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In 1968, a study conducted by the sanitarians of the State Health Division and Benton County Health Department revealed a high failure rate of on-site sewage disposal systems in Southwest Corvallis. The survey team concluded that sewage disposal in this area was inadequate, and a significant health hazard existed due to contamination of the watershed. Following these findings, a part of Southwest Corvallis was annexed to the city of Corvallis and sewered. The rest of the community remained unsewered and continued to use on-site sewage disposal systems.

This follow-up study, therefore, was designed to quantitatively determine and compare the bacteriological levels of watershed contamination in the sewered and the unsewered area. Specifically, this investigation was to determine if the replacement of on-site sewage disposal systems by municipal sewer service in the sewered area significantly reduced surface water contamination and subsequently eliminated the sewage related health hazards.

Major hypotheses tested in this study were:

Ho_1: μ_{1968} bacteriological levels = μ_{1979} bacteriological levels in the sewered

area (i.e.: There is no significant difference between the mean bacteriological levels before and after municipal sewer connections.)

Ho_2: u_{1968} bacteriological levels = u_{1979} bacteriological levels in the unsewered area (i.e.: There has been no significant change in bacteriological level in the unsewered area since 1968.)

According to the 1968 investigating team, sampling sites were chosen within the guidelines of sampling procedures given in The Standards Methods for the Examination of Water and Wastewater. The current investigator closely followed the same guidelines, and since this was a comparative study, samples were obtained from the 22 sampling sites that were chosen in 1968 by previous investigators.

From the findings of this study the following conclusions have been drawn.

1. The replacement of individual on-site sewage disposal systems with municipal sewage systems significantly reduced the level of surface water contamination. Subsequently, the sewage related health hazards has significantly diminished in the sewered areas. The null hypothesis was rejected at $\alpha = 0.01$.

2. The levels of surface water contamination were still the same in the unsewered area. Thus, the sewage related health hazards still existed in the area. The null hypothesis was rejected at $\alpha = 0.01$.

The findings, therefore, strongly suggested that municipal sewer systems were more effective than the on-site sewage disposal systems in the area studied.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

A COMPARISON OF WATERSHED CONTAMINATION BETWEEN A SEWERED AND AN UNSEWERED COMMUNITY

INTRODUCTION

The improper disposal of human excreta and sewage is among the most important problems of environmental health. It is currently a major factor threatening the health and comfort of individuals in areas where municipal sewage systems are not available (57). The human excreta is not only offensive but also dangerous to health since it is responsible for the perpetuation of certain diseases. Investigations have revealed that very large numbers of different disease-producing organisms can be found in the fecal discharges of ill and sometimes healthy individuals. The greatest biological danger in water, is pollution from human and animal sources. All the discharges from the body -- urine, feces, expertoration, secretions from the nose, and washings from the skin find their way sooner or later into streams, lakes, creeks or even into a public water supply. Leich poignantly sums up the extent of this sewage problem when he states:

> Human beings can land on the moon, but anticipated, unsanitary sewage disposal systems are still used on the earth. To a visitor from another planet it would seem incredible that human beings, sophisticated enough for space travel, solve their problems of personal hygiene by flushing their body wastes into the public water supply and then spend billions in futile efforts to restore the water to its original condition (73, p. 9)

Leich (73) adds that it is scientifically possible, but just not practical to restore water completely once it has been contaminated with sewage. The purification of drinking water has long been a part of envirionmental control programs and is considered a traditional "environmental sanitation" activity. Yet, a study in the early 1970's showed that approximately eight million people in the United States were using water supplies which did not meet the quality standards recommended by the federal government and, thus, were potentially dangerous to public health (60).

On a worldwide scale, the pollution of water supplies is probably responsible for more human sickness than any other environmental influence. Water contaminated with sewage serves as a common and important vehicle of transmission for the pathogens which cause many serious human diseases. Approximately 4,000 cases of waterborne illnesses occur annually in the United States (40).

The principal pathogens include strains of Salmonella, Shigella, Enteropathogenic Escherichia Coli, Leptospira, Vibrio, Mycobacterium, human enteric viruses, cysts of Endamoeba Histolytica, and hookworm larvae (20). Since human excreta is a major source of these pathogens, monitoring sewage for their presence has been demonstrated to be an excellent epidemiological tool for determining what diseases may be prevalent in the community at any moment. A few human pathogens are also found to frequent the intestinal tract of the other warm-blooded animals, including animal pets, livestock, poultry and the wild animal community (19). The animals acquire these pathogens through contaminated foods and water sources. Such animals may themselves become infected by these pathogens or serve merely as natural carriers. Inappropriate use of septic tank systems and other ineffective disposal methods have contributed to the increase of these pathogens in our environment (21).

In the United States, the most commonly used sewage treatment systems in the unsewered areas are the septic tank systems. However, the proper performance of these systems depends largely upon the ability of the soil materials to absorb and purify the wastewater. Failure occurs if either of these functions are not performed simply because both are directly related to the hydraulic conductivity characteristics of the soil, which are controlled by the pore geometry of the material. Recent reports indicate that soils in many areas, perhaps in as much as ½ of the United States, are not suitable for septic tank-soil absorption systems (29). Brewer et al states that:

> Nearly one-third of the homes in the United States are located in unsewered areas and must rely on some form of individual treatment and disposal systems dealing with household waste. The most commonly used treatment system is the septic tank and leach field. However, in several areas and in some circumstances, septic tank-leaching field systems may not be the best choice. Such systems are normally ruled out on the basis of limited land area for leaching, shallow ground water table or high rockstrata, or poorly permeable soil (tight soil). The U.S. Soil Conservation Service estimates that at least 68 percent of the land in the United States is unsuitable for leaching systems (55, p. 186).

In spite of these obvious limitations and potential for pollution, millions of conventional septic tank systems will continue to be used throughout the United States and the rest of the world. The U.S. Public Health Service estimated that in 1967, 25 percent of the homes were being constructed with on-site sewage disposal systems (40). During 1970, approximately 30 percent (19.5 million households) in the United States disposed of their sewage by some form of private sewage facilities (42).

Further, this number is growing at an increasing rate, largely because of an emerging trend of population movement to rural areas where community sewage treatment facilities are not accessible. Otis et al reported that:

> Retired persons are moving back to rural areas, as well as young families who are following the growth of industries on the outlying fringes of metropolitan centers. Most of these rural households utilize septic tank systems to dispose of their wastewater. Because of poor soil, design, construction or maintenance, however, a large number of these systems are failing to provide adequate treatment and disposal of their sewage. In such instances, failing septic tank systems which allow raw or poorly treated sewage to reach the ground surface, surface body of water or even the groundwater, create a severe public health hazard and nuisance because of the close proximity of homes. Public wastewater facilities are often the only solution to abate the problem (42, p. 1).

Many public health authorities feel that septic tank systems are suitable only in areas where population density is strictly small and soil conditions are suitable for effective absorption (29). Others (44, 42) believe that it is almost impossible to protect public water supplies from sewage contamination so long as people continue to use septic tank systems and any other ineffective on-site sewage disposal systems. In any case, the primary goals of proper disposal of sewage are to protect the public health and prevent deterioration of our environment.

STATEMENT OF THE PROBLEM

A survey which was conducted by Public Health sanitarians of the Oregon State Health Division and the Benton County Health Department, in

1968, concluded that sewage disposal in south Corvallis and southwest Corvallis was so inadequate that significant health hazards existed due to failure of individual sewage disposal systems. In 1969, south Corvallis was annexed and is currently utilizing the municipal sewage disposal system, whereas the southwest Corvallis area is still on individual sewage disposal systems and continues to have failing septic tank systems.

The purpose of this investigation, therefore, was to quantitatively determine the bacteriological levels of watershed contamination in two Corvallis neighborhoods before and after municipal sewer service.

Statement of the Hypotheses

This investigation was designed to test the following hypotheses which are stated in the null and alternate forms.

Ho_1: μ_{1968} bacteriological levels = μ_{1979} bacteriological levels in the sewered area (i.e.: There is no significant difference between the mean bacteriological levels before and after municipal sewer connections.)

Ha_1: μ_{1968} bacteriological levels $\neq$ μ_{1979} bacteriological levels in the sewered area (i.e.: There is significant difference between the mean bacteriological levels before and after municipal sewer connections.)

Ho_2: μ_{1968} bacteriological levels = μ_{1979} bacteriological levels in the unsewered area (i.e.: There has been no significant change in bacteriological level in the unsewered area since 1968.)

Ha_2: μ_{1968} bacteriological levels $\neq$ μ_{1979} bacteriological levels in the unsewered area (i.e.: There has been significant change in bacteriological levels in the unsewered area since 1968.)

Assumptions

This study was conducted on the premise of the following assumptions:

1. Any environmental variable which remains outside the researcher's rigid control, such as rain and temperature, will affect both neighborhoods uniformly.
2. Water samples collected from each sampling site will be a true representative sample.
3. The sum variance ($S_1^2 + S_2^2$) remains constant for the paired observations.
4. Populations have not changed significantly in either neighborhood.

Definition of Terms

COLIFORM INDEX - A rating of the purity of water based on a count of fecal bacteria (coliforms).

COLIFORM ORGANISMS - Organisms found in the intestinal tract of humans and animals, their presence in water indicates pollution and potentially dangerous bacterial contamination.

DRINKING WATER STANDARDS - A list of standards prescribed for water acceptable for public consumption. The standards concern sources, protection, and bacteriological, biological, chemical, and physical criteria - some mandatory, some desired.

EFFLUENT - Sewage, water, or other liquid, partially or completely treated or in its natural state, flowing from a reservoir, basin, or treatment plant into receiving streams or marine coastal waters. Generally refers to water pollution.

FECAL COLIFORMS - A subgroup of coliform bacteria that has a high positive correlation with fecal contamination associated with all warm blooded animals. These organisms can ferment lactose at 45.5^{o}C and produce gas in a multiple tube procedure or acidity in the membrane filter procedure (M-FC Medium).

FECAL STREPTOCOCCI - Bacterial indicators of fecal pollution whose normal habitat is the intestinal trace of man and other warm-blooded animals.

GROUNDWATER - The supply of freshwater under the earth's surface in an aquifer or soil that forms a natural water resource.

INDICATOR ORGANISMS - Enteric microorganisms which are used to detect fecal pollution of water.

INDIVIDUAL SEWAGE DISPOSAL SYSTEM - A single system of sewage treatment tanks and disposal facilities serving only a single lot.

ON-SITE SEWAGE DISPOSAL SYSTEM - A subsurface sewage treatment facility in which soil plays an important role in the treatment of sewage.

PERCOLATION - Downward flow or filtering of water through pores or spaces in rock or soil.

RECEIVING WATER - Any body of water where untreated waste are dumped such as rivers, lakes, and creeks.

SEEPAGE - Water that flows through the soil.

SEPTIC TANK - An enclosure that stores and processes wastes. It is utilized in the areas where no sewer systems exists, as in rural areas or on boats. Bacteria decompose the organic matter into sludge, which is pumped off periodically.

SOIL ABSORPTION FIELD - A system of absorption trenches.

SOIL ABSORPTION SYSTEM - Any system that utilizes the soil for subsequent absorption of the treated sewage; such as an absorption trench, seepage bed, or seepage pit.

SUBSURFACE SEWAGE DISPOSAL SYSTEM - A system for the treatment and disposal of domestic sewage by means of a septic tank and a soil absorption system.

II. REVIEW OF RELATED LITERATURE

History of Sewage Disposal and the Development of Septic Tanks

Unlike the many hazardous products of our modern civilization, the problem of sewage is not a new one. In fact, sewers have been found in ancient Indian civilizations (3750 B.C.), in Bagdad (2600 B.C.), and ancient Rome(22). However, the widespread use of water-borne waste collection and treatment systems is relatively recent social novelty. It was not until 1840, in the filthy, sewage laden industrial cities of London, Boston, Cologne, Edinburg, and New York that social pressures forced the introduction of the water-carriage system of waste disposal (5). After a rainfall in the city of London in 1740, Jonathan Swift commented that:

> Now from all parts of the swelling kennels flow and bear their tropies with them as they go; filth of all hues and odors seem to tell what street they sailed from by the sight and smell, sweeping from the butchers' stalls, dung, guts, and blood, drowned puppies, stinking sprats, all drowned in mud; dead cats and turnip tops come tumbling down the flood (5, p. 131).

Written descriptions of conditions in streets of European and American cities in the eighteenth and nineteenth centuries undoubtly show the regrettable conditions in which the people lived. One traveler wrote:

> In the tenements of Glasgow, dung was left lying in the courtyards as there were no lavatories in the houses. This lack of lavatories led to the habit of house

> dwellers filling chamber pots with excreta and after some days, when completely full, and with a shout of, Beware Slops, emptying the contents out of the window into the street below (5, p. 31).

This practice evidently resulted in large accumulations of garbage and sewage which soon led to the pollution of wells and to the infestation of cities with rodents, flies, and cockroaches; both gave rise to diseases of epidemic proportions, which occasionally took a great toll in human lives.

Prior to and throughout the eighteenth century, such major rivers as river Thames were the receiving bodies of raw sewage. Sewage from cities, industries, and feedlots were directly channelled into the river without any treatment. The results of discharging untreated sewage from a large and growing population into the river Thames was poignantly described by Dr. William Budd in London in 1858:

> For the first time in the history of man, the sewage of nearly three million people had been brought to seethe and ferment under a burning sun in one vast open cloaca lying in their midst. The result we all know. Stench so foul we may well believe had never before ascended to pollute this lower air. Never before at least has a stink risen to the height of an historic event. . . For months together the topic almost monopolized the public prints. . . 'India is in revolt and the Thames stinks' were the two great facts coupled together by a distinguished foreign writer, to mark the climax of a national humiliation (70, p. 11).

Water pollution may be defined as the presence of any foreign substance in the water that tends to degrade its quality so as to constitute a hazard or impair the usefulness of the water. The foreign substance may be organic, inorganic, radiological or biological (60).

Pollution by domestic waste (sewage), is a matter of public record and is obviously not a new problem. Evidently disposal of domestic sewage did not cause major problems in the past when populations were scattered or reasonably small. It was only with the growth of large conurbations that domestic sewage disposal became a national, or even an international problem (30).

