adequate.

6) Amount of effluent handled per day: The city's flow of effluent is relatively constant at approximately 3 mgd, but 4 to 5 mgd is anticipated when the secondary treatment facility if completed. The city will treat much of the industrial wastewater produced in the vicinity of Twin Falls when its secondary facility is constructed.

7) Type of treatment: Presently Twin Falls provides primary treatment with chlorination. The city utilizes 59 lb of chlorine per million gallons, and is presently paying $124 per ton for the chlorine.

8) Industrial effluent not processed in city system: Several food processing plants, a starch plant, and several meat packing plants do not utilize city facilities at this time. The specific company names were not available, and those firms listed in Tables 14 and 15A and 15B may or may not at this time be emptying

into city sewer lines.

9) City land adjacent to plant: The city owns a total of 28 acres at the site, and in addition owns a community golf course on the opposite bank of the Snake River and approximately 1 mile upstream. If the city were to contemplate the irrigation of its land adjacent to the plant, problems could occur with an inadequate hydrogeologic environment because of shallow soil, faulted and fissured bedrock, and other associated problems. More investigation into the structure of the soil and underlying strata is necessary.

10) Devices for monitoring of ground water: Some domestic wells are in use for rural residences in the canyon, but the existence of such wells in the vicinity of the treatment plant has not been determined. Springs and seeps occur in quantity in the basalt cliffs above the plant, but disappear into the alluvial deposits of the benchland upon which the plant is located. Ground water discharge points may exist in the slopes downstream from the plant site.

11) Amount of water applied during the irrigation season: This information has not been determined for those areas of agricultural land in the canyon bottom. It is safe to assume, however, that if irrigated agriculture is practiced in these areas, water use will parallel that in adjacent but higher areas, which usually averages approximately 4 acre-feet per acre for the growing season.

12) Irrigation districts: There are no canals established in this portion of the river canyon.

13) Geologic data: The basalt exposures are largely from the Lower Pliocene age, and are predominantly porphyritic. There are some deposits of Mellon Gravel (boulders, cobbles, and pebbles of basalt) in portions of the canyon floor. The topsoil ranges from 0 to several feet, with fluviatile and eolian deposits of clays, silts, sand and gravel ranging greatly in depth.

Comments: Although the site of the plant is poor from the standpoint of access to agricultural land, there are some possibilities. The water table is not a problem, and there is an extent of pasture available downstream on the canyon bottom. Mr. Alfred Urie has 80 acres 20 miles downstream; Mr. Gerald Taylor has 100 acres adjacent to the plant; and Mr. Dick Cameron owns some uncleared land and some irrigated land downstream, all in the floor of the canyon. The community-owned country club on the north side of the stream lies at elevations equal to or higher by some 150 feet than that of the treatment plant. If one were to consider irrigation of fairways and other grassy areas with effluent at the country club site, it would be necessary to transport the effluent across the Snake River and then pump it up to the elevations of the various fairways. Another problem with this consideration is the fact that there is a plentiful supply of water for present irrigation requirements on that side of the canyon. Twin Falls has abandoned surface water withdrawn by canal from Milner reservoir as its source of domestic water, and now pumps from the abundant spring flow of water at Blue Lakes alcove on the north side of the canyon. The additional expense of pumping this water across the river and lifting it approximately 450 feet to the elevation of the city, with a horizontal carry of 3 miles to the city limits, is still less expensive than that of treating the polluted water withdrawn originally from the reservoir, which originally was transported via canal and gravity flow.

Burley. (City data - Leonard Staker, Plant Supervisor. Agricultural data - no Cassia County AES Agent)

1) Location of treatment plant: The major portion of Burley is located on the south side of the Snake River; it is $\frac{1}{4}$ to $\frac{1}{2}$ mile from the stream bank. The treatment plant is located between the northeast corner of the city and the stream. The site is poorly drained and subject to flooding during high water.

2) Distance to irrigated cropland: It is approximately $1\frac{1}{2}$ miles to irrigated agricultural land, and 2 miles to the nearest irrigation canal.

3) Type of crop grown and fertilizer amounts applied: Row crops predominate but specific information is not available because at the time of field observation there was no county agent assigned to Cassia County.

4) Type of irrigation system used: The topography suggests that flood irrigation is possible in the level areas, with corrugate in the farming plots having higher relief. But once more, no specific information is available.

5) Vertical lift necessary: A 35 foot lift would be required to move the effluent from the elevation of the treatment plant to the elevation of the nearest canal which could be used for the transport of the effluent to irrigated farm land.

6) Amount of effluent handled per day: Burley experiences problems with a high water table and infiltration of ground water into its city sewer system during the months of irrigation. The high flow occurs in the late summer, with 1.7 mgd of inflow during August. In March the flow may drop to as little as .65 mgd.

7) Type of treatment: The city utilizes a series of lagoons, with no chlorination of the final effluent.

8) Industrial effluent not processed in city system: J. R. Simplot Co., Burley Processing, Ore-Ida (two plants in the region), A & P, and Del Monte all process food products and treat their wastewater with lagoons. Boise-Cascade paper board mill also treats its own wastewater. There are several meat packing plants in Burley, and it is not known at this time whether or not these firms treat their own effluent or utilize city facilities. Among these firms are Armour Meat Company and B & L Meat Packers.

9) City land adjacent to site of treatment plant: There is no land in addition to the plant site which is owned by the city in the region of the treatment plant.

10) Devices for monitoring of ground water: The city utilizes deep wells (240 feet) for its domestic water supply; these wells could be used to monitor ground water under a program of irrigation with wastewater. There are numerous private domestic wells for rural residences in agricultural areas south of the city.