Although definite proof of disease transmission through water was not demonstrated until the later part of the nineteenth century, awareness of the insult to the senses of unsanitary practices is a common thread throughout recorded history (70). Most health authorities believe that modern society, as we know it today, could not have emerged without the benefits of clean water and the removal of sewage literally from its doorsteps (38). "If public health authorities in the United States and Western Europe were asked to point to their single greatest accomplishment, it would undoubtedly be eradication of the classical waterborne diseases" (5, p. 161). Recognition, in 1849, of the role of fecal pollution of drinking water in the epidemicity of cholera no doubt led to increased demand for proper disposal of sewage (30).

> In addition to cholora, typhoid, and dysentery, the developing countries contend with biharziasis, commonly contracted when bathing in fecal and urine polluted streams and canals; urban filariasis, transmitted by the bite of an insect vector that breeds in polluted water; and infectious hepatitis, which was responsible for a recent major epidemic that included approximately thirty thousand cases in New Delhi, India (5, p. 161).

While the objective of proper sewage disposal is to get rid of sewage, a more important objective if community health is to be maintained is to collect, treat, and dispose of domestic waste in a manner calculated to protect health, preserve natural resources, and prevent nuisance conditions (60). The modern sewers collect the waste water from homes, industries, and many businesses and deliver it to the plants for the treatment to make it fit for discharge into streams or for reuse.

In the areas without community sewage treatment facilities, septic tank systems continue to be an important method of sewage disposal. The septic tank was developed in England in 1881 and put into use in 1883. Its first use in the United States was in Boston in 1883 (44). It soon gained wide acceptance across this country, especially in areas where there was no central sewage collection and treatment facilities (23).

In 1956, over 24 million people in the United States were served by septic tank systems (44). During this time, there were six million septic tanks in use in this country, and their number was increasing at a rate of about one-half million per year. Over a third of the new housing constructed at that time utilized a septic tank system (70). Approximately 13 million private septic tank systems are currently in use in the United States, serving approximately 50 million people. It is estimated that the number of septic tanks performing inadequately range up to 50 percent of those in use today (44). These multifactional systems constitute a severe public health problem and a major source of contamination of the environment. An almost infinite number of things can cause trouble with septic tank systems. Furthermore, the modification of the septic tank system took place a few years after it was first used in the United States (44). These modifications involved basic design and operating principles of the septic tank systems. These systems are currently constructed and installed in much the same way as before World War I. In fact, there have been no major modification of this unit within the past 40 years (23, 6).

Septic Tank System Design

The basic septic tank system consists of a water-tight buried tank where water-borne wastes are collected; scum, grease, and settleable solids are removed from the liquid by gravity separation, and a subsurface drain system where clarified effluent percolates into the soil. Inadequate field size and too compact a solid prevent percolation of the liquid sewage and results in ponding, which leads to nuisances and health hazards (5).

Septic tanks are not designed to purify the sewage, eliminate odors, or destroy all the solid matter. It can be made of metal, precast in concrete, built in place of masonry or poured concrete, or made of other suitable materials (23). Generally, very few system failures have been attributed to failure of the tank per se. Springing of a gas or liquid leak is about the only recognizable thing that could go wrong with the septic tank since the tank itself has no moving parts (70). Part of the solids entering the tank are broken down into liquids or gases and some settle out in a sludge layer on the bottom or rise to the top and form scum, which is primarily undigested fats and oils. The longer the influent is detained in the tank, the greater the degree of settling out of solids, and the cleaner the effluent. As the sludge accumulates, the effectiveness of the septic tank decreases, and when the fluid capacity is reduced sufficiently, the water will flow through rapidly enough to pull some of the sludge with it and effectively defeat the purpose of the tank. Thus, while the tanks may not fail structurally, failure to have the tanks serviced regularly as required can lead to failures downstream in the absorption system.

When these systems fail they may result in pollution of surface water, groundwater, individual wells, surface soil, lakes and rivers which lie adjacent to septic tank installations (23).

> Outbreaks of typhoid fever, gastrointestinal infection, infectious hepatitis and infant methemoglobinemia have been traced to malfunctioning septic tank systems, often coupled with improperly sited and constructed private wells (44, p. 3).

According to the Environmental Protection Agency, the most critical environmental effect of septic systems is contamination of private wells by sewage related pathogens. Thus, the absence of water-borne pathogens is one major criterion of good water quality. Ordinarily, then those families who obtain their own water from wells have the highest risk of water-borne diseases (3).

Stewart states that disease outbreaks could be drastically reduced by eliminating the travel of pathogens into water supplies. He argues that:

> .... improper sitting and design of the on-site system in the initial installation phase and failing system at the end of their life cycle are the major sources of contamination. These systems pose a potential threat to public health and many officials have adopted the attitude that the use of on-site systems is to be generally discouraged ... Seeking replacement where possible with central systems (73, p. 224).

Kiker (44) also noticed that less than 50 percent of the septic tanks in the five state midwestern areas of Illinois, Indiana, Michigan, Ohio, and Wisconsin were not operating satisfactorily and in 1956 he stated that:

> ... at best, septic tanks .... are poor substitutes for central (sewage) collection and treatment systems, and should be avoided whenever possible (44, p. 5).

Factors Contributing to Failure of Septic Tank Systems

In many areas, septic tanks are still viewed by many peoples as temporary expedients until central sewer systems can be constructed. Amazingly, the number of septic tanks being used in the United States is growing at an increasing rate simply because of an emerging population movement to rural areas where community sewage treatment facilities are not commonly available. More than 60 million people in the United States depend on individual home sewage disposal systems. It is estimated (4) that of the 60 million, 50 million are served by approximately 13 million septic tanks which are currently in use in the United States. Estimates of the number of septic tanks performing inadequately range up to 50 percent of those currently in use. Newer innovations, such as aerobic systems, are being installed in many areas. A significant number of people also still rely on older methods of waste disposal such as cesspools and privies.

> Reports of the 1971 Canada census show that about half a million conventional sewage disposal systems, like septic tank-tile fields systems or sanitary private privies, are also in operation in Ontario, and serve more than 1.5 million people living in areas beyond reach of public sewers. Some of the rural sewage disposal systems in this area have contributed to contamination of surface and ground waters with chemical and bacteriological pollutants from human wastes (3, p. 24).

This wide use of septic tank systems has persisted in the face of a consistent history of septic tank failure and almost unanimous disapproval by public health engineers of their use in heavily populated areas (6, 53). The United States Department of Agriculture's Economic Research Service stated that:

> Use of septic tanks and cesspools, except under the most favorable conditions, should be considered a temporary stopgap until public facilities can be developed (3, p. 8-9).

An almost unlimited number of things can cause trouble with a septic tank installation. These range from the choked fixtures and broken sewer lines that are common to any sewage disposal system, to the sludge-filled tanks and clogged soil which are almost inherent in every septic tank installation (44). Where properly installed and adequately maintained, septic tank systems can provide a very suitable and inexpensive method of waste disposal in less populated areas. As a result, these disposal systems in some areas are staunchly defended by their owners, who often refuse to have any part of public sewer systems. On the other hand, home owners who have experienced septic tank failures show a strong preference against septic tank systems in their subsequent home purchases (23). The failures of septic tank systems and other on-site disposal systems have largely been due to the lack of sound design and installation criteria being readily available and/or enforced, coupled with the fact that approximately 2/3 of the total land area in the United States has soil conditions which appear to be poorly suited to this method of disposal. Further, those lands best suited for septic tanks are also best for agriculture because they drain easily. Thus, the growing use of septic tank systems and other on-site disposal systems have not only caused concern in public health and environmental quality but have also limited non-urban development, hindered rational land-use planning, and frustrated both public and private interests (68).

Septic tanks basically perform only one major function prior to release of the waste into the surrounding soil. Appproximately 30-80 percent of the solid sewage are trapped within the tank. The remaining solids, dissolved organics and minerals, and intestinal micro-organisms are carried over into the soil. In other words, the septic tank acts as a preconditioner of wastewater that is further processed by the soil which is the primary treatment of the process of the septic tank system (44).

Not all material settling out of the incoming wastewater undergoes biological decomposition.

> Over time, undigested solids at the bottom of a tank increase in volume, eventually disrupting the gravitional settling process and increasing the amount of solids in the final effluent, a process known as sludge wasting. Excessive solids content in the effluent can

> lead to clogging of the soil system and backing up of the system or eruption to the ground surface (70, p. 60).

Recent studies have clearly shown that effective maintenance of septic tanks require periodic inspection and sludge removal. "This service is usually available commercially from firms who operate pumping and hauling vehicles" (44, p. 25). Health authorities do agree that it is a difficult task to quantitatively document the magnitude of system failures ascribable to improper construction, installation and maintenance procedures, since the rate and frequency of septic tank system failures are rarely documented. However, many discussions with researchers in the field support this statement. McGauhey et al. (23) reported in 1964 that:

> Except in a few cases of very unsuitable soils, regulatory agencies rarely have a legal basis on which to prohibit the use of septic tank systems in urban situations. Most health authorities feel uneasy in dealing with this prospect (44, p. 10).

Mackenzie in 1952 (44) reported that only about half of the millions of private sewage disposal systems in the United States were installed under state or local health agency control, and the authority of health agencies to control installation of septic tank systems was, in all cases, extremely limited. Further, the codes and regulations which governed the use of septic tank and cesspool systems in the post-World War II housing boom were generally administered by local health agencies which tended to be poorly staffed for such activities. As for the content of the codes, MacGauhey et al. noted:

> Over the years what was either known or presumed to be true concerning the design and construction of individual septic tank systems was codified by state and federal health authorities in manuals of practice or in leaflets for use by the individual citizen or by the local jurisdiction (23, p. 6).

In 1952, MacKenzie (32) estimated that 40 percent of the four million septic tank installations that were in use at the time were installed without supervision or inspection by state or local health agencies. Polkowski et al (44) reported in 1970 that sets of plans obtained from the architect, engineer and contractor of one high school were all different regarding the location of a high school septic tank and drainage field. "These all differed from the plan on file with the State Board of Health and all four plans were inaccurate with respect to the actual location of septic tank and drainage field" (44, p. 58-59). Further, the field was not functioning properly. Perhaps Winneberger summed up this problem when he stated that:

> Probably at the heart of poor on-site wastewater disposal practices is the assumption that septic-tank systems are so reliable and troublefree that they can be designed by Codes and buried forever with no more care than homeowners may choose to give them. Public responsibility for septic tank practices is desperately needed, and in some places has come about (6, p. 215).

Ordinarily, several factors are usually considered in the selection of a site. The ability of the soil to absorb liquid, usually estimted by the percolation test, is a common requirement. In other words, the percolation rate or the ability of the local soil to absorb water must be fast enough to handle the anticipated volume of effluent.

> It is assumed that if the percolation rate is acceptable and the tile field is large enough there will be removal of pollutants from the effluent by natural adsorption and biological processes in the soil zone immediately adjacent to the field (29, p. 12).

Errors in placing septic tank systems in soils where conditions are unfavorable for their operation has been found to result in failure; in many cases, within the first year (33).

Disease Causing Agents in Sewage

Biological Agents (Microorganisms)

Bacteria and other microorganisms excreted by humans pass easily through the sewage treatment facilities and may end up in soil around drainage field, wells, public water supplies, streams, lakes or rivers (21, 56). Ordinarily, most of these microorganisms are not capable of self-movement or migration, but are carried along by the liquid flowing through soil (37, 106).

In studying the microbiological characteristics of septic tank effluent, public health investigators have primarily monitored the occurrence of a group of bacteria commonly known as coliforms. The coliform group of organisms includes, by definition, "all aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35°C (4)." Coliform bacteria, while not themselves disease producers (pathogens) necessarily, are often associated with pathogenic organisms and are a good index of the degree of bacteriologic safety of water. Coliform bacteria occur normally in the intestines of human and other warm-blooded animals and are discharged in great numbers in human and animal feces; usually averaging about 50 million organisms per gram (25). Untreated domestic water generally contains more than 3 million coliforms per 100 ml. Pathogenic bacteria and viruses causing enteric diseases in man originate from the same source, namely, fecal discharges of diseased persons. Consequently, water contaminated by sewage is identified as being potentially dangerous by the presence of coliform bacteria.

The principal pathogens found in sewage can be divided into four major categories: bacteria, protozoa, helminths (intestinal worms), and viruses (15). These organisms and the diseases they cause are presented in Table 1. Recent investigations have provided abundant evidence that effluents and sludges contain detectable amounts of each of the above four categories of organisms (56, p. 32).

TABLE 1. ORGANISMS WHICH CAN BE PATHOGENIC TO MAN AND ARE TRANSMITTED BY SEWAGE CONTAMINATED WATER.

Organism	Disease	Principal Site Which is Affected
I. Bacteria		
Salmonella spp.	Salmonellosis	Gastro-intestinal tract.
Salmonella typhi	Typhoid fever	
Salmonella choleraeusis	Enteric fevers	
Salmonella enteritidis and other serotypes	Gastroenteritis	
Shigella spp.	Shigellosis (Dysentry)	Gastro-intestinal tract
Vibrio cholerae	Cholera	Lower intestinal
Enteropathogenic Escherichia coli	Gastroenter-itis	Gastro-intestinal tract.
Francisella tularensis	Tularaemia	Respiratory tract. Gastro-intestinal tract. Lymph nodes.
Leptospira icterohae-morrhagiae	Leptospirosis	Generalized.
Mycobacterium tuberculosis	Tuberculosis	Lungs and other organs.

Organism	Disease	Principal Site Which is Affected
II. Protozoa		
Entamoeba histolytica	Amoebiasis (Amoebic dysentry)	Gastro-intestinal tract.
Giardia lamblia	Gardiasis	Gastro-intestinal tract.
Naegleria gruberi	Amoebic Meningo-encephalitis	Central nervous system.
III. Helminthic parasites (Intestinal worms)		
Ascaris lumbricoides	Ascaris	Small intestines.
Taenia saginata	Beef tapeworm (Taeniasis)	Gastro-intestinal tract.
Schistosoma mansoni Schistosoma japonica Schistosoma haematobuim	Schistosomia-sis	Bladder
Necator Americanus Ancylostoma duodenale	Ancylostomiasis (Hookworm infection)	Gastro-intestinal tract
Anisakis spp.	Anisakiasis	Gastro-intestinal tract.
Echinococcus granulosus	Echinococcosis	Liver and lungs.
IV. Viruses		
Poliovirus	Poliomyelitis	Spinal cord
Coxsackievirus	Aseptic menin-gitis	Membrane of the brain or cord and gastrointestinal.
Echovirus	Aseptic menin-gitis	Membrane of the brain or cord
Adenovirus	Respiratory infection	Respiratory organs.
Hepatitis virus	Infectious hepatitis	Liver.