11) Amount of water applied during the irrigation season: These data were not obtained, but the figure should follow the pattern that has been established for other areas of the State; that is, between 3 and $4\frac{1}{2}$ acre-feet of irrigation water per acre are applied during the irrigation season.

12) Irrigation districts and water charges: Data on irrigation districts and water charges were not available.

13) Geologic data: The Burley area is covered primarily by alluvium of Pleistocene origin, with Portneuf Silt Loam and fluviatile and eolian deposits covering the underlying Snake River basalt to an undetermined depth. Soil depth is not known.

Comments: Burley is not a feasible site at this time for consideration of irrigation with domestic effluent. The location of the plant is relatively far removed from potential agricultural land which could be irrigated with effluent; the high water table might result in economic costs which could not be justified. But the industrial plants in Burley are not located so disadvantageously. It may be feasible to consider agricultural irrigation with wastewater from those plants which are located west of Burley and on somewhat higher ground. These plants are also adjacent to agricultural areas. Del Monte, A &P, and Ore-Ida (both plants) are all located in proximity to the river and approximately 2 miles west of town. Boise Cascade is also located out of town and some distance from the river. It may be feasible to consider alternative means of terrestrial disposal of its wastewater as well. These producers of effluent should investigate these alternatives.

Rupert. (City data- Gary Towell, Plant Supervisor. Agricultural data - Vance Smith, LaMont Smith, Minidoka County AES Agents)

1) Location of treatment plant: The treatment plant is 1 mile south of Rupert and approximately 3 miles northwest of the northern bank of the Snake River.

2) Distance to irrigated cropland: The plant is adjacent to cropland, with both pasture and row-crops surrounding the facility.

3) Type of crop grown and ferilizer amounts applied: Pasture, beans, sugar beets, potatoes, and alfalfa predominate among the crops grown. It is recommended that 160 pounds of nitrogen be applied to sugar beets and potatoes, and 100 pounds of nitrogen to pasture, per acre. Recommended amounts of phosphate vary.

4) Type of irrigation system used: Both flood and corrugate irrigation are practiced in the area of the treatment plant. There is little spray-irrigation practiced.

5) Vertical lift necessary: Under present operating conditions, the vertical lift necessary to apply the effluent to adjacent farm land is already provided in order that the effluent can be pumped to the river 3 miles away. It is estimated that the effluent is given the equivalent of a 100 foot head in order to raise it from the bed of the secondary trickling filter and then up over a canal embankment to the river.

6) Amount of effluent handled per day: The city experiences problems with infiltration of ground water into its collection system during the summer month, and their peak inflow occurs during July and August when the plant must process 2.4 mgd. In March the low flow is about 1.0 mgd.

7) Type of treatment: The plant provides secondary treatment with

chlorination of the final effluent, but at the present time the design capacity is inadequate to handle the quantities of domestic and industrial wastes which the city is attempting to process. The amount of chlorine used varies, but for a flow of 1.4 mgd 42 pounds of chlorine are used, at a cost of 17¢ per pound.

8) Industrial effluent not processed in city system: It is not known whether all meat packing plants in the area utilize the city facilities. Custom Packing Company utilizes a septic system at present. Both Kraft Foods Company and Magic Valley Foods utilize city facilities for the treatment of their wastewater.

9) City land adjacent to site of treatment plant: The city owns no additional property in the vicinity of the treatment plant other than that required for the plant site.

10) Devices for monitoring of ground water: The city water supply is from deep wells drilled to 600 to 700 feet. There are private domestic wells in the rural area adjacent to the plant which could be monitored if a program of irrigation with the city effluent were initiated.

11) Amount of water applied during the irrigation season: The amount of water applied for irrigation varies from 3 to $3\frac{1}{2}$ acre-feet per acre for the growing season. There is a plentiful water supply for users withdrawing water from the canal company in the vicinity of the plant, but north of town there are some restrictions on the amount of water available to users.

12) Irrigation districts and water charges: The Minidoka Irrigation District (MID) charges users $4 per acre in the vicinity of the treatment plant. North of town the water charges are higher, ranging close to $10 per acre for the growing season. This averages out to approximately $1.15 per acre-foot and $3.00 per acre-foot, respectively.

13) Geologic data: Like the Burley area, Rupert's geology consists of a bedrock of Snake River Basalt covered by fluviatile and eolian sediments including Portneuf Silt Loam from the Pleistocene Epoch. The soil is light and sandy, with good infiltration characteristics. There are some problems with a high water table in those portions of the farmed land adjacent to the river.

Comments: Rupert has very good potential for the initiation of a program of irrigation with wastewater. At the present time, if it were deemed feasible to utilize existing canals for the distribution of effluent, all that would be required to accomplish the introduction of effluent into the distribution network of the MID would be the opening of a valve in the outfall line where it passes over MID's A Canal. The pumping pressure applied to the effluent as it leaves the plant also offers the possibility of spray-irrigation in pasture and row-crop in fields adjacent to the plant. A program of monitoring of the percolating effluent would be advisable in order to determine what negative effects, if any, the relatively high water table might have upon the efficiency of wastewater renovation enacted by the soil column.

Pocatello. (City data - Al McGee, Plant Supervisor. Agricultural data - M. R. Samson, Bannock County AES Agent)

1) Location of treatment plant: The treatment plant is northwest of Pocatello and approximately $\frac{1}{4}$ mile north of the Portneuf River. It is situated almost

directly opposite the J. R. Simplot phosphate processing plant and the Food Machinery Corporation (FMC) plant.

2) Distance to irrigated cropland: There is agricultural land adjacent to the plant, but the agriculture of the area has been somewhat blighted in the area by fluorine fallout (U. of I. 1968).

3) Type of crop grown and fertilizer amounts applied: The list of major crops includes forage, alfalfa, grain, sugar beets, and potatoes. Amounts of fertilizer applied vary from 10 to 120 pounds of nitrogen per acre, including 30 pounds of nitrogen on pasture, 80 to 100 pounds of nitrogen for beets and potatoes, 80 pounds of phosphate on potatoes and beets, and 40 pounds of phosphate on alfalfa.

4) Type of irrigation system used: In the Fort Hall Indian Reservation north of Pocatello there is corrugate irrigation, but in the Michaud Flats development west and southwest of Pocatello most of the irrigation is spray-irrigation. The source of water for Fort Hall Reservation is surface water, but more and more farmers in the Michaud Flats area are turning to water from private wells because the water supplied by the irrigation district serving that region is relatively expensive.

5) Vertical lift necessary: To apply the effluent to agricultural land north of the plant it would be necessary to lift the effluent between 30 and 40 feet. The elevation of the treatment plant is approximately 4430 feet, and the elevation of the rolling terrain behind the plant to the north rises to approximately 4470 feet.

6) Amount of effluent handled per day: There is no seasonality to the flow of effluent at Pocatello, and the flow ranges between 5.5 and 5.8 mgd.

7) Type of treatment: Pocatello provides primary treatment with chlorination. At present the city attempts to maintain a .5 ppm residual of chlorine in its final effluent, but the residual usually averages around .3 ppm. The plant uses 210 pounds per day of chlorine.

8) Industrial effluent not processed in city system: Simplot Chemical Company utilizes settling ponds to remove sediments from their wastewater. Zweigarts Meat Packing Company utilizes its own lagoon for the processing of its wastewater.

9) City land adjacent to site of treatment plant: The city does not own any area of land adjacent to the plant site.

10) Devices for monitoring of ground water: There are many wells in the area of the treatment plant, most of them relatively deep irrigation wells. There are some springs and seeps along the Portneuf River.

11) Amount of water applied during the irrigation season: The amount of water applied per acre to crops during the growing season averages about $3\frac{1}{2}$ acre-feet.

12) Irrigation districts: The Tyhee Flat project provides irrigation water to most of Fort Hall Reservation, while the Michaud Flats District pumps water from the Portneuf River at a point 2 miles downstream from the treatment plant. It was estimated that water costs ranged around $15 per acre-foot for the Michaud Flats area, however, this figure seems slightly high. The figure for the Tyhee Flat project was not known.

13) Geologic data: The subsoil consists of Portneuf Silt Loam overlying fluviatile and eolian sediments of sand and gravel, all of Pleistocene or later origin. The bedrock consists of Snake River Basalt.

Comments: There are possibilities of irrigation with the wastewater from the Pocatello treatment plant. Because of lack of available irrigated land closely adjacent to the plant, more study is necessary before recommendations can be made for feasibility of reuse at specific sites. An additional complicating factor is the fact that all area that could be irrigated by Pocatello effluent is Fort Hall Reservation land. Although there is no shortage of irrigation water, it may be advisable to reuse wastewater in lieu of irrigation water in order to reclaim the fertilizer in the wastewater. However, there is very little land irrigated in that portion of the reservation immediately downstream from the plant. As to the possibilities of irrigating with industrial effluent from Simplot or FMC, it is understood that Simplot's wastewater contains no toxic substances, it does contain inorganic phosphate. FMC, because of the nature of their chemical extractions, may have some toxic residue in their effluent. Before a program of terrestrial disposal could be inaugurated it would be necessary to determine the content in both sources of effluent, especially with respect to trace elements and pH.

Blackfoot. (City data - Frank Miles, Plant Supervisor. Agricultural data - M. B. Weston, Bingham County AES Agent)

1) Location of treatment plant: The treatment plant is located on the south bank of the Snake River, approximately $1\frac{1}{2}$ miles west of Blackfoot. The Blackfoot River flows parallel to the Snake River at this point, and is approximately 1 mile south of the treatment plant. A narrow band of agricultural land is sandwiched between the Snake River and the Blackfoot River. The site of the plant is a depression adjacent to the river bank, which has the appearance of an old gravel pit. This situation creates an embankment east and especially south of the plant.

2) Distance to irrigated cropland: It is approximately $\frac{1}{2}$ mile to the nearest irrigated cropland, which is to the south of the treatment plant.

3) Type of crop grown and fertilizer amounts applied: Pasture, hay, grain, and some potatoes are grown in the area near the treatment plant. Grain receives between 50 and 75 pounds of nitrogen per acre, pasture between 50 and 100 pounds of nitrogen, and potatoes as much as 200 pounds of nitrogen. Alfalfa hay is fertilized with up to 100 pounds of phosphate per acre.

4) Type of irrigation system used: Most of the irrigation is done with the corrugate system; there is very little sprinkling or spray-irrigation.

5) Vertical lift necessary: It would be necessary to lift the effluent approximately 20 feet to put it at an elevation equal to that of the embankment to the east. The elevation of the higher embankment to the south was not obtained.

but would not be more than 30 feet above that of the treatment plant.

6) Amount of effluent handled per day: The high flow occurs in the summer months as a consequence of infiltration of irrigation water into the city sewer lines. The average high flow volume is 1 mgd, but can go as high as 2 mgd. In March the low flow averages .5 mgd.

7) Type of treatment: The city provides primary treatment with chlorination of its effluent at this time. The chlorine residual is very low, varying between zero and .1 ppm. The zero reading occurs during the maximum flow period for the day, and this reading occurs in spite of the fact that between 70 and 80 pounds of chlorine were being used per day, at a cost of 13¢ per pound. Secondary facilities are scheduled, and will have a design capacity of 250,000 population equivalent.