Perhaps the occurrence and transmission of pathogens in sewage wastes may be illustrated by a practical example described from Colorado. In that state, and like in other parts of the arid Southwest, sewage wastes are used for crop irrigation.

> Effluent water that had received primary treatment and chlorination contained only about 1% of its initial level of coliform and enterococcal organisms, but numerous ascaris eggs and amoeba cysts were present. About 50% of the samples of river water receiving the sewage effluent and used for irrigation contained salmonellae. No shigellae were isolated. Amoeba cysts and ascaris ova could be isolated from the river water; 2 of 34 vegetable samples taken contained ascaris ova. These two were from a field irrigated with river water receiving raw sewage (69, p. 393).

Burge et al. (9) also reported that the use of night soil, raw sewage wastes in growing vegetables to be eaten raw can result in outbreaks of typhoid fever, cholera, ascariasis, amoebiasis, bacillary dysentery, enteric fevers, and diarrhea.

> Numerous infections of city dwellers with round worms were caused in Germany by the eating of sewage polluted vegetables. Annual outbreaks of typhoid fever in Paris resulted from eating of raw vegetables grown illegally on sewage farm utilizing raw waste water. China has had many severe outbreaks of ascaris. In some provinces, practically all the inhabitants were reported to have been infected as a result of fertilization of vegetables with night soil (9, p. 1).

Chemical Agents

Septic tank systems and other on-site sewage disposal systems are also ineffective in removal of potentially troublesome chemicals found in the wastewaters (typically nitrogen and phosphate, both possibly present in several forms). These chemicals represent both a potential public health threat and a source of undesirable nutrients which affect both surface and groundwaters by promoting their rapid eutrophication. Nitrate and phosphates are considered to be the most important among the nutrients responsible for enrichment of lake waters and causing deterioration of water quality. Although the threat to public health due to water-borne diseases is generally the major problem raised when discussing the attributes and disadvantages of on-site sewage disposal systems, current reports (73) indicate that infant methemoglobinemia (caused by high levels of nitrates) is on the increase. This is especially the case in those areas where people are utilizing failing septic tanks and obtaining their water from individual wells (6). Sikora et al have reported that:

> Widespread concern over the presence of high nitrate concentration in water well as food has been noted in recent reports (Nat. Acad. Sci., 1972, EPA, 1973). This concerns on: (a) the toxicology of nitrate to infants drinking water with NO_3-N levels higher than 10 ppm (USPHS, 1962); (b) toxicology of nitrate in waters given to livestock; and (c) eventual contribution of N to surface waters resulting in the increases in productivity, and hence, eutrophication of these waters (73 , p. 64).

Further, the available evidence (3) shows that nitrates are mobile in natural soils and only small amounts are fixed in most soils. Nitrogen principally occurs in the organic and ammonia forms in sewage and in septic tank effluents. These forms are converted to nitrate through biological action under aerobic conditions.

> The link between excessive nitrate in well water and infant methemoglobinema is well established. According to the U.S. Public Health Service Drinking Water Standards, nitrate-nitrogen levels in excess of 10 mg/l in drinking water are considered harmful. Incidents of livestock poisoning due to high nitrate have also been reported (44, p. 35).

Consumption of water high in nitrate, and conversion of nitrate to nitrite by the intestinal bacteria results in metheglobinemia in infants and certain livestock. Bosch, et al. (70) reported 139 cases of infant methemoglobinemia in Minnesota due to high nitrite levels in well waters. As a result fourteen infants died. The well waters had nitrate-nitrogen levels of 36 to 500 mg/l and none of the contaminated wells were considered to have been properly situated or constructed according to the Minnesota Department of Health.

Nitrate concentrations build up quickly in soil absorption fields, as pointed out by Susag, et al. in a discussion of Preul's work (44). Nitrate-nitrogen concentration ten times greater than the normal groundwater levels were found within 40 days, and 22 times greater within 65 days in an absorption field receiving septic tank effluent (44).

According to Birch (23) each person contributes 12 lbs. per year to lake waters through septic tank absorption fields adjacent to lakes or streams. Based on this rate, Birch (44) estimates that the un-sewered population of the Hoover Reservoir Drainage Basin in Ohio contributes 76,500 lbs. of nitrogen each year to the reservoir via septic tank drainage systems. Nitrate dynamics in soil have been studied by several investigators and the results strongly indicate that nitrates are mobile in natural soils and only small amounts are fixed in most soils. Phosphate, on the other hand, is a more controllable nutrient (70).

Polkowski, et al.(44) in a study of a septic tank absorption field drainage, found orthophosphate to be reduced from 4.15 mg/l in the septic tank effluent to 0.04 mg/l in a shallow well situated only 15 feet downstream of the absorption field. These findings were the same as those obtained in a similar study which was conducted at Pennsylvania State University, in which sewage effluent was applied to soil by spraying. Phosphates were found to be 99 percent removed in the top 12 inches of soil.

Similar results were reported by Preul in 1968 when he studied groundwater contamination due to infiltration from surface water stabilization ponds. His data revealed rapid reducing in orthophosphate within ten feet of the edge of each pond studied.

> Pondwater orthophosphate concentrations ranged from 4-20 mg/l and groundwater orthophosphate was reduced to 0.2-2.0 mg/l within ten feet (23 , p. 33).

Phosphate extensively absorbs onto soil and in the presence of calcium ions to form insoluble soils. Although phosphate absorbs readily onto soil, the potential for phosphorus contribution to surface water from septic tanks still remains since many septic tank systems malfunction and ultimately discharge to the surface. Sawhney, et al. (53) estimates that in the United States, more than 2,500 million gallons of wastewater containing large quantities of phosphorus are discharged daily into the soil surrounding septic tank drainfields.

Movement of Microorganisms Through Soil

Because of increased reliance on natural soil and sand for treating sewage, there is currently a great concern over the fate of pathogenic microorganisms in wastewater moving through soils (21, 48). "Questions relative to microorganisms movement in soils have been raised but only for domestic sewage disposal systems but also for the relatively new practice of land spreading of sewage" (48, p. 30).

Estimates (66,29,63,73) indicate that approximately 50 million Americans and 4 million Canadians use septic tank systems for sewage disposal. It is also estimated that 50 percent of these systems are operating improperly and continue to release raw sewage into the environment. The effluent from a septic tank contains solids, many plant-fertilizing nutrients, particularly nitrogen and phosphorus compounds, and many microorganisms, including viruses and several pathogenic parasites. In the septic tank-soil absorption systems the soil through which the effluent percolates plays an important role in the treatment process (66).

Most microorganisms which are present in sewage pass easily through the septic tanks, and into the soil around the absorption field. These microorganisms are not capable of self movement to migration, but are transported easily along by the liquid flowing through the soil (44). The general course and approximate rate of movement of these intestinal microorganisms with the groundwater flow is known to be limited in fine soil simply because of the straining or filtering action of the soil particles (48, 70). Flow through coarse sand or gravel, or through rock formations with crevices, fractures and faults may carry fecal organisms rapidly and far from their point of discharge into the ground (29).

Intensive studies on groundwater pollution have taken place in the Netherlands where many precautions are necessary because of the unique water situation; the water table is often less than 10 feet from the land surface. In 1957, J. K. Baars, a leader in current Netherlands' pollution studies, studied chemical and bacterial pollution of two types: (a) Severe pollution of surface layers of soil matter with small quantities of water; (b) moderate pollution of surface layers of soil with large quantities of water; and (c) penetration into dry and wet soils. Baars concluded that:

1. Self purification requires time.
2. Harmful bacteria might travel 25 feet or more in very coarse material where the rate of groundwater flow is 25 feet or more per day.
3. A sand size of 0.15 mm or less is required.
4. Self purification occurs best in dry soils containing a sufficient supply of free oxygen.
5. In groundwater systems containing much pre-existing nutrient material self purification might require a much greater length of time.
6. Pathogenic bacteria is generally absorbed in the first 10 feet of travel due to oxygenation and nitrification (48, p. 39).

Contamination of Water Supplies and Disease Outbreaks

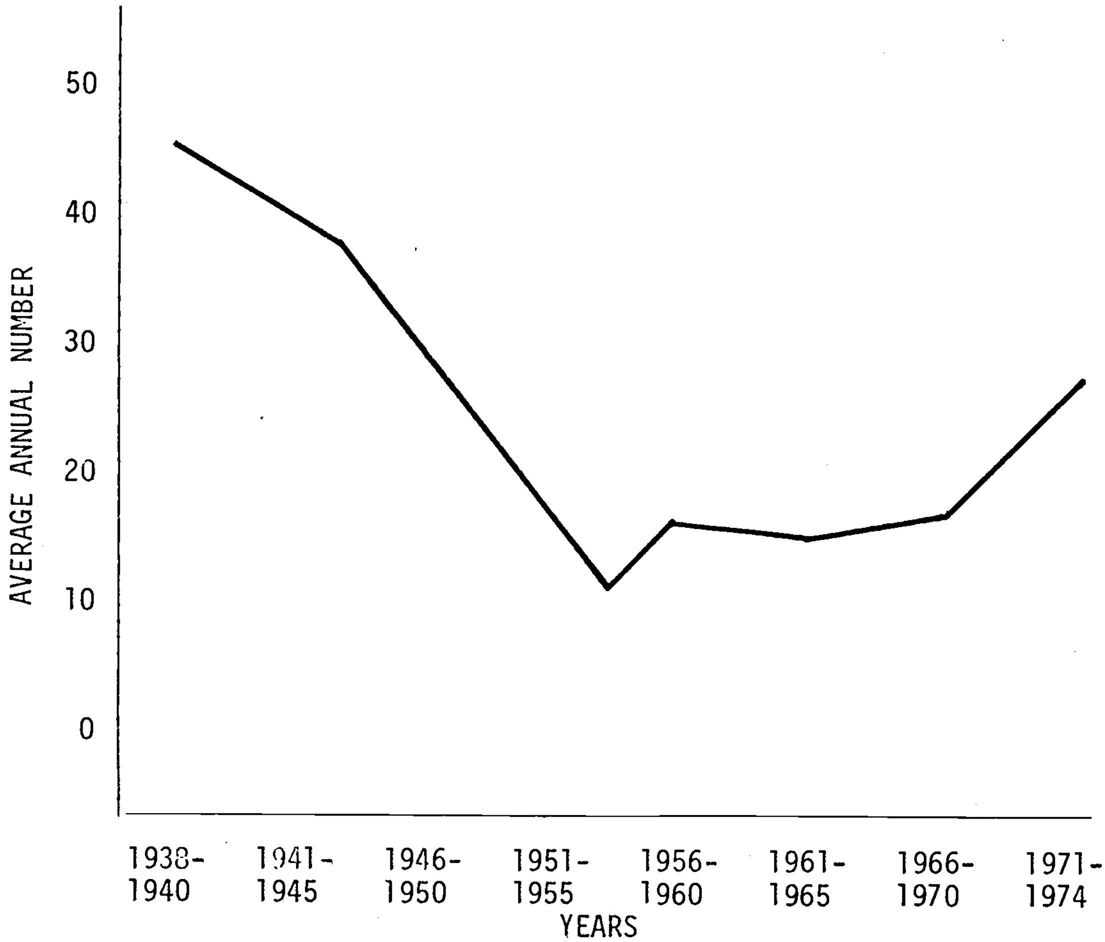
History gives ample evidence of the penalties paid by past civilizations which failed, through ignorance or neglect, to provide for the safety of their water systems. Yet, even the ancients recognized the acute effects of waterborne diseases which the new sciences of epidemology and bacteriology only began to catalog during the last century (46).

The Chinese, wasted by cholera from probably the seventh century onward, referred to a condition named "huo luan". This is today the Chinese term for cholera (40, p. 28).

During the period of European Colonist expansion (1847), troops posted to Africa, to Egypt in particular, were advised to wear penis sheaths and condoms while bathing in rivers. It was believed that small leeches bearing the disease bored into the urethra and caused the bleeding. This disease was bilharziasis (17).

Modern history shows that such waterborne diseases as typhoid, dysentery and cholera are controllable. They were all but eliminated in the United States by the 1930's by applying the principles identified in what are commonly referred to as the U.S. Public Health Service Drinking Water Standards (63). Recent studies, however, have suggested that we may have began to backslide. Epidemiological evidence presented by Crown and McCabe (68) shows that the average annual number of waterborne outbreaks of biological etiology stopped falling around 1951 and may have increased slightly since that time. The Center for Disease Control (CDC) in Atlanta, Georgia, has also been reporting

FIGURE 1*. Average annual number of waterborne disease outbreaks in United States, 1938-1975.



* Adapted from "Drinking Water and Health". National Academy of Sciences. Washington, D.C. 1977 (40, p. 64).

a pronounced increase in the outbreaks, especially since 1971. The reason for this apparent increase is not very clear but some investigators believe that it is because of overloading of sewage treatment facilities (40), increase use of sewage contaminated water (42), and the increased use of on-site sewage disposal systems (63).

Since 1971, the CDC, the Environmental Protection Agency (EPA), state epidemiologists, and engineers in state water supply surveillance agencies have cooperated in the annual reporting of outbreaks. The purposes of such reports are to control disease by identifying contaminated water sources and purifying them, and to increase knowledge of disease causation (40).

The average annual number of waterborne outbreaks in the United States reported from 1938-1975 is shown in Figure 1.

The true incidence and clinical spectrum of human disease in the United States caused by the ingestion of impure drinking water is difficult to estimate (63). Outbreaks of various acute bacterial infections such as typhoid fever, non-typhoid salmonellosis, shigellosis, and pathogenic Escherichia Coli have been caused by consumption of contaminated water (32). As for the viral infections, there are many well documented reports of waterborne transmission of hepatitis A (67). In addition, many outbreaks of sewage poisoning, an acute gastrointestinal illness presumably caused by either coliform organisms or viruses have also been recognized (63, 40, 76).

These large numbers of waterborne diseases or poisonings are one of the major factors which lead to the enactment of the Safe Drinking Water Act (PL 93-523). During the 10 years, 1961-1970, 128 documented outbreaks or poisonings involving drinking water resulted in 46,374 illnesses and 20 deaths (40). This represents an average of one waterborne outbreak per month, each involving 350 people (55). The State of California has experienced six major waterborne outbreaks since 1965. In 1965, an outbreak of intestinal disease affected more than 20,000 persons and caused several deaths at Riverside, California. This was later traced to Salmonella typhimurium (62).

Browning et al (40) reported that there was an outbreak of gastroenteritis in the Southwestern portion of Madera, California during the same year. The people in the area obtained their domestic water exclusively from two wells; one of which was later found to be contaminated with raw sewage used to irrigate an adjacent sewage farm.