8) Industrial effluent not processed in city system: The American Potato Company provides primary clarifiers for its wastewater; it produces the effluent of a population equivalent of 75,000. Idaho Potato Starch Company provides sedimentation for its wastewater, but the treatment is largely inadequate. Several meat packing companies, including Hopkins Packing Company and Mickelsens Packing Company treat wastewater independently of the city system.

9) City land adjacent to site of treatment plant: The city owns 9 or 10 acres adjacent to the plant in addition to that land incorporated into the treatment plant site. High rate application via infiltration basins to obtain a final, "polished" effluent may be feasible. There is some riparian ground consisting of unconsolidated silts, sands, and gravels with excellent infiltration characteristics which could be used for this purpose. This riparian ground would not be available during periods of high flow in the Snake River, but during periods of low flow the lower water table may allow the use of such ground.

10) Devices for monitoring of ground water: There are no irrigation wells in the area of the treatment plant, but a number of domestic wells for rural residences would be available to monitor the quality of ground water under a program of irrigation with effluent. Springs and seeps along the bank of either the Snake River or the Blackfoot River could also be monitored.

11) Amount of water applied during the irrigation season: There is an abundant supply of water for users withdrawing water from the canals of the several irrigation districts. As much as 4 to 5 acre-feet of water are applied per acre.

12) Irrigation districts and water charges: The Miners Ditch passes by closely adjacent to the plant, and the Treageau Ditch and the Peoples Canal also serve water users in the area. Water charges average around $2.33 to $3.00 per acre, or between $.60 and $.75 per acre-foot.

13) Geologic data: The area is characterized by fluviatile and eolian deposits of clay, silt, sand and gravel from both Pleistocene and Recent deposition. The soil is basically Portneuf Silt Loam, varying from 6 inches to 5 feet in depth. The area is underlain by basalt at a range of depths.

Comments: Blackfoot has possibilities for the irrigation of cropland with its effluent, but such a program will face complications common to several of the other sites discussed. One of the complications is the fact that during the irrigation season the water table is close to the surface in areas adjacent to the treatment plant. A problem that the city must cope with when secondary facilities are completed is the fact that the principal suppliers of wastewater, Idaho Potato Starch and American Potato, are situated on the north bank of the Snake River, upstream and opposite the site of the treatment plant. Expensive transfer facilities will be required to move the effluent to the treatment plant. These firms do have a locational advantage with respect to consideration of irrigation with their wastewater. Abundant cropped land lies north of these facilities, and it is possible that an economic means of treating their wastewater could be the irrigation of crops with the effluent. More study and geologic analysis of the site should be conducted before specific recommendations are made. The nutrients in the effluent from either the domestic wastewater or the industrial wastewater should promote interest on the part of agriculturists in the use of such a valuable resource.

Shelley. (City data - Earl Barsanti, City Foreman. Agricultural data - M. B. Weston, Bingham County AES Agent)

1) Location of treatment plant: The treatment plant for Shelley is adjacent to the south bank of the Snake River, approximately $1\frac{1}{2}$ miles west of the city. The plant is at approximately the same elevation as the level, low-lying agricultural area adjacent to the site.

2) Distance to irrigation cropland: Irrigated cropland is adjacent to the plant site.

3) Type of crop grown and fertilizer amounts applied: Potatoes, grain, corn, sugar beets, and alfalfa are the major crops for the region. Nitrate applications range from 50 pounds to 300 pounds per acre for different crops, and phosphate applications range from 50 to 200 pounds per acre.

4) Type of irrigation system used: In the flat, level ground adjacent to the treatment plant, flood irrigation is common. The more recently developed agricultural land in areas removed from the plant site utilize sprinkler irrigation.

5) Vertical lift necessary: There would be only a minimum lift (less than 15 feet) necessary to empty the effluent into Reservation Canal, which flows adjacent to the southeast corner of the plant.

6) Amount of effluent handled per day: These data are not known as no flow meters are utilized in the city system.

7) Type of treatment: The city utilizes lagoons for its wastewater treatment. There is no chlorination of the final effluent.

8) Industrial effluent not processed in city system: According to Mr. Earl Barsanti, Shelley City Foreman, the R. T. French potato processing company presently dumps its wastewater directly into the Snake River through a 24 inch outfall line. This large-capacity line is required because of the periodically

high-volume flow emanating from the plant during operating periods. Wattenbarger Meat Products also empties untreated wastewater into the Snake River at Shelley.

9) City land adjacent to site of treatment plant: There is no additional land owned by the city in the vicinity of the treatment plant other than that incorporated into the plant site itself.

10) Devices for monitoring of ground water: There are some domestic wells for rural residences, and the city utilizes deep wells for its domestic supply. There are springs and seeps along the bank of the Snake River that would also aid in monitoring ground water if a program of agricultural irrigation with effluent were initiated in the area adjacent to the plant.

11) Amount of water applied during the irrigation season: There is an abundant supply of water for users in Shelley, and it is common for agriculturists to apply 4 to 5 acre-feet per acre for a growing season.

12) Irrigation districts and water charges: Reservation Canal irrigation water is diverted from the Snake River into the canal at a point approximately $\frac{1}{2}$ mile upstream from the lagoon system for Shelley. Water charges are approximately $3 per acre for the irrigation season, or about $.75 per acre-foot.

13) Geologic data: Fluviatile and eolian deposits of clay, silt, sand and gravel from Pleistocene and Recent times predominate in the alluvial material of the rivery valley. In areas closely adjacent to the valley are found large expanses of Snake River Basalt exposed at the surface with little soil material overlying the lava flows. Soil depths in the agricultural land vary from 1 to 15 feet in depth, and the soil is classified as Bannock Loam.