In February and March 1973, 210 cases of typhoid fever, 170 of which required hospitalization, occured in a migrant labor camp in Dade County, Florida (63).

In November 1972 a shigellosis outbreak affecting 208 students and staff occurred at a school in Stockport, Iowa (69). Epidemiologic investigation implicated the school's water supply. The system deficiency associated with this outbreak was untreated groundwater. Control measures consisted of superchlorinating the wells and promptly connecting the schools to the municipal water supply (63).

A disease outbreak in Ottawa, Canada (44) resulted in 60 cases of dysentery and approximately 12 cases of typhoid fever. The source of the outbreak was traced to contamination of a well by groundwater containing sewage. There was a similar epidemic which occurred in Pennsylvania when several families living on small farms within 15 mile area became sick. The epidemiologic investigations implicated contamination of groundwater, and subsequent contamination of the wells on each farm (70).

Between 1974 and 1975, the largest waterborne outbreak of giardiasis occurred in Rome, New York. Three hundred and fifty residents had laboratory-confirmed giardiasis, and epidemiologic investigation estimated that 4800-5300 individuals were affected during the outbreak (14).

According to Craun (14), it was the first waterborne outbreak where a G. lamblia cyst was found inmunicipal drinking water and the first time that such water had been shown to produce giardiasis in laboratory animals (40).

During 1975 and 1976, there were three waterborne outbreaks of shigellosis reported in the United States: 56 cases of Shigella Sonnei in Montana attributed to the use of untreated, contaminated well water, 25 cases of shigella flexneri; in Alaska attributed to the use of wastewater contaminated surface water, and 2,150 cases of Shigella Sonnei in a municipal water supply in Puerto Rico attributed to inadequate disinfection of a contaminated well (13).

Despite the fact that documented waterborne enteric viral disease has been recognized for nearly two decades, the public health significance of enteric viruses in water has not been adequately evaluated and remains poorly understood (63). In fact Winneberger has stated that:

> Viral gastroenteritis is the term often used to describe episodes of gastroenteritis and diarrhea when a pathogen cannot be recognized (74, p. 2).

The viruses of major concern in the water, however, are those that infect the alimentary tract of man and are excreted in large quantities with the feces by infected persons (24).

Documented epidemiological evidence for waterborne transmission of enteric virus is largely limited to outbreaks of hepatitis Type A which have resulted from lack or inadequacy of treatment of private or public water supplies (74). In recent years, more than 50,000 cases of Type A hepatitis have been reported annually in the United States, but of this total, only a fraction of a percent have been attributed to drinking water as a source (63). Craun et al (13) stated that "In the period 1961 to 1970, a total of 30 water outbreaks of hepatitis type A involving 903 cases was reported" (14, p. 78).

During the spring and summer of 1959 an outbreak of hepatitis A occurred in Posen, Michigan, a closely-knit community of about 400 people. Water for the community was obtained from individual wells in which most of them were "poorly constructed and frequently located near septic tanks" (44, p. 49).

Viruses are more resistant to environmental effects than bacteria. An excellent example of this was outbreak of infectious hepatitis in New Delhi, India, which occurred between 1955-1956. This is the most serious outbreak of hepatitis known and approximately 30,000 people become ill after drinking reportedly clean water (9). The water had been tested and found free of coliform bacteria, which are used as indicators for fecal contamination of water. "This example underlines the fact that bacteriological tests are not completely reliable for evaluating potable water quality" (33, p. 152).

In 1962 an eminent panel of public health experts (1957) concisely summarized their views of water related enterovirus by stating that:

> More than 70 viruses have been detected in human feces. All may be present in sewage. Viruses pass through sewage treatment plants, persist in contaminated waters, and may penetrate the water treatment plants. Numerous outbreaks of infectious hepatitis have been traced to contaminated drinking water. The occurrence of such incidents appears to be increasing (33, p. 15).

In 1965 another group of scientists concluded that "The capabilities of present water pollution control technology are clearly inadequate as far as viruses are concerned" (67, p. 57). Thus, the need to monitor water for viruses becomes apparent.

History clearly indicates and the present strongly confirms that on a worldwide scale, the population of water is responsible for more human illness than any other environmental influence (60). The World Health Organization estimated in 1968 that 5 million deaths per year and 500,000,000 cases of disease were associated with polluted water (33). "Less than one-third of the urban world population has piped water supplies. Another one-third has no access to safe supplies or suffers from shortages of water" (33, p. 221).

Contamination can occur at various points in the water supply system, including catchment areas, streams, channels, wells and springs, water treatment plants, storage reservoirs, distribution systems, and public standpoints.

> The presence of human dwellings, barns, and stables within catchment areas is a potential hazard; sewer and septic tank discharges,

> defective latrines, manure piles, and the indiscriminate and other insanitary disposal of sewage may be responsible for widespread pollution (60, p. 35).

One of the least recognized contamination problems in the United States, and in the entire world for that matter, is the slow, insidious degradation of underground-waters which has developed as a result of man's careless disposal of waste (8). The loss of streams, rivers and lakes as sources of water supply and for recreation can have a tremendous impact on a particular region, leading to "construction of a long pipeline to import acceptable water, for example, or the closing of a popular swimming area to local residents" (39, p. 113). At the same time degradation of the quality of water in a stream, river or lake can be rather obvious through door, discoloration and visible floating debris.

Problems of groundwater contamination, on the other hand, have never received much attention because they are usually localized and out of sight. An investigator, for example, has no major problem collecting water samples from streams, lakes and rivers in order to measure directly the extent of contamination (70).

In the case of groundwaters, however, the situation is markedly different. If contaminants enter the groundwater source, they rarely can be detected by random monitoring methods, and usually their presence only becomes evident if they reemerge in water wells or other points of surface discharge (52). When this occurs, it is almost too late to do anything about it. Thus, in many ways the correction of groundwater quality degradation is considerably more complex than in the case of surface waters (35).

Approximately one-third of waterborne disease outbreaks reported in the United States from 1971-1974 were traced to the consumption of untreated water from groundwater sources (31). Further, the increasing demand for potable water to supply domestic and commercial needs has necessitated the growing use of groundwater all over the world (11). This is partly because in some areas surface water supplies are insufficient or unavailable and partly because surface supplies require extensive purification and treatment before use (35).

Approximately one-half of the population of the United States is dependent on groundwater for drinking purposes (35). About 94 percent of the rural population and 37 percent of the population served by public water supply systems obtain their water from groundwater sources (52). In addition, groundwater sources provide drinking water for millions more industrial plants, office buildings, restaurants, recreational areas, schools and other facilities that avail themselves of the source (64). The total groundwater withdrawal in the nation is 6.8×10^{10} gallons per day or 21 percent of all fresh water used (52).

> In 1977, Americans tapped their underground reservoirs for approximately 70 million gallons daily, consumption that is increasing by conservative estimates, at a rate of 25 percent per decade (64, p. 13).

Since the passage of the Federal Water Pollution Control Act Amendments of 1972 and the Safe Drinking Water Act of 1974, a "Federal-State campaign has been mounted with objectives to prevent and eliminate contamination of national water resources" (8, p. 33).

Environmental Protection Agency (EPA) reports that on-site sewage disposal systems rank highest in total volume of wastewater discharge directly into the groundwater and are also the most frequently reported source of groundwater contamination (40).

III. RESEARCH METHOD AND DESIGN

Description of the Study Area

The study area was situated within Benton County of the State of Oregon. The study area was composed of both sewered (South Corvallis) and unsewered (Southwest Corvallis) neighborhoods encompassing approximately 2,000 acres (3.13 square miles).

This study area was bounded on the north by the Southern Pacific Railroad right of way to 53rd Street; then north to Oak Creek Road; then west along Oak Creek Road to a point approximately 1600 feet from 53rd Street; then south along imaginary line to a point 500 feet south of Nash Road; then east along an imaginary line to the Corvallis city limits. This area was also bounded on the east by the Corvallis city limits. The south and western boundaries of the study area were established by the early survey team (Benton County Health Department and State Health Division) at the points generally conforming with ridge lines bounding and draining to the study area. This description includes the West Hills area, Country Club and Fairhaven Heights as well as other less populated areas.

A survey was conducted by Public Health sanitarians from the State Health Division and Benton County Health Department in 1968 to determine the extent of failure of the on-site sewage disposal systems in the area. The survey concluded that sewage disposal in this area was so inadequate that significant health hazards existed due to failure of individual sewage disposal systems.

Following these findings, the South Corvallis neighborhood was annexed and sewered. Several attempts have been made to sewer Southwest Corvallis but the majority of the residents in the area have continued to protest any annexation or sewering of this neighborhood.

The Southwest Corvallis neighborhood encompassed approximately 158 acres of land adjacent to the westerly city limit line of the city of Corvallis and was entirely within the city's urban growth boundary. Presently all wastewater and sewage within this area is disposed of via individual on-site disposal systems.

The City of Corvallis, upon order of the State Health Division, has completed a report as to the feasibility of providing sewer facilities for this area via a forced health hazard annexation process.

Subsequent to this report, the State Health Division ordered the City of Corvallis to begin a forced health hazard annexation of the Southwest Corvallis Study Area.

Within this area there were 180 developed properties, 54 of which had been determined to have inadequate on-site sewage disposal systems. At the time of this study, this area had an estimated population of 540, with a forecasted population of 1,800 by the year 2000. An expected growth rate of approximately 60 persons per year will increase the existing population density of 34 persons per acre to approximately 11.4 persons per acre by the year 2000.

The State Health Division has ordered the City of Corvallis to implement a forced health hazard annexation of the Southwest Corvallis Study Area. The city does not have sufficient funds to extend sewers to the health hazard annexation area. The primary scope and intent of facilities planning is to provide a cost effective, environmentally sound waste water collection system. Properly funded facilities planning is fundamental to the elimination of the present danger to public health within the study area.

Both the City of Corvallis and the Benton County Comprehensive Plans identify the City of Corvallis as the primary provider of sewage collection and treatment within the Corvallis urban growth boundary.

Although the State Health Division had ordered the City of Corvallis to implement a forced health hazard annexation of the Southwest Corvallis, it was still evident that the residents of this area were not convinced that the municipal sewer service would be more effective than their individual septic tank systems. The purpose of this investigation, therefore, was to quantitatively determine and compare the bacteriological levels of watershed contamination in a sewered and an unsewered neighborhood and find out if the municipal sewer service significantly reduced the sewage related health hazard in the sewered neighborhood.

The reference organisms chosen for this study were 1) total coliforms, 2) fecal coliforms, and 3) fecal streptococci. A discussion of the significance of these water quality indicators is contained in the next section.

The Indicator Principle in Sanitary Bacteriology

The most important biological indicator of fecal water pollution is a common group of gram-negative bacteria known collectively as coliforms (57). The concept of coliforms as indicator organisms was first applied in 1914 when the United States Public Health Service adopted a bacteriological standard applicable to any water supply provided to any interstate carrier (22). Similarly, coliform standards have been set for water utilized for shellfishing, food production, and food processing (19).

Although methods for direct detection of pathogens have been improved, there is still a need to use coliform organisms as indicators of fecal contamination of water (4). It might seem that the most logical test for purity of water would be to examine it for the kind of bacteria in question (4). But, in actual practice, it has been found impracticable to test waters for the presence of *samonella typhosa*, *salmonella paratyphi*, *shigella dysentriae*, viruses or other microorganisms causing enteric diseases. There are several reasons for this:

1. Pathogenic organisms are likely to gain entrance into water periodically, yet fail to survive for long periods of time and consequently, may not be detected in samples submitted to the laboratory.
2. The best known methods are too slow, tedious, and expensive for use in general routine water analysis, and many people would already have consumed the water by the time the pathogens are detected.

3. There are many other harmless microorganisms which may interfere with the detection of pathogens.
4. By the best methods known, low levels of pathogens are likely to escape detection by laboratory procedures because only a small amount of water is routinely examined.

The pathogenic organisms that gain entrance into bodies of water arrive there via intestinal discharges of humans or other warm blooded animals (43). Furthermore, certain bacterial species, particularly Escherichia coli, Streptococcus faecalis, and Clostridium perfringens, which are normal inhabitants of the large intestine of humans and other animals, are consequently present in feces (19). Thus, the presence of any of these microorganisms in water is evidence of fecal pollution of human or animal origin. Detection of these microorganisms in water should indicate that the way is also open for intestinal pathogens to gain entrance, since they, too, occur in feces. Because the laboratory examination of water for pathogens is beset with the disadvantages already enumerated, techniques have been developed for the demonstration of bacterial group (57). This new approach has proved satisfactory in practice and has the following advantages (40).

1. The coliform group, especially Escherichia coli, are constantly present in the human intestine in large numbers. It is estimated that several millions of these organisms are excreted by an average person in one day.

2. These group organisms live for an extended period of time in water as compared to intestinal pathogens.
3. Most health individuals normally do not excrete pathogenic organisms, yet if an intestinal-tract infection develops, the pathogens are shed in the feces. Therefore, the presence of coliforms in water is regarded as a warning signal; the water is subject to potentially dangerous pollution.

Total Coliform

Organisms in the coliform group differ in biochemical and serological characteristics and in their natural sources and habits. The Standard Methods For The Examination of Water and Wastewater (Standard Methods) defines the coliform group as including "all of the aerobic and facultative anaerobic gram-negative, nonspore-forming, rodshaped bacteria that ferment lactose with gas formation within 48 hours at 35°C." (57, p. 913) The current use of the membrane filter technique has led to the establishment of another definition for coliforms, which is described in Standard Methods (57) as follows:

> All organisms which produce a dark colony (generally purplish-green or greenish sheen) within 24 hours of incubation (on a specified medium and at a specified temperature) are considered members of coliform group (111, p. 2-1).

The coliform group, however defined, include members of four genera recognized by the International Committee on Bacteriological Nomenclature: Escherichia spp. Citrobacter spp. Klebsiella spp., and Enterabacter spp. From a medical point of view, the only two with an established pathogenic potential are Escherichia and Klebsiella (19).

Escherichia coli is the only important species of the genus Escherichia, while the genus Klebsiella contains three pathogenic species--Klebsiella pneumonia, Klebsiella rhinoscleromatis, and Klebsiella ozanae (57).

Escherichial coli characteristically inhabits the human and warm-blooded animal intestine and though individual variations do occur, Escherichia coli accounts for over 88 percent of the coliform types in feces. Some scientists, Geldreich et al (19) for instance, report fecal coliforms to be a small percentage of the coliform organisms associated with vegetation and insects, indicating that warm-blooded animal contamination is usually not observed on plants. Most microbiologists (19, 15, 14, 10) agree that the Enterobacter group is the most common coliform group found on various types of vegetation.