Comments: The water table is less of a problem at Shelley than at most of the other sites discussed, but it could still present problems because it rises above a depth of 5 feet on occasions in some of the area near the treatment plant. The soil has ideal characteristics for an efficient renovation of effluent, and the region presently has a need for an economical means of treatment of wastewater, especially for the industrial wastewater generated by the R. T. French Company and the Wattenbarger Meat Products Company. A difficulty that would be experienced with the use of domestic effluent from the city is that during the summer months there is no discharge from the city lagoons. This means that evaporation and infiltration account for the total inflow of effluent, resulting in a minimum contribution by the city to the nutrient load of the Snake River.

Idaho Falls. (City data - Lowell Roskelley, Idaho Falls and Bonneville County Sanitarian and personnel of City Planning Commission. Agricultural data - John Moss, Doyle J. Hanson, Bonneville County AES Agents)

1) Location of treatment plant: The treatment plant is adjacent to the south bank of the Snake River, approximately $1\frac{1}{2}$ miles downstream from Idaho Falls. The plant elevation is 4675 feet, while the elevation of the water surface of the river is 4654 feet. The plant site is at a level with the surrounding agricultural land.

2) Distance to irrigated cropland: Irrigated cropland is adjacent to the plant.

3) Type of crop grown and fertilizer amounts applied: Potatoes, grain, alfalfa hay and some sugar beets predominate among the crops grown in the area adjacent to the plant. Between 100 to 150 pounds of nitrogen per acre are applied to potatoes, with similar figures for phosphate. For grains 100 to 150 pounds of nitrogen and 40 to 80 pounds of phosphate are applied, and up to 180 pounds of nitrogen and phosphate are applied to sugar beets. Farmers apply 80 to 100 pounds of phosphate to alfalfa.

4) Type of irrigation system used: Flood irrigation and corrugate irrigation predominates, with very little sprinkling or spray-irrigation.

5) Vertical lift necessary: The outfall line is at some depth beneath the elevation of the treament plant. If distribution of the effluent via canals was to be considered, it would require a lift of approximately 20 feet and a horizontal carry of .75 miles to a major distribution canal (Butte Arm Canal). Pumping directly from the plant and bypassing the outfall line would minimize this lift.

6) Amount of effluent handled per day: The peak volume occurs in the summer months, with infiltration of irrigation water into the city sewer lines occurring when the water table rises close to the surface. In this period the volume will range between 4.5 to 6 mgd. In the winter months the inflow volume will drop to 2.5 mgd. The total volume of effluent will double when the city inaugurates a system of treatment for the industrial sources of wastewater. Presently few of the industrial operations utilize city facilities.

7) Type of treatment: Primary treatment with chlorination is provided by the city. The cost of chlorination for an average flow is approximately $24 per day (300 pounds at 8¢ per pound), and chlorine residual is minimal (less than .5 ppm). Secondary facilities will be required by 1971.

8) Industrial effluent not processed in city system: Rogers Brothers Potato Company, Idaho Potato Growers, Idaho Potato Foods, Utah-Idaho Sugar, Taylor Meats, Idaho Falls Meats, Challenge Dairy, Wallace Dairy, Pleasant Valley Dairy, Southland Produce, Menan Potato Starch, and Idaho Potato Starch presently connected to the city sewers, but choose not to utilize the connection and presently continue to empty relatively untreated wastes into the Snake River and American Falls Reservoir. Only Utah-Idaho Sugar Company plans to remain separate from the system.

9) City land adjacent to site of treatment plant: The city owns some acreage adjacent to Fielding Memorial Cemetary, approximately $\frac{1}{4}$ mile from the plant site. The exact extent of acreage was not determined.

10) Devices for monitoring of ground water: There are no deep irrigation wells in the area of the plant, but domestic wells for rural residences exist. Springs and seeps do exist that will facilitate the monitoring of ground water quality if a program of irrigation with wastewater is inaugurated.

11) Amount of water applied during the irrigation season: Between 3 and 4 acre-feet of irrigation water are applied per acre.

12) Irrigation districts and water charges: The Butte Arm Canal District serves the agricultural area adjacent to the plant, but water charges were not determined. There is no shortage of water for present day users.

13) Geologic data: The bedrock of basalt from Early and Late Pliocene and Pleistocene flows crop out over much of the area west of Idaho Falls. In the river valley, Portneuf Silt Loam of varying depth overlies fluviatile and eolian deposits of Pleistocene origin, comprised of sands and gravel and some clay. Thickness of unconsolidated sediments is variable.

Comments: There are very good possibilities that Idaho Falls could develop a system of tertiary treatment of its effluent utilizing terrestrial disposal. The city owns a limited amount of acreage close to the plant, and during the course of the field visit the possibilities of utilizing portions of this property for a pilot program of irrigation with city effluent were discussed with members of the City Planning Commission. The water table does not rise within 5 feet of the surface in the agricultural land adjacent to the plant, and the geology indicates promise of favorable conditions for infiltration and percolation. There may be some problems associated with the monitoring of ground water quality and with the acquisition of meaningful readings from the samples because of the adjacency of the cemetary to the site for potential irrigation. Tertiary treatment of the industrial and domestic wastewater in the Idaho Falls area would be a valuable service; there is a good possibility that an awareness of the nutrient value contained in wastewater will interest the adjacent agricultural community relative to the reuse of this resource.

Potential for Reuse of Wastewater in Northern Idaho

The lower population and the smaller number of centers of high population and industrial concentration in northern Idaho have resulted in fewer problem areas in that portion of the state. Furthermore, irrigation is practiced to a lesser extent in northern Idaho than in southern Idaho. Therefore, the potential for wastewater reuse is somewhat diminished. However, a few areas do merit consideration.

The cities along the South Fork of the Coeur d'Alene River do not as yet provide primary treatment and it has been demonstrated that the South Fork is a source of phosphorous for Coeur d'Alene Lake (Williams, 1969). Although algae blooms have been reported in portions of Coeur d'Alene Lake, the effect of this source of nutrients on the lake has not been sufficiently documented for strong generalizations. If future studies should deem it necessary, there is some potential for terrestrial disposal of the wastewater from the cities along the South Fork and the main stem of the Coeur d'Alene River via forest irrigation. The mining companies along this river either have installed or are in the process of installing settling ponds to eliminate their contributions of suspended solids.

Sources of nutrients for other lakes in northern Idaho also need additional investigation. In some cases wastewater from residences on these lakes may be sources of nutrients. Where such is the case the installation of a holding tank would facilitate periodic spraying of the wastewater onto adjacent forested or shrub covered land. The advisability and feasibility of the implementation of residential reuse systems should be investigated in areas such as Hayden Lake.

Data are needed on volumes of effluent produced, nutrient content of effluent, density of residences, frequency of occupancy, and hydrogeologic conditions adjacent to each lake in question.

Two of the larger communities in northern Idaho can be included within a discussion of the cities of the Snake River Basin. These two cities are Lewiston and Moscow. Both centers are experiencing problems as a consequence of pollution of streams receiving the effluent discharge from each center. Moscow experiences its problems because the receiving stream has no significant diluting capacity during the summer. Lewiston experiences a problem now because even with the flow of two major streams (the Clearwater and Snake Rivers) its output of effluent is still capable of creating obnoxious and unaesthetic conditions along the bank the stream course. Changes will occur in the Lewiston situation once slack water is created in the area as a consequence of downstream impoundment. Increased treatment facilities are being planned. Outside the Snake River Basin the City of Coeur d'Alene produces sufficient effluent to merit discussion. A discussion of each site in more detail follows.

Lewiston. (City data - Mr. Vern Grieser, Lewiston Sewage Treatment Plant Supervisor. Agricultural data - R. L. Kambitsch, Charles Thomas, Nez Perce County AES Agents)

1) Location of treatment plant: The Lewiston plant is situated on the north bank of the Clearwater River approximately ½ mile above the confluence of the Clearwater with the Snake River. The site is a narrow terrace of alluvium; to the north the sloping valley wall rises from the 750 foot elevation at river level to the 2500 foot plus elevation of the North Idaho Palouse hills.

2) Distance to irrigated cropland: Some irrigation of truck garden crops has been practiced in the past in portions of the alluvial terrace adjacent to the adjacent to the plant, but this agricultural area will be converted to dock sites and some urban development. The sloping area directly above the plant is in wheat and dry-land pasture at present. It may be possible to consider the application of secondary or primary effluent to sprinkler irrigation of this agricultural area above the plant.

3) Type of crop grown and fertilizer amounts applied: The land under cultivation is planted primarily in grain crops and pasture. Phosphate is quite limited in use but recommended in some areas of farming in the Lewiston area. The average nitrogen application is 60 pounds on irrigated pasture and somewhat less on orchards.

4) Type of irrigation system used: No irrigation is practiced at this time on most of the land in question.

5) Vertical lift necessary: To apply the effluent from Lewiston's treatment plant to pasture and cropped land located on the rolling surface of the hills above and north of the plant would require a lift of 50 to 200 feet.

6) Amount of effluent handled per day: During the high flow period in the summer the July flow has averaged 2.12 mgd, while in February it has been as low as 1.60 mgd.

7) Type of treatment: Presently Lewiston provides primary treatment with chlorination. By 1972 Lewiston is scheduled to have completed facilities for secondary processing of wastewater.

8) Industrial effluent not processed in city system: Potlatch Forests Industries presently treats its own wastewater. The two food processing plants, Seabrook Farms (now Twin City Foods) and Smith Frozen Foods, do not provide treatment for their wastewater and face the necessity of finding an economical means of handling their large volume of high BOD effluent during the seasonal period of plant operation or else cease operations.

9) City land adjacent to plant: The city owns approximately 10 acres near the plant. This land is in grass and a rose test garden. The remainder is used for a ball park.

10) Devices for monitoring of ground water: It would be necessary to install shallow piezometers to collect ground water samples for chemical analysis if a program of irrigation with effluent were initiated at Lewiston. Some springs and seeps are also available for such a program of monitoring of ground water quality during irrigation with effluent.

11) Amount of water applied during the irrigation season: No irrigation of agricultural crops is done in the area of the treatment plant, and there is no known demand for such irrigation at this time.

12) Irrigation districts: There are no irrigation districts in this portion of the Lewiston area.

13) Geologic data: Terrace deposits of sand, gravel, silt, and boulders in former stream channels are located in areas adjacent to the plant, with the Clearwater escarpment (the hills rising north of the plant) consisting of a structural downwarp of Miocene Columbia River Basalt with intercalated sediments, rising above and north of the plant approximately 2000 feet. The alluvial deposits in the valley bottom are of Pliocene, Pleistocene and Recent origin. Topographically the area is somewhat similar to that of the Lake Tahoe wastewater reuse project described by Foster (1965).