Fecal Coliforms

Fecal coliforms are a subgroup of the coliform bacteria that have a high positive correlation with fecal contaminant since they grow mainly in the intestines of warm-blooded animals, including humans (40). Escherichia coli and Escherichia intermediens are representatives of this group. Other members of the total coliform group come from a variety of nonfecal sources, including soil runoff and decaying organic matter (19).

Therefore, fecal coliforms are a more definitive measure of recent fecal pollution and the majority of water quality laboratories have adopted these procedures for the determination of fecal coliforms; in addition to the required total coliform test (36). In domestic sewage, the fecal coliform concentration is usually at least four times greater than the fecal streptococci and may constitute 30 to 40 percent of the total coliforms (51).

In storm water and wastes from livestock, animal pets, poultry, and rodents, the fecal coliform concentration is usually less than 0.5 percent the fecal streptococci, whereas in streams receiving sewage, the fecal coliforms may average approximately 15 to 20 percent of the total coliforms in the contaminated stream (19). Colonies produced by fecal coliform group are described in Standard Method (57) as being blue, whereas, the non fecal coliform colonies are gray to cream colored. Background color on the membrane filter will vary from a yellowish-cream to a faint blue, depending on the age of the rosolic acid salt reagent (19). Ordinarily few nonfecal coliform colonies will be observed on M-FC medium (medium for enumeration of fecal coliforms) because of the selective action of the elevated temperature. Addition of rosolic acid salt reagent helps to eliminate the gram negative organisms (19).

Fecal coliform organisms ferment lactose at 45.5^{o}C and are detected by gas production in multiple tube procedure and acid production in the membrane filter procedure (m-FC medium)(57).

Fecal Streptococci

The Standard Methods (57) indicate that the terms "fecal Streptococcus" and "lancefield group D Streptococcus" are used synonymously, and when used as indicators of fecal contamination, the following species and varieties are implicated: *Streptococcus faecalis* var. *liquefaciens*, *Streptococcus faecalis* var. *Zymogenes*, *Streptococcus faecium*, *Streptococcus faecium* var. *durans*, *Streptococcus bovis*, and *Streptococcus equinus* (19). Since fecal Streptococci, particularly *Streptococcus faecalis*, are abundant in the human large intestine, their occurrence in a public drinking water is indicative of a serious health hazard (43). According to the Standard Methods (57) analysis of water for fecal streptococci provides valuable supplementary data on the bacteriological quality of streams, estuaries and lakes but because of their survival characteristics, it is not recommended to use only the fecal streptococci when determining water quality. In other words, an investigator would be on the safe side if he used other fecal indicators concurrently.

Because certain fecal streptococci are host-specific, biochemical characterization or speciation may provide more valuable information about the source pollution (19). For instance, a large number of *Streptococcus bovis* and *Streptococcus equinus* would be indicative of pollution from the excrement of non-human, warm-blooded animals. Current investigations have demonstrated elevated numbers of these species associated (18) with pollution involving meat processing plants, dairy wastes, feed lots, and farmland runoff. *Streptococcus bovis* and

Streptococcus equinus do not survive for very long outside of their natural host so their presence in water is indeed indicative of very recent contamination (15).

On the other hand, Streptococcus faecalis var. Liquefaciens is not restricted to the intestines of man and animals. Current information (57) shows that it has been associated with vegetation, insects, and certain types of soil.

Fecal streptococci are spherical to avoid organisms about one micron in diameter and are nonspore-forming, motile, gram-positives. Human feces may contain at least 100,000 streptococci per gram (22). Streptococci are present in animal extreta as numerously as the coli-aerogenes bacteria (14). In sewage, the number of fecal streptococci is usually about 10 percent the number of Eschenchia coli (22).

Field Sampling

The sampling in the study area was conducted April 18, 1979.

All samples collected in the field were taken to the Environmental Health Laboratory at Oregon State University, located on the second floor of Waldo Hall (Rooms 242, 244, and 246).
The laboratory was fully equipped with all the apparatus and materials needed for microbiological examination of water. These included a membrane filtration apparatus powered by an electric pump for performing the enteric indicator tests, air and water incubators, two refrigerators for storing media, water samples and reagents, an autoclave, laboratory thermometers, a pH meter, a trip

pan balance with a sensitivity of better than 2 grams per 150 gram load; microscope with a light source, colony counter, forceps and selective media for detection of total coliform, fecal coliform, and fecal streptococci.

Care was exercised to collect samples representative of the water to be tested and to insure that the sample did not become contaminated at the time of collection or before examination. Because this was a comparative study, the current investigator obtained the samples from the sites that were already chosen by the previous investigators. According to the earlier investigators which included Benton County Health Department and the Oregon State Health Division, sampling sites were chosen within the guidelines of sampling procedures given in Standard Methods (57). According to this book, bacteriological examinations should be carried out on samples collected at representative points throughout the distribution system. The sampling procedures and the sampling locations should be such as to insure accurate determination of the bacteriological quality of the treated water supply which may be controlled in part by the known quality of the untreated water and, thus, by the need for the treatment.

> Every effort should be made to maintain a consistent series of identical observations once the program has been firmly launched. Units, techniques, and sampling stations should be standardized as far as possible so that observations of one year can be compared directly with those of preceding years (1, p. 141).

The 1968 investigating team, which included Benton County Health Department and Oregon State Health Division reported in their study that sampling sites were chosen within the guidelines of sampling procedures given in The Stnadard Method for The Examination of Water and Wastewater. The current investigator closely followed the same guidelines and since this was a comparative study, samples were obtained from the exact locations (22 sampling sites) that were already chosen by the previous investigations.

It should be pointed out, however, that although samples from all the 22 sampling sites were analyzed, only data from 14 sampling sites was used to test the hypotheses for this study. This was mainly because it was not possible to pair all the sampling sites. Therefore, from the 22 sampling sites that were chosen by the earlier survey team of 1968, the current investigator selected 14 sampling sites; seven from the unsewered neighborhood (Southwest Corvallis) and seven more from the sewered neighborhood (South Corvallis).

Water samples of seepage, questionable liquid wastes, and suspected effluents were collected from the creeks, roadside ditches and back or front yards of residences and other buildings. Additional samples were collected from streams and drainage ways. All these samples were immediately iced and brought back to the Environmental Health Laboratory, Oregon State University (OSU) for bacteriological analysis to determine the presence or absence of fecal contamination. The water samples were analyzed for three types of bacterial indicators--as it was done by the earlier team in 1968. These three indicators, which have already been discussed, included: total coliform, fecal coliform, and fecal streptococci.

Sample Collection

Proper sampling techniques are a critical part of sanitary water testing. It is most important that the testing equipment does not introduce unwanted contamination into the test samples. Sampling bottles, therefore, were prepared according to the procedures described in Standard Methods (57) and presented in the next paragraph.

Approved plastic bottles of suitable size (greater than 250 mls) and wide-mouth were used to collect samples for this study. A few additional glass bottles of the same acceptable size and shape were also used, since there were not enough plastic bottles. All bottles were thoroughly cleansed with hot water and "Alconox", an approved detergent for cleaning laboratory equipment and glassware. The bottles were then rinsed with hot water to remove all traces of residual washing compound and eventually rinsed with distilled water.

Before autoclaving, the caps and the necks of the sampling bottles were covered with small sheets of aluminum foil. This wrapping or "hood" remained on the bottle top at all times before and after sampling. All sampling bottles were loosely capped and autoclaved at 120^{o}C. for 15 minutes. The sampling bottles were then labeled for proper sample identification and kept unopened until the moment they were to be filled. Care was exercised to take samples that were representative of the water that was being tested for fecal contamination. Likewise, care was exercised to avoid accidental contamination of the samples at the time of collection, transportation to the laboratory, and before examination. While collecting each sample, the bottle cap and the aluminum hood were removed as a unit. The bottle was held in one hand and the cap in the other, keeping the bottle cap right side up (threads down) while making sure that the fingers did not touch the inside of the cap. The bottle was held near the base and filled without rinsing. Samples from creeks and streams were taken by holding the bottle near its base and plunging it, neck downwards, below the surface. The bottle was then turned until the neck pointed slightly upward, and the mouth was directed toward the current. When there was no current, as in the case of a roadside ditch, a current was created artifically by pushing the bottle forward horizontally in a long, scooping motion. The cap was immediately replaced and the hood was secured around the neck of the bottle. Water samples were collected, leaving ample air space in the bottle which was at least 25 cm. This air space was to facilitate mixing of the sample by shaking, prior to examination. In order to carry out all the tests required, sufficient water samples were collected; 500 mls of water from each sampling location.

The water samples were kept cold, until their return to the laboratory, by storing them in an ice chest. Observations of ice chest temperatures indicated temperatures of 6 to 9°C. The Standard Methods (57) describes that the temperatures of all stream pollution samples should be held at temperatures below 10°C. during a maximum transport time of six hours. Upon their return to the laboratory, the water sample bottles were placed in the refrigerator which was set, prior to analysis, at a temperature below 10°C.

During the sampling period, the United States Department of Commerce, Environmental Science Service Administration, recorded 3.93 inches of rainfall in the Corvallis area. Observations made during that time indicated plenty of surface water run-off to roadside ditches, curbsides, drainage ways and streams. In most cases, the ground was found to be saturated, and in most instances, was found to have considerable amounts of standing water. Inadequately treated sewage from several homes in the area was seen discharging to the surface of the ground and flowing into roadside ditches, drainage way and sometime into other private lots. These observations were very similar to those reported by the 1968 survey team. During the explicit period of the 1968 survey, the United States Department of Commerce, Environmental Science Service Administration, showed that approximately 3.25 inches of precipitation was measured. A copy of the report of 1968 survey may be obtained from the Benton County Health Department, Corvallis, Oregon.

Laboratory Analysis

Materials

Media used in this investigation for isolation of total coliforms (MF Endo) and fecal coliform (m FC broth) were purchased from Millipore Corporation in Bedford, Massachusetts. Agar medium (m Enterococcus) used for isolation of fecal streptococcus was purchased from Difco Laboratories in Detroit, Michigan.

All media was obtained in a dehydrated form two weeks before the beginning of the analysis of water. All the media was rehydrated and sterilized according to the manufacturer's directions. Only chemically clean glassware was used to prepare and dispense the media into sterile petri dishes. The mixture of distilled water and medium were gently agitated by hand and finally by a magnetic stirrer to ensure rapid dissolution. The electronic pH meter (model number 9600 Zeromatic, Beckman Instruments, Inc.) was precaliberated in the range of intended use by means of a precision buffer standard before using it to obtain the final pH of each medium.

The composition and directions for rehydration and sterilization of each medium was stated on the label of the bottle with the quantities of the ingredients present in one liter of the finished medium. All that was necessary to rehydrate the medium was to weigh accurately the dehydrated medium, dissolve the powder in freshly distilled water, and sterilize the solution. The media and the procedures discussed below were used in this investigation for bacteriological examination of water in accordance with the procedures given by the manufacturer and Standard Methods (57).

MF Endo Medium (Medium for enumeration of Total Coliformis)

Bacto-Endo agar in general is recommended for the confirmation of the presumptive test for members of the coliform group in the bacteriological analysis of water, milk, and other dairy products, according to the Standard Methods (57).

To rehydrate the medium, 48 grams of the dehydrated powder was suspended in a liter of purified water, containing 20 ml of 95 percent ethanol. The mixture was agitated thoroughly using a glass rod, then stirred with a magnetic stirrer while heating it to boiling point. It was immediately removed from the heat and cooled to below 45°C. The medium was not autoclaved since excessive heat has been known to destroy the sodium sulfide. This destruction results in poor sheen development on coliform colonies (19). For most of the m-F Endo used in this investigation, the final pH was 7.2.

The finished medium was distributed (pipetted) into small sterile plastic petri dishes (catalog number PD10 04700), also obtained from Millipore Corporation. The amount of medium pipetted into each petri dish was about 1.8 to 2.0 ml - enough to saturate the absorbent pad (36). Each petri dish was immediately closed, marked appropriately for sampling identification and set aside until the filters were ready. Although it is indicated on the label that the medium may be used after storage of no more than four days, if kept refrigerated in tightly closed containers, m-F Endo broth used for this investigation was prepared and used the same day.

m FC Broth Base (Medium for Isolation of Fecal Coliforms)

m FC broth is recommended for the detection and enumeration of fecal coliforms by the membrane filter technique. Background color on the membrane filter will vary from a yellowish cream to faint blue, depending on the age of the reagent. When rosolic acid salt reagent has been prepared within an hour or two of its addition to the medium, it has been shown to have a differential effect on some of the non-fecal coliform colonies.

Aniline blue is the indicator system in the M-FC broth. It is used to detect lactose fermenting, and development of the blue colony color does not depend upon the addition of the rosolic acid salt reagent. The sodium salt of rosolic acid is added to the medium to suppress a variety of non-fecal coliform organisms, which may grow at the elevated temperature and which are common to some specific source waters and the first flush of stormwater runoff. Without the inhibitory effects of the rosolic acid salt, a substantial background development of white to gray-colored colonies may appear and cause interference with the discrete growth of the blue-covered fecal coliform colonies. The formulation of the M-FC was prepared according to the formation of Geldreich, Clark and Kabler for the detection and enumeration of fecal coliforms by the membrane filter technique and may be found in Appendix I.

To rehydrate the medium, 3.7 grams dehydrated M-FC broth base was suspended in 100 mls of purified water in a 250 ml screw-cap Erlenmeyer flask. One ml of a one percent solution rosolic acid in 0.2 N sodium hydroxide was added to the mixture. The one percent rosolic acid solution was prepared in a separate flask by adding 100 ml of 0.2 N NaOH solution to one gram of rosolic acid dihydrate in distilled water. The mixture was agitated thoroughly using a glass rod then eventually stirred with a magnetic stirrer while heating it to boiling point in a loosely covered flash. Promptly, it was removed from the hot stirrer and cooled to room temperature (or at least below 45^{o}C). Like the MF Endo medium, the m FC broth was not autoclaved. All unused rosolic acid salt reagents were stored at 2 to 10 C (refrigerator) in an Erlenmeyer flask with the outside surface fully covered with a sheet of aluminum foil. The solutions were immediately discarded after one week and would have been eliminated earlier if they had changed color from dark red to muddy brown or if after the addition of the rosolic acid, the prepared medium had shown the proper color (19). The finished medium with the final pH adjusted to 7.4 was pipetted into sterile plastic petri dishes. The amount of medium pipetted into each petri dish was between 1.8 to 2.0 ml or just enough to saturate the absorbent pad. Again, each petri dish was promptly closed, marked appropriately for sampling identification and set aside until the filters were ready. The m FC broth used for this investigation was prepared and used the same day.

m Enterococcus Agar (Medium for enumeration of fecal streptococci)

m Enterococcus agar is an approved medium containing 2, 3, 5-triphenyltetrazolium chloride (TTC) for use with membrane filters for the enumeration of enterococci in water and other materials. In this medium, coliform and other gram-negative organisms are inhibited. Sodium azide which has been added to this medium is the selective agent for the isolation of streptococci. The formula for m Enterococci agar utilized for this investigation may be found in Appendix I.