Comments: There is potential for the reuse of wastewater via irrigation of pasture on the Lewiston Hill. Such a program could be conducted on a year-round basis, and could prove economically feasible. This is particularly true with respect to the irrigation with food processing wastewater. At this time it is not known whether the two plants in Lewiston can economically implement secondary treatment of their wastewater at a cost low enough to justify their continued operation at the present sites on the south shore of the Clearwater River. For the City of Lewiston to undertake the treatment of this source of industrial wastewater would require an expansion of the city treatment plant capacity; this increased plant capacity would lie idle and unused for about 9 of 12 months each year. But, a program of irrigation with food processing wastewater should be examined further as an economical answer to the problem of disposal and renovation of this effluent. A similar proposal is also suggested for consideration by Potlatch Forest Industries. It is possible that dry-land pasture south of PFI could be utilized for the irrigation of pulp-and-paper-mill wastewater on a year-round basis, and provide disposal and renovation of such wastewater at a cost less than that for conventional advanced treatment facilities. The literature on such irrigation with pulp-and-paper mill wastewater has demonstrated this fact of economics. In addition, the city may wish to consider reuse of its wastewater for irrigation of the land above the treatment plant site. Irrigation during the summer would minimize the nutrient contribution to the slack water of the anticipated reservoir.

Moscow. (City data - Orrin Crooks, Sewage Treatment Plant Supervisor. Agricultural data - Homer Futter, Leonard Burns, Latah County AES Agents)

1) Location of treament plant: The Moscow plant is located adjacent to Paradise Creek approximately ½ mile west of the city limits for Moscow. Paradise Creek joins the South Fork of the Palouse River at Pullman, Washington, approximately eight miles west of Moscow and of the treatment plant. The Palouse River eventually empties into the Snake River. The agricultural land adjacent to the plant is owned by the University of Idaho.

2) Distance to irrigated cropland: Some irrigation water for the University of Idaho farms is withdrawn from Paradise Creek approximately 200 yards downstream from the outfall line for the treatment plant. This water is utilized for the spray-irrigation of a tree farm on University property. In the summer when the University is withdrawing water from the creek, its flow is largely composed of treatment plant effluent.

3) Agricultural data: The University maintains a varied program of cropping and fertilization in their experimental operations. For this reason there is little purpose served in attempting generalizations for such practices as amounts of fertilizer applied, amounts of irrigation water used, or types of crops grown.

4) Vertical lift necessary: The University must lift irrigation water between 20 to 230 feet to apply it to the land presently irrigated. If it were deemed feasible to irrigate portions of the University Golf Course, a horizontal carry of approximately ½ mile to 3/4 mile would also be required.

5) Amount of effluent handled per day: The high flow period for the Moscow plant occurs in the winter months. The plant handles from 1.5 to 2.1 mgd during this period. In the summer months the flow drops to a range between .85 and .98 mgd.

6) Type of treatment: The City of Moscow provides secondary treatment for its effluent, and its treatment plant is one of the most efficient and complete in terms of wastewater renovation within the State of Idaho. Even so, a considerable concentration of nutrients are made available for the increased growth of aquatic vegetation in the receiving stream (Paradise Creek).

7) Additional data: There is no additional land adjacent to the treatment plant site owned by the city that could be used in a program of wastewater irrigation. There is no industrial effluent produced in the area of Moscow.

8) Geologic data: The Moscow area is underlain by Columbia River Basalt of Upper Miocene age covered by variable deposits of loess of eolian deposition (Palouse Formation) during and after the Pleistocene Epoch. The topography is gently rolling terrain with local relief seldom more than 250 feet. In the creek bottom are found terrace deposits of Pleistocene and Recent origin.

Comments: The Moscow-Pullman area is identified by the FWPCA as one of the 11 areas in the Snake River Basin that requires attention because of a distinct problem with water pollution of the streams adjacent to these cities. The source of this pollution is nearly entirely contributions from domestic wastewater. If a program of irrigation with domestic wastewater were inaugurated, much of Moscow's contribution to this stream pollution during the critical summer months would be ended. Irrigation of golf course fairways in the summer months would provide a practical solution to disposal of effluent where University agricultural experiments might not allow the use of all the nutrient-containing irrigation water. The lack of ability to control the concentrations of fertilizer value contained in the effluent might have negative consequences with respect to the control needed to be exercised over the agricultural experiment. But irrigation of the golf course or pasture would be highly desirable in the area of the treatment plant. The soil profile and the thick, unconsolidated loess are excellent with respect to the ability of the soil column to treat and renovate the effluent applied in a system of terrestrial disposal. Treatment and irrigation with effluent during the summer months is especially critical as this is the period of low streamflow and minimum dilution of effluent.

Coeur d'Alene. (City data - James Key, Assistant City Engineer and Glen Dill, Plant Supervisor. Agricultural data - Clyde Stranahan, Kootenai County AES Agent)

1) Location of treatment plant: The Coeur d'Alene sewage treatment plant is located on the southwest side of the city approximately 50 to 100 feet from the north bank of the Spokane River, on the edge of the Coeur d'Alene city limits.

2) Distance to irrigated cropland: Approximately two miles downstream from the treatment plant irrigation approximately 4500 acres are utilized pasture and cropland. One mile from the plant site a golf course is located which could be considered as a site for the potential irrigation with treated sewage effluent. The course presently is irrigated with ground water.

3) Agricultural data: The crops planted in the 4500 acre area consist largely of wheat, lawn grass seeds, green beans, hay and pasture. Fertilizer amounts applied are 150 pounds of nitrogen and 60 pounds of phosphate per acre of grass seed, and 50 to 60 pounds of nitrogen and 20 to 30 pounds of phosphate per acre on grains and pasture. An average of 33 inches of water per acre are applied to grass seed, 12 inches per acre are applied to grains, and 21 inches on pasture and hay.

4) Vertical lift necessary: The elevation of the outfall line for the treatment plant is not known, but irrigation water is presently pumped from the Spokane River at a point approximately 2 miles downstream from the plant site. If the treatment plant effluent were to be transported via canal or pipe downstream to the point where irrigation water is presently being pumped from the river, the total lift required to apply the wastewater to agricultural land would be less than the lift required for the use of river water because the wastewater transport would be situated some distance above the stream bank.

5) Amount of effluent handled per day: The high flow occurs in the summer months when the plant is required to process as much as 3 mgd, with approximately $\frac{1}{2}$ of this inflow coming from the inflow of groundwater into the city sewer lines. In the winter and early spring the inflow drops to an average of 1.5 mgd.

6) Type of treatment: The city provides secondary processing of its effluent with chlorination. A chlorine residual of 6 ppm is generally sought, and the city utilizes slightly less than 9 tons of chlorine per year at an average cost of $2500 (about $.14 per pound). The detention time is short because the city plant has no holding tank for the final effluent after the chlorine is added. This is the reason for the high chlorine residual.

7) Additional data: The city obtains its domestic water supply from both surface water and groundwater. Two wells (approximately 200 feet) supply a portion of the city's domestic water, and the rest is obtained from Coeur d'Alene Lake. Domestic wells are located in the area.

8) Geologic data: The golf course and the agricultural ground are situated upon thick deposits of Pleistocene gravels and sand. The Garrison gravelly loam and Springdale gravelly loam occur at the surface.

Comments: The soil column offers excellent potential for renovation of wastewater and has good infiltration and percolation characteristics for the handling of volumes of the effluent. Problems with high water tables should be minimal near the irrigated area. The potential for forest irrigation with effluent is not known, but should be examined, although the transport of the wastewater to the irrigated area should receive first consideration.

SUMMARY AND RECOMMENDATIONS

The studies discussed and cited herein have demonstrated that the reuse of wastewaters is feasible and safe under proper management and under proper hydrogeologic conditions. Reuse of wastewater aids in the elimination of the addition of nutrients contained therein to surface water bodies. Concomitantly, aquatic plant growths which feed on these nutrients are reduced.

These studies have ascertained also that the fertilizer value of the nutrients in a domestic effluent may be as much as $18 per acre-foot of effluent. This fertilizer value may make the use of wastewater preferable to the use of ordinary irrigation water even where the latter is not in short supply. It has been demonstrated that intermittent spray irrigation produces the most desirable results, although other techniques can be utilized. Chlorination of domestic effluent is recommended prior to reuse; however, food processing plant effluents are commonly used without chlorination.

Optimum hydrogeologic conditions include the occurrence of near surface unconsolidated materials which can act as a renovating medium for the wastewater. The water table should be at least 5 feet below the ground surface. Wastewater has been reused in areas where the water table is less than 5 feet below the surface, after the installation of tile fields. Israeli studies have suggested that a saturated flow path length of about 260 feet is required to renovate domestic wastewater to potable standards without renovation by vegetation at the area of application; however, this figure can be expected to vary considerably with geologic conditions.

Included among those communities in Idaho where wastewater reuse merits consideration are Coeur d'Alene, Lewiston, Idaho Falls, Weiser, Rupert, and Nampa. Wastewater from the cities of Moscow, Buhl, Mountain Home, and Jerome are already used on a part-time basis. Wastewater reuse in some of the latter communities may have potential for expansion. In Moscow, for instance, it should be possible to use all the effluent from the treatment plant during the summer period of low flow in Paradise Creek if the University golf course were irrigated with the effluent. This report discusses the pros and cons of wastewater reuse in each of the above areas.

Further investigation is needed in the vicinity of several other communities in Idaho prior to reuse of wastewater. The Boise area is an example of such a case. Although the area immediately adjacent to the city has potential shallow water table problems, it may be advisable to transport the city's effluent downgradient in an existing canal to locations such as the Dry Creek area where this problem is less acute.

A surprising number of cities in southern Idaho experience an increase in sewage treated during the irrigation season. The implication is that during these periods the water table rises to or above the elevation of the sewage collection system. If irrigation with wastewater is implemented near such cities, the quality of the shallow ground water and the effluent should be monitored on a regular basis. Regardless of whether reuse is implemented in such communities the local use of ground water which has been recharged coincidentally with irrigation should be considered. Pumping from shallow wells may reduce the hydraulic loading on treatment plants by lowering the water table to elevations below that of sewage collection systems, in addition to being an inexpensive source of water.

In northern Idaho additional research is needed to ascertain the residential contribution of nutrients to several small lakes. Wastewater reuse may be adaptable to such environments, however, the relationship between residential development and nutrient contribution should be the subject of further investigation.

Finally, there are several food processing operations in Idaho which should investigate reuse of their own wastewater, particularly if there is no plan for future incorporation of these wastes into a municipal treatment system. The food processing plants in Idaho are listed in Tables 12 and 13A. This list can be compared with the discussion on the geology adjacent to the city near which each plant is located in order to identify those operations located in hydrogeologically favorable environments. A thorough analysis of each plant's wastewater should be conducted before the water is reused. Such analysis will authenticate the absence of compounds and trace elements which may be harmful to plants.

Little effort has been devoted to the legal aspects of wastewater reuse in Idaho. Any legal problems concomitant with terrestrial disposal undoubtely can and should be resolved on an individual site basis. Similar statements apply to cooperative arrangements between supplier and user. On the basis of interviews with persons associated with both groups, it appears that most potential participants are genuinely interested in the elimination of the addition of nutrients to Idaho's water bodies and to the reuse of those nutrients for fertilization. The predominance of this attitude offers encouragement for the establishment of wastewater reuse projects throughout the State where hydrogeologic and agricultural conditions permit.

The dollar value of a clean stream has received no mention in this report. Indeed, it has been pointed out that many wastewater reuse operations have functioned on their own economic merit. The writers have discussed several communities in Idaho wherein wastewater could be diverted into already existing canals for distribution with little or no additional pumping cost. It should be noted, however, that the assignment of a small value to a clean stream may make some wastewater reuse operations economically more palatable.

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