To rehydrate the m Enterococcus medium, 42 grams were suspended in 1000 ml of cold distilled water and heated to boiling point to dissolve completely before dispensing into small sterile plastic petri dishes. Medium in each petri dish was allowed to solidify completely before using it.

Data Collection Instrument

Several instruments were used in the data collection, but the most important ones were those that make up the membrane filtration unit. The membrane filter (MF) procedure for the enumeration of total coliforms was introduced into standard methods as a tentative method in 1955 and established as both a standard test and an alternate to the multiple tube procedure in 1960 with the publication of the 11th Edition of Standard Methods (57). This method involved filtering a measured volume of water sample through a membrane filter of optimum pore size for full bacterial retention. As the water passed through the pores, bacteria were entrapped on the upper surface of the membrane filter. The filter was then placed in contact with either an absorbent pad saturated with a selective, differential culture medium or directly over an agar medium to provide nutrients for bacterial growth. After the incubation under specified conditions of time, temperature, and humidity, the cultures were removed and examined for coliform colonies that were then counted and recorded as a density of coliforms per 100 ml of water sample. It was assumed that each bacterium retained by the filter grows and forms a small colony.

The membrane filter technique has been widely adopted for use in water quality monitoring studies, mainly because it requires much less laboratory apparatus than the standard multiple-tube technique. More recently, portable membrane filter apparatus have been developed for conducting coliform tests in the field (25).

The wide acceptance of the membrane filter technique as a standard method for coliform analysis is documented in the following quotation from Standard Methods (57).

> Since publication of the 11th Edition, widespread use of the technique has confirmed its value, especially its high degree of reproducibility, the possibility of testing relatively larger volumes of samples, and its ability to yield definite results more rapidly than the standard tube procedure. The method has proved particularly valuable in the routine analysis of a given water after its applicability has been established. (57).

Public Health Service Drinking Water Standard, revised in 1962, recommends the membrane filter method for analysis of interstate waters (36). Among the advantages cited by the National Training Center of the U.S. Environmental Protection Agency are the following:

(a) Results are obtained quicker, as compared to standard fermentation tube method.

(b) Much larger and, hence, representative water samples can be sampled routinely with membrane filters.

(c) Numerical results from membrane filters have much higher reproducibility (precision) than is expected with the fermentation tube method.

(d) Because the equipment and supplies required are not bulky, a great many samples can be examined with minimum requirements for laboratory space, equipment, and supplies.

Special apparatus required to conduct membrane filter coliform tests includes: filtration units, membrane filters, absorbent pads, alcohol burner, stereoscopic microscope, smooth-tipped forceps, two vacuum tubings, two vacuum flasks and culture media graduated pipettes. The type of filter holder used in this investigation was the "PVC filter holder manifold" and it allowed three simultaneous filtrations of samples. Pyrex millipore filter holders were also employed for this study.

The membrane filter techniques described above deal primarily with the analysis of total coliform bacterial in drinking water, where ideally the coliform bacteria count is extremely low and, hence, a large sample size of at least 100 ml is necessary in order to obtain some growth. The same techniques, however, can be applied to the analysis of other types of waters where a much higher bacterial count may be expected. Ordinarily, the only modification required in such cases is a downward adjustment of sample size to yield a countable number of colonies on the test filter.

> In tests made to determine the bacteriological safety of finished water, the standard sample volume should be at least 50 ml -- preferably 100 ml -- if it is to meet the requirements of the U.S. Public Health Service drinking water standards. (4)

TABLE 2. Suggested Sample Volume for Membrane Filter Total Coliform Test.*

	Volume Filtered (ml)							
Water Source	100	50	10	1	0.1	0.01	0.001	0.0001
Drinking water	X							
Swimming pools	X							
Wells, springs	X	X	X					
Lakes, reservoirs	X	X	X					
Water supply intake			X	X	X			
Bathing beaches			X	X	X			
River water				X	X	X	X	
Chlorinated sewage				X	X	X		
Raw sewage					X	X	X	X

*Taken from the Standard Methods for the Examination of Water and Wastewater 14th Edition, 1975, page 932 (57).

TABLE 3. Suggested Guide For Fecal Coliform Filtration Quantities*

	Quantities Filtered (ml)						
	100	50	10	1	0.1	0.01	0.001
Lakes, reservoirs	X	X					
Wells, springs	X	X	X				
Water supply, surface intake		X	X	X			
Natural bathing waters		X	X	X			
Sewage treatment plant secondary effluent			X	X	X		
Farm ponds, rivers				X	X	X	
Stormwater runoff				X	X	X	
Raw Municipal sewage					X	X	X
Feedlot runoff					X	X	X

*Taken from Handbook For Evaluating Water Bacteriological Laboratories, Second Edition, EPA -- 670/9-75-006, U.S. Environmental Protection Agency, August 1975, page 129 (19).

Whenever there are fluctuations in coliform bacteria density expected, it is recommended that several filtrations should be performed to obtain reliable results. For instance, "if the coliform bacteria count is expected to fall between 300 and 16,000 per 100 ml, it is better to filter one sample each of 6, 2, and 0.5 ml" (4).

Since earlier analysis gave a fluctuating bacterial density, it was deemed necessary in this study to filter several volumes from each sample, especially since this was only single sample investigation. The sample volumes filtered from each sample taken from each selected location were 0.001 ml, 0.01 ml, 0.1 ml, 1.0 ml, 10 ml, 100 ml, and 250 ml. Only those petri dishes showing colonies ranging from 50 and 200 after incubation were used to compute the bacterial density.

Sample Analysis

Before sample collection, all glassware (filters, holders, funnels, graduated cylinders, beakers, dilution bottles, and water pipettes) was thoroughly cleansed, rinsed (with great care, giving a final rinse with distilled water) and autoclaved as described in Standard Methods (57). The filter holders, funnels, beakers, and graduated cylinders were wrapped in sheets of aluminum foil before autoclaving at 121°C for 15 minutes.

Phosphate buffer solution was used for rinsing the filter funnels following addition of the sample filtration volume and again during the process as outlined in the figure below. The buffer was prepared and stored in tightly capped flasks which were wrapped in sheets of aluminum foil before placing them in the refrigerator until later use.

TABLE 4. Buffer Rinse (volume)

Sample Size (ml)	Pre-Rinse (ml)	Rinses (ml)
0 - 20	20	2 x 10
20 - 50	30	2 x sample size
50 - 100	0	2 x sample size

The phosphate buffer was prepared according to the directions given in Standard Methods and are cited below.

> To prepare stock phosphate buffer solution, dissolve 34.0 g potassium dihydrogen phosphate, KH_2PO_4, in 500 ml distilled water, adjust to pH 7.2 with 1 N NaOH, and dilute to 1 liter with distilled water. Add 1.25 ml stock phosphate buffer solution and 5.0 ml magnesium sulfate (50 g $MgSO_4 \cdot 7H_2O$ per liter of distilled water)

> to 1 liter distilled water. Dispense in amounts that will provide 99 ± 0.2 ml after autoclaving at $121^{\circ}C$ for 15 minutes (57, p. 892).

Sample volumes greater than 10 ml were first measured into a sterile graduated cylinder and poured into the filter funnel. Sample volumes of 10 ml or less were taken directly from the sample bottle and dispensed into the funnel using sterile water pipettes. Dilution blanks which had been prepared early in accordance with Standard Methods (57) was available in the laboratory for use whenever filtering extremely small size samples (of less than 1 ml).

Prior to filtration, all bench tops used for sample analyses were thoroughly cleansed with water and disinfectant solution before placing any equipment on them. As soon as all bench-tops were dry, all the necessary equipment (glassware, electric pump, membrane filter unit, reagents, alcohol jars with forceps, a gas burner, and petri dishes with media) was placed on the laboratory table and arranged for convenience. Petri dishes, each saturated with known medium, were placed in a series of rows and labeled to correspond with the sample shown on the data sheet.

To filter each sample, a sterile membrane filter, grid side up, was placed on the basal part of the filtering unit and centered over the porous part of the membrane support plate. Because membrane filters are easily damaged, smooth-tipped forceps were used to grasp them at the parts outside the portions of the filters through which the water sample passed through. Prior to pouring or pipetting any volume of sample into the funnels, the sample bottle, tightly capped, was shaken vigorously approximately 25 times, using up and down motion. The cap was then removed and the mouth of the bottle quickly passed over the flame before removing each required sample. At this point, the electric vacuum pump was turned on to hasten filtration of the sample through the membrane filters. The pump was turned off after the sample had passed through and each of the three funnels were rinsed with 20 to 30 ml of phosphate buffer solution or as shown in Table 4.

After filtration of the sample volume and buffer rinse, the filtration assembly was disassembled aseptically to allow removal of the membrane filter. Likewise, forceps used to grasp the membrane filters were alcohol disinfected and immediately flamed before each manipulation of membrane filter. Each membrane filter was lifted carefully and placed grid-side up on the nutrient surface of a previously prepared petri dish that corresponded to that sample. Because air bubbles interfere with the diffusion of culture medium from the absorbent pad through the membrane filter, the entrapment of air bubbles was reduced by having enough culture medium on the absorbent pad for nutrients, and by rolling the membrane filter into proper position on the absorbent pad. Any excess liquid was carefully poured off whenever liquid broth was used instead of agar. With either the agar or the broth medium, the tightly closed and labeled petri dishes were incubated under prescribed conditions of time, temperature, and humidity. The sealed petri dishes for total coliform and fecal streptococci were incubated in inverted position in a 35^{o}C incubator. The fecal coliform plates were first placed into plastic bags and sealed. The bags were then wrapped loosely in aluminum sheets before placing them in rectangular and square plastic containers. Half of the containers were immediately taken to the Microbiology Laboratory in Nash Hall and incubated in a 45.5^{o}C incubator for 22-24 hours. There were no significant differences in growth between those plates that were incubated in the Microbiology Laboratory (Nash Hall) and those that were incubated in the Environmental Health Laboratory (Waldo Hall).

Collection of Data

Following the prescribed incubation period, petri dishes were removed from the incubators and placed on the table for bacterial examination. Using a stereoscopic microscope, each petri dish was examined and all colonies exhibiting specific required characteristics were counted and recorded. It was assumed that each colony observed developed from a single bacterial cell in the original sample. All colonies counted as total coliforms on MF Endo plates were pink to dark-red color with a green metallic sheen. The colonies exhibiting a blue color on plates that had m FC broth were counted and recorded as fecal coliforms. On m Enterococcus agar plates, the colonies exhibiting red to pink colonies were counted and recorded as fecal streptococcus colonies.

The acceptable way of expressing the total coliform, fecal coliform, and fecal streptococcus in water using the membrane filter technique is in terms of the number of organisms (showing specific characteristics) per 100 ml. When a 100 ml sample was used, then the number of coliform or streptococcus organisms counted was the same as the number reported. However, for waters where less than 100 ml sample was used, the following formula was utilized:

$$\text{Total Coliform Colonies/100 ml} = \frac{\text{Coliform Colonies Counted} \times 100}{\text{ml sample filtered}}$$

The same equation was used to compute the number of fecal coliform and fecal streptococcus making sure that each colony has met the specific characteristic described above. Raw data (bacteriological results) are presented in Tables 5 through 9.

TABLE 5. BACTERIOLOGICAL RESULTS, 1968. Sewered and Unsewered Areas. Number of organisms/100 ml sample.

SITE	TOTAL COLIFORM	FECAL COLIFORM	FECAL STREPTOCOCCUS
1. Oak Creek	2,400	2,400	130
2. Squaw Creek	70,000	2,400	13
3. Control Point	62	62	12
4. Squaw Creek	700,000	62,000	2,400
5. Oak Creek	24,000	6,200	2,400
6. Timian St.	240,000	62,000	4
7. Sunset Drive	70,000	6,200	28
8. S.W. 53rd	240,000	62,000	2,400
9. Squaw Creek	24,000	620	240
10. Squaw Creek	70,000	620	620
11. Martin St.	6,200	2,300	210
12. Nash Road	240,000	23,000	210
13. Knollbrook Ave.	240,000	6,200	2,400
14. Knollbrook Ave.	70,000	24,000	2,400
15. Long Ave.	240,000	23,000	7,000
16. Whiteside Ave.	70,000	24,000	12
17. DeArmond Dr.	50,000	2,400	2,400
18. Chintimini Ave.	240,000	240,000	7,000
19. Cascade Ave.	37,000	700,000	2,400
20. Brook Lane	70,000	70,000	4
21. Brook Lane	70,000	70,000	7,000
22. Oak Creek	70,000	5,000	2,400

TABLE 6. BACTERIOLOGICAL RESULTS, 1979. Sewered and Unsewered Areas. Number of organisms/100 ml sample.

SITE	TOTAL COLIFORM	FECAL COLIFORM	FECAL STREPTOCOCCUS
1. Oak Creek	2,000	6,000	180
2. Squaw Creek	88,000	2,200	240
3. Control point	50	100	18
4. Squaw Creek	800,000	58,000	3,200
5. Oak Creek	26,000	4,800	1,600
6. Timian St.	800,000	64,000	5,600
7. Sunset Drive	76,000	5,000	74
8. S. W. 53rd St.	42,000	60,000	3,000
9. Squaw Creek	26,000	150	26
10. Squaw Creek	42,000	130	13
11. Martin St.	240	2,800	240
12. Nash Rd.	22,000	20,000	170
13. Knollbrook Ave.	230	160	28
14. Knollbrook Ave.	400	0	0
15. Long Ave.	620	180	16
16. Whiteside Ave.	740	240	0
17. DeArmond Dr.	2,400	800	620
18. Chintimini Ave.	320	0	0
19. Cascade Ave.	250	100	18
20. Brook Lane	34,000	170	24
21. Brook Lane	30,000	200	40
22. Oak Creek	72,000	4,600	2,100

TABLE 7. BACTERIOLOGICAL RESULTS, 1968 and 1979. Sewered and unsewered areas. Number of organisms/100 ml sample.

SITE	Total Coliform		Fecal Coliform		Fecal Streptococcus	
	1968	1979	1968	1979	1968	1979
1. Oak Creek	2,400	2,000	2,400	6,000	130	180
2. Squaw Creek	70,000	88,000	2,400	2,200	13	240
3. Control Point	62	50	62	100	12	18
4. Squaw Creek	700,000	800,000	62,000	58,000	2,400	3,200
5. Oak Creek	24,000	26,000	6,200	4,800	2,400	1,600
6. Timian St.	240,000	800,000	62,000	64,000	4	5,600
7. Sunset Dr.	70,000	76,000	6,200	5,000	28	74
8. S.W. 53rd	240,000	42,000	62,000	60,000	2,400	3,000
9. Squaw Creek	24,000	26,000	620	150	240	26
10. Squaw Creek	70,000	42,000	620	130	620	13
11. Martin St.	6,200	240	2,300	2,800	210	240
12. Nash Rd.	240,000	22,000	23,000	20,000	210	170
13. Knollbrook Ave.	240,000	230	6,200	160	2,400	28
14. Knollbrook Ave.	70,000	400	24,000	0	2,400	0
15. Long Ave.	240,000	620	23,000	180	7,000	16
16. Whiteside Ave.	70,000	740	24,000	240	12	0
17. DeArmond Dr.	50,000	2,400	2,400	800	2,400	620
18. Chintimini Ave.	240,000	320	240,000	0	7,000	0
19. Cascade Ave.	37,000	250	700,000	100	2,400	18
20. Brook Lane	70,000	34,000	70,000	170	4	24
21. Brook Lane	70,000	30,000	70,000	200	7,000	40
22. Oak Creek	70,000	72,000	5,000	4,600	2,400	2,100

TABLE 8. BACTERIOLOGICAL RESULTS. Sewered area. Number of organisms/100 ml.

Site	Total Coliform		Fecal Coliform		Fecal Streptococcus	
	1968	1979	1968	1979	1968	1979
11. Martin St.	6,200	240	2,300	2,800	210	240
13. Knollbrook Ave.	240,000	230	6,200	160	2,400	28
14. Knollbrook Ave.	70,000	400	24,000	0	2,400	0
15. Long Ave.	240,000	620	23,000	180	7,000	16
16. Whiteside Ave.	70,000	740	24,000	240	12	0
18. Chintimini Ave.	240,000	320	240,000	0	7,000	0
19. Cascade Ave.	37,000	250	700,000	100	2,400	18

TABLE 9. BACTERIOLOGICAL RESULTS. Unsewered area. Number of organisms/100 ml.

	Total Coliform		Fecal Coliform		Fecal Streptococcus	
	1968	1979	1968	1979	1968	1979
2. Squaw Creek	70,000	88,000	2,400	2,200	13	240
4. Squaw Creek	700,000	800,000	62,000	58,000	2,400	3,200
5. Oak Creek	24,000	26,000	6,200	4,800	2,400	1,600
6. Timian St.	240,000	800,000	62,000	64,000	4	5,600
7. Sunset	70,000	76,000	6,200	5,000	28	74
8. S.W. 53rd	240,000	42,000	62,000	60,000	2,400	3,000
22. Oak Creek	70,000	72,000	5,000	4,600	2,400	2,100

Method of Statistical Analysis

In consulting with OSU statisticians, it was decided that a special use of the "t" test referred to as "paired comparisons" or "paired t" test was the appropriate tool to be utilized for this investigation. The paired "t" test is often used when one is comparing two groups at two different times. Thus, the experimental design consists in taking individual samples, making a measurement on each one, and then after some treatment making a second measurement in the same unit as the first. The point is to determine if any real difference, on the average, occurs as a result of the treatment. Thus, the difference in measurements for each individual is obtained, and these differences constitute a sample which is used to test the hypothesis that there is no real difference (72). Although there are other variables that may bring the difference about, the paired "t"-test is designed to measure any effect the treatment might have. For the purpose of this investigation, the question that was to be answered was: have municipal sewers in South Corvallis made any significant difference? The paired experiment is usually more efficient than independent sample experiment, simply because fewer sample observations are generally required to detect a true difference between μ_1 and μ_2 when the paired sample experiment is used instead of the two independent sample experiment (72). This is due to the fact that the pairing usually eliminates effects that may make it difficult for the two independent sample experiments to detect a true difference. Secondly, the paired experiments does not require that the population variance, S_1^2 and S_1^2 be equal. For this study then, the variance S_1^2 and S_2^2 did not need to remain constant through out the experiment. However, the sum S_1^2 - S_2^2 had to remain constant for n paired observations. With these assumptions it follows that

$$t = \frac{\bar{d} - 0}{Sd/\sqrt{n}}$$

$$= \frac{\bar{d} - 0}{Sd} \sqrt{n} \; .$$

with n-1 degrees of freedom.

Where $\bar{d}$ = Sample mean difference.

Sd = Sample standard deviation of difference.

n = Number of paired observations.

In consideration of the limitations of this study, the analysis of data utilizing the paired "t" test is presented with appropriate findings in the next section. The decisions were that each hypothesis was to be retained, rejected, or not rejected at a selected probability level of α = 0.01.

IV. ANALYSIS OF DATA

Statistical Findings and Hypothesis Test Results

The main purpose of this investigation was to determine whether or not the replacement of individual septic tank systems with a municipal sewerage systems significantly reduced suface water contamination in South Corvallis.

The data collected by the Benton County Health Department and the State Health Division in 1968 was used as the initial measurements. The data collected by the current investigator in 1979 represents the second measurements. To bring the data more closely in line with the normal distribution, raw data utilized in the analysis was transformed into logarithmic scales which appear in Tables 10 and 11.

The statistical tool used to test all three null hypotheses was the paired "t" test discussed in the preceeding section. This section describes the statistical analysis performed for this study. Tables 10 and 11 illustrate the analysis of data. The procedures for testing each hypothesis are also explained. The "t" tabular values which are read from the statistical tables act as the tolerance points for making decisions about the "retainment" or "rejection" of the null hypothesis.

The analysis of data for the hypothesis one (Ho_1) using the paired "t" test yielded the results shown in Table 10.

TABLE 10. Sewered Area (South Corvallis). Differences in Measurements, paired, logarithmic (Log 1968-Log 1979)

	Total Coliform/ 100 ml	Fecal Coliform/ 100 ml	Fecal Strep./ 100 ml
LOCATION	Log 1968 —	Log 1979	
Martin Street	3.252	-.1967	-.134
Knollbrook Ave.	6.950	3.657	4.451
Knollbrook Ave.	5.165	10.086	7.783
Long Ave.	5.959	4.850	6.081
White Side Ave.	4.550	4.605	2.485
Chintimini Ave.	6.620	12.388	8.854
Cascade Ave.	4.997	8.854	4.893
Total (Σd) =	37.493	44.243	34.413
Mean difference ($\bar{d}$) =	5.356	6.321	4.916
Σd^2 =	210.562	391.603	225.890
S^2 =	1.624	18.674	9.452
S_d =	1.274	4.321	3.074
$H0{:}_1\ \bar{d} = 0$ (or $\mu_{1968} = \mu_{1979}$)			
$Ha_1\ \bar{d} \neq 0$ ($\mu_{1968} \neq \mu_{1979}$)			
$t^1 = \frac{\bar{d}-d_2}{S/\ n}$			
$t = \frac{\bar{d}-0}{S/\ n}$	$\frac{5.356}{(1.274/\sqrt{7})}$	$\frac{6.320}{(4.321/\sqrt{7})}$	$\frac{4.916}{(3.074/\sqrt{7})}$
Computed "t" =	11.129	3.869	4.231
Risk level =	$\alpha = 0.01$	$\alpha = 0.01$	$\alpha = 0.01$
df =	6	6	6
Tabular "t" =	3.143	3.143	3.143

*Decision: Reject all three at $\alpha = 0.1$, but the result has a p value of less than 0.005.

The results of the analysis of data for hypothesis one using the paired "t" test are shown in table 10. The computed "t" values generated by the analysis of data are 11.129 for total coliforms, 3.869 for fecal coliforms and 4.231 for fecal streptococci. The tabular value with the degrees of freedom (df) = 6 at the .01 level of significance was 3.143.

Since the computed values were larger than the tabular "t", the null hypothesis was rejected for all three measurements (total coliforms, fecal coliforms and fecal streptococci). This concludes that the sewer connections in South Corvallis significantly reduced the bacteriological contamination of surface water in the area.

The analysis of data for the hypothesis two (Ho_2) using the paired "t" test yielded the results shown in Table 11.

TABLE 11. Unsewered Area (South Corvallis). Differences in Measurements, paired, logarithmic scale (Log 1968-Log 1979).

	Total Coliform/ 100 ml	Fecal Coliform 100 ml	Fecal Strep./ 100 ml
LOCATION	Log 1968 —	Log 1979	
Squaw Creek	-.229	.087	-2.916
Squaw Creek	-.134	.067	- .288
Oak Creek	0.080	.256	.405
Timian Street	-1.204	-.032	-7.244
Sunset Drive	-0.82	.215	-.972
S.W. 53rd	1.743	.033	-.223
Oak Creek	-.028	.083	.134
Total (Σd)	-.014	.709	-11.104
Mean difference ($\bar{d}$)	-.002	.101	-1.586
Σd^2 =	4.572	.1328	62.238
S_d^2	.762	.0102	7.437
S_d	.873	.1008	2.727

$Ho_1: \bar{d} = 0$ (or $\mu_{1968} = \mu_{1979}$)
$Ha_1: \bar{d} \neq$ (or $\mu_{1968} \neq \mu_{1979}$)

$$t = \frac{\bar{d}_1 - \bar{d}_2}{s/\ n}$$

$t = \frac{\bar{d}-0}{S/\sqrt{n}} =$	$\frac{-.002}{.873/\sqrt{7}}$	$\frac{.101}{.100/\sqrt{7}}$	$\frac{-1.586}{2.727/\sqrt{7}}$
Computed "t" =	-.006	2.651	-1.539
Risk level	$\alpha = 0.01$	$\alpha = 0.01$	$\alpha = 0.01$
df = 6	6	6	6
Tabular "t" =	3.143	3.143	3.143

* Decision: Retain all three at $\alpha = 0.01$.

The results of the analysis of data for the hypothesis two (Ho_2) using the paired "t" test are shown in Table 11. The computed "t" values generated by the analysis of data were: -.006 for total coliforms, 2.651 for fecal coliforms and -1.539 for fecal streptococci. The tabular value with the degrees of freedom (df) = 6 at the .01 level of significance was 3.143.

Since all the computed values were smaller than the tabular values, the null hypothesis for all three measurements (total coliforms, fecal coliforms and fecal streptococci) were retained at .01.

Based upon these results, it was concluded that there was no change in levels of surface water contamination in Southwest Corvallis since 1968.

V. SUMMARY AND CONCLUSIONS

Summary

The main purpose of this study was to determine whether or not the replacement of on-site sewage disposal system with a municipal sewer system in Southwest Corvallis significantly reduced the level of fecal contamination of the watershed in the area. In 1968 a study conducted by sanitarians from the State Health Division and Benton County Health Department revealed a high failure rate of on-site sewage disposal systems in Southwest Corvallis.

The investigating team concluded that sewage disposal in the area studied was so inadequate that a significant health hazard existed due to fecal contamination of surface water. In 1969, following these findings, a part of Southwest Corvallis was annexed and sewered. The remaining area was still on individual sewage disposal systems and continued to have a high rate of failing systems. This follow-up study, therefore, was designed to quantitatively determine and compare the bacteriological levels of watershed contamination in the sewered and unsewered area. Specifically, this investigation was designed to test the following major hypotheses which are stated in the null forms:

Ho_1: u_{1968} bacteriological levels = u_{1979} bacteriological levels in the sewered area (i.e.: There is no significant difference between the main bacteriological levels before and after municipal sewer connections.)

Ho_2: u_{1968} bacteriological levels = u_{1979} bacteriological levels in the unsewered area (i.e.: There has been no significant change in bacteriological level in the unsewered area since 1968.)

It was decided that each hypothesis was to be retained, rejected or not rejected at a selected probab lity level of $\alpha = 0.01$.

Water samples of seepage, questionable surface water and suspected effluents were collected from roadside ditches, creeks and back or front yards of residences and other buildings, streams and drainage ways. The samples were taken to the environmental health laboratory, Oregon State University, for bacteriological analysis to determine the presence of total coliform, fecal coliform and fecal streptococci.

The current investigator closely followed the same guidelines and procedures of the 1968 investigative team. Since investigation was a comparative study, samples were obtained from the 22 sampling sites that were already chosen by the previous investigators.

The data was analyzed using the paired "t" test. The 1968 data collected by the Benton County Health Department and the State Health Division was used as initial measurements. The data collected in 1979 by the current investigator represents a second measurement.

The results of this study dictated that the null hypothesis one (Ho_1) was rejected. This demonstrated a significant difference between the mean bacteriological levels of watershed contamination before and after connection to the municipal sewer.

The null hypothesis two (Ho_2) was retained and it was concluded that there was no significant change in the level of watershed contamination within the unsewered area since 1968.

The results clearly indicate that: (1) The level of bacteriological contamination in the sewered area has been reduced significantly,

(2) Bacteriological contamination in the unsewered area remains at the same level. The results also indicate the presence of contamination of fecal origin in Oak and Squaw Creeks. This suggests that sewage in the form of run-off effluent from failing on-site sewage disposal systems has an influence on both streams which flow through the area.

Conclusions

Based on the statistical analyses of data from this study, the following conclusive statements can be made.

(1) The replacement of individual on-site sewage disposal systems with municipal sewers significantly reduced the level of surface water contamination in the area.

(2) The sewage related health hazards have significantly diminished in the sewered area.

(3) The levels of surface water contamination in the unsewered area has not changed significantly in the period between two studies.

(4) The sewage related health hazards still exist in the unsewered area.

The findings, therefore, conclude that sewer systems are more effective in eliminating ground water contamination than on-site sewage disposal systems in the areas studied.

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APPENDICES

APPENDIX I

THE INGREDIENTS OF CULTURE MEDIA USED:

MF ENDO MEDIUM, mFC BROTH, AND m ENTEROCOCCUS AGAR

The preparation of culture media for laboratory use has undergone considerable advancement from the early laborious art of processing crude animal and plant materials into peptones, suppressing agents, and agar substrates plus the further refining of textile dyestuffs into usable indicator agents (19). Various commercial suppliers now manufacture a wide variety of the basic ingredients for culture media formulations. For convenience and labor-saving advantages, most laboratories use commercially prepared dehydrated media for increased volume, routine, and bacteriological procedures. Dehydrated culture media are available as finely ground powders, granules or tablets. The choice is largely dictated by cost, availability and convenience.

Media used in this investigation for isolation of total coliforms(MF Endo) and fecal coliform (m FC broth) were purchased from Millipore Corporation in Bedford, Massachusetts. Agar medium (m Enterococcus) used for isolation of fecal streptococcus was purchased from Difco Laboratories in Detroit, Michigan.

TABLE 12.

I. MF Endo Medium

MF Endo broth contains the following ingredients per liter:

Polypeptone[tm] peptone	20.00g
Yeast Extract	1.50 g
Lactose	12.50 g
Sodium Chloride	5.00 g
Potassium Phosphate	5.75 g
Sodium Lauryl Sulfate	0.50 g
Sodium Desoxycholate	0.10 g
Sodium Sulfite	2.10 g
Basic Fuchsin	1.05 g

Final pH 7.2 ± 0.2 (no autoclaving).

Single strength dehydrated medium, 48 g/l.

II. m FC Broth:

Ingredients per liter

Bacto-Tryptose	10 g
Proteose	5 g
Bacto-Yeast Extract	3 g
Sodium Chloride	5 g
Lactose	12.5 g
Bacto-Bile Salts No. 3	1.5 g
Aniline Blue (water Blue)	0.1 g

Final pH 7.4 at 25°C.

Single strength dehydrated medium, 48 g/l.

III. m Enterococcus Agar:

Ingredients per liter

Bacto-Tryptose	20 g
Bacto-Yeast Extract	5 g
Bacto-Dextrose	2 g
Dipotassium Phosphate	4 g
Sodium Azide	10 g
Bacto-Agar	10 g
2, 3, 5-Triphenyl Tetrazolium Chloride	0.1 g

Final pH 7.2 at 25°C.

APPENDIX II

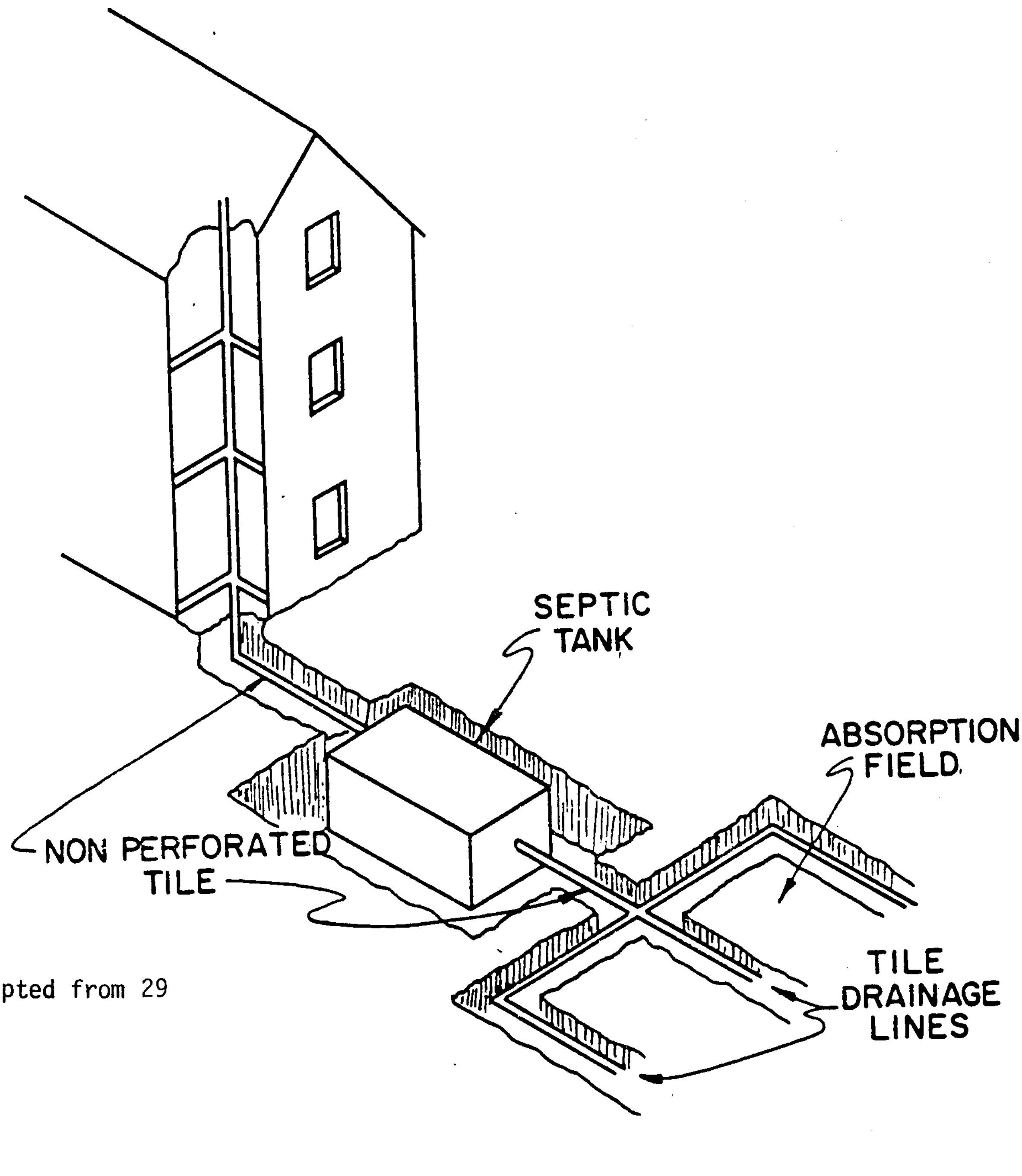
SEPTIC TANK (ILLUSTRATIONS)

SEPTIC TANK (Illustrations)

A septic tank is simply a tank buried in the ground to treat the sewage from individual home. Wastewater from the home flows into the tank where microorganisms in the sewage may break down the organic matter and the cleaner water flows out of the tank into the ground through subsurface drains.

Septic tanks remove about 90 percent of the settleable solids and reduce the BOD by about 30 percent. Periodically the sludge or solid matter in the bottom of the tank must be removed and discarded somewhere else.

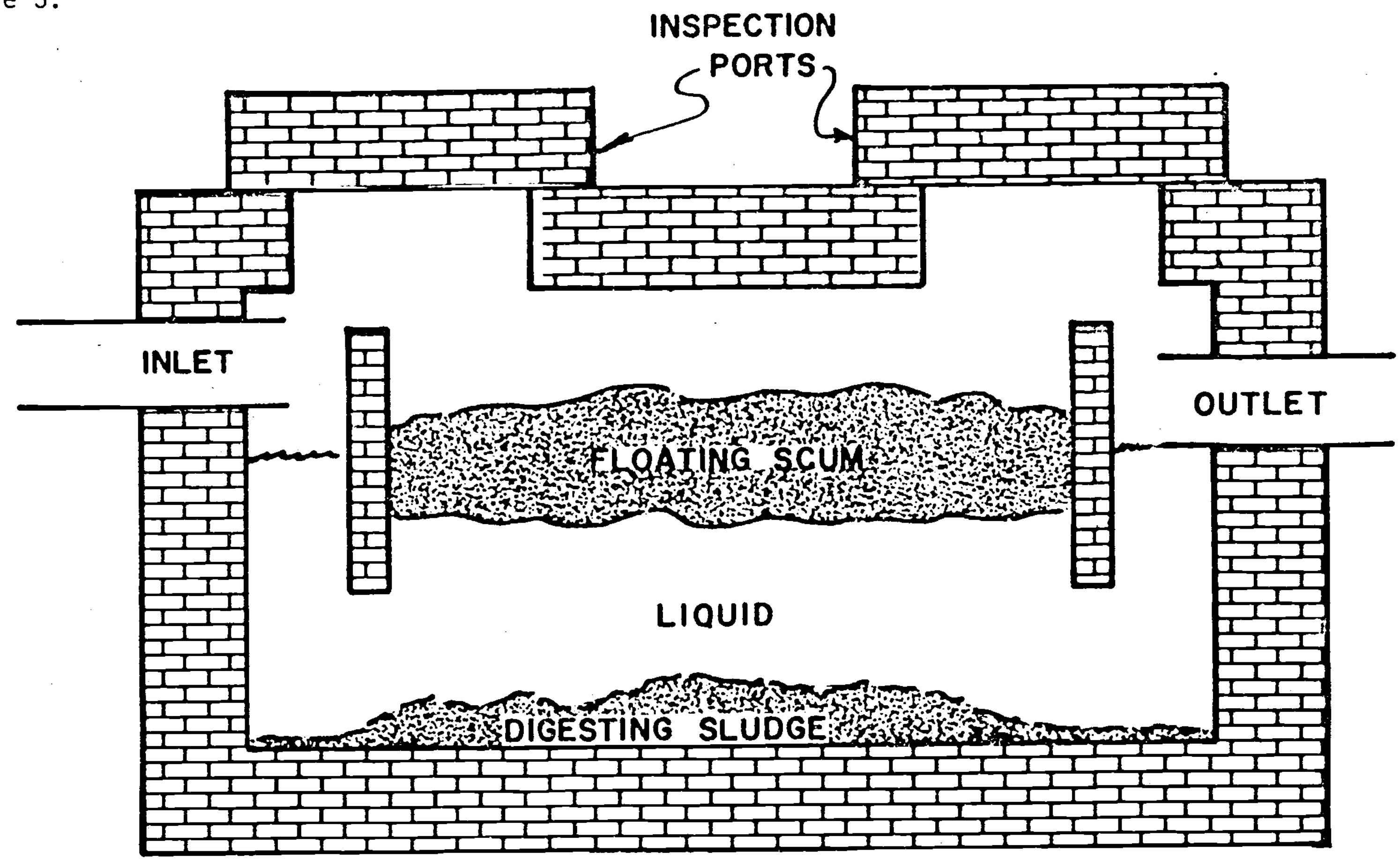
An absorption field, where the majority of the biological stabilization takes place, consists of looped or lateral trenches 18 to 24 inches wide, and at least 18 inches deep. Drain tile or perforated pipe in an envelope of gravel are used to distribute the wastewater uniformly over the trench bottom.



*Adopted from 29

FIGURE 2. Typical septic tank systems.*

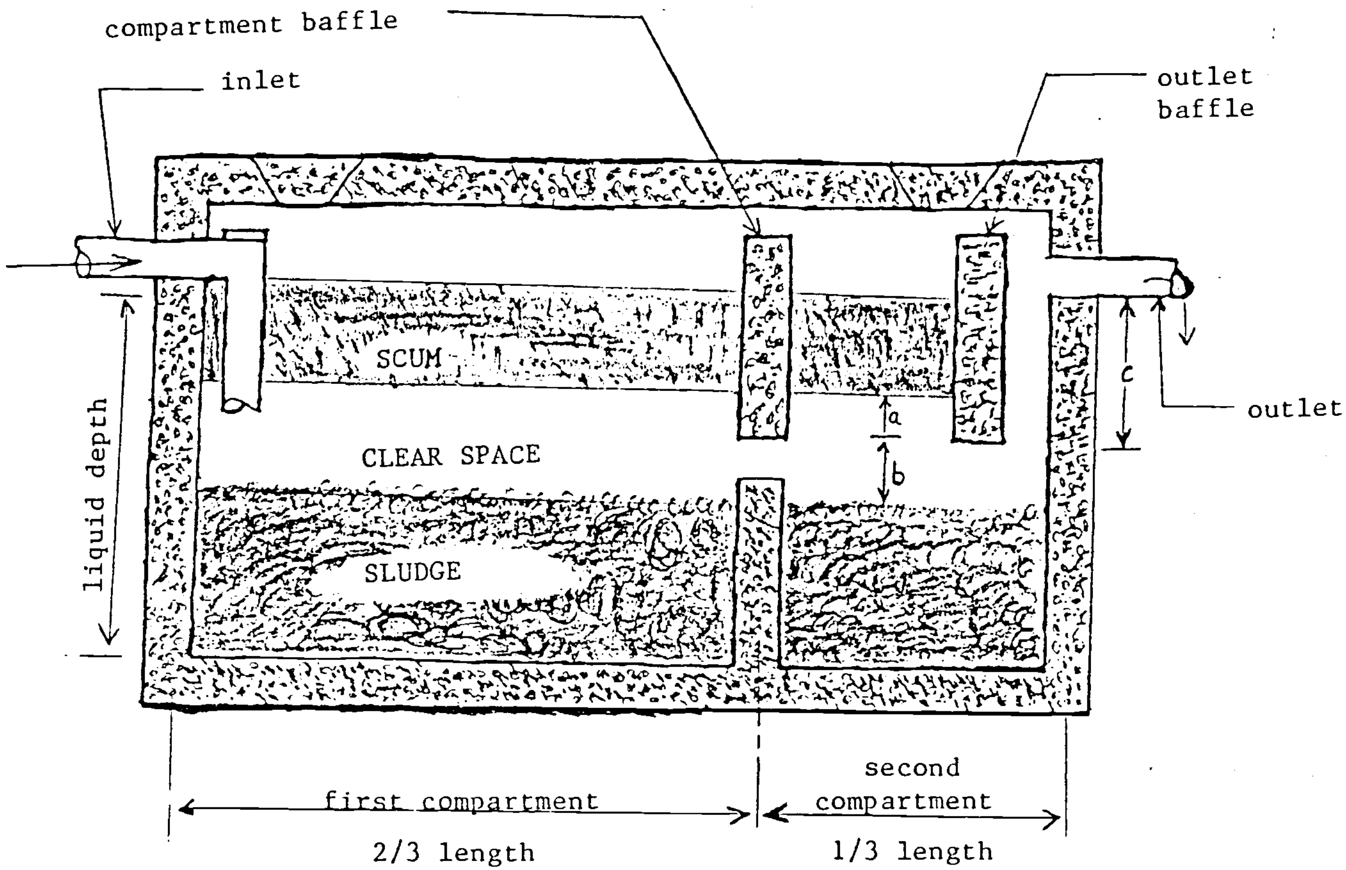
Figure 3.



*Adopted from 29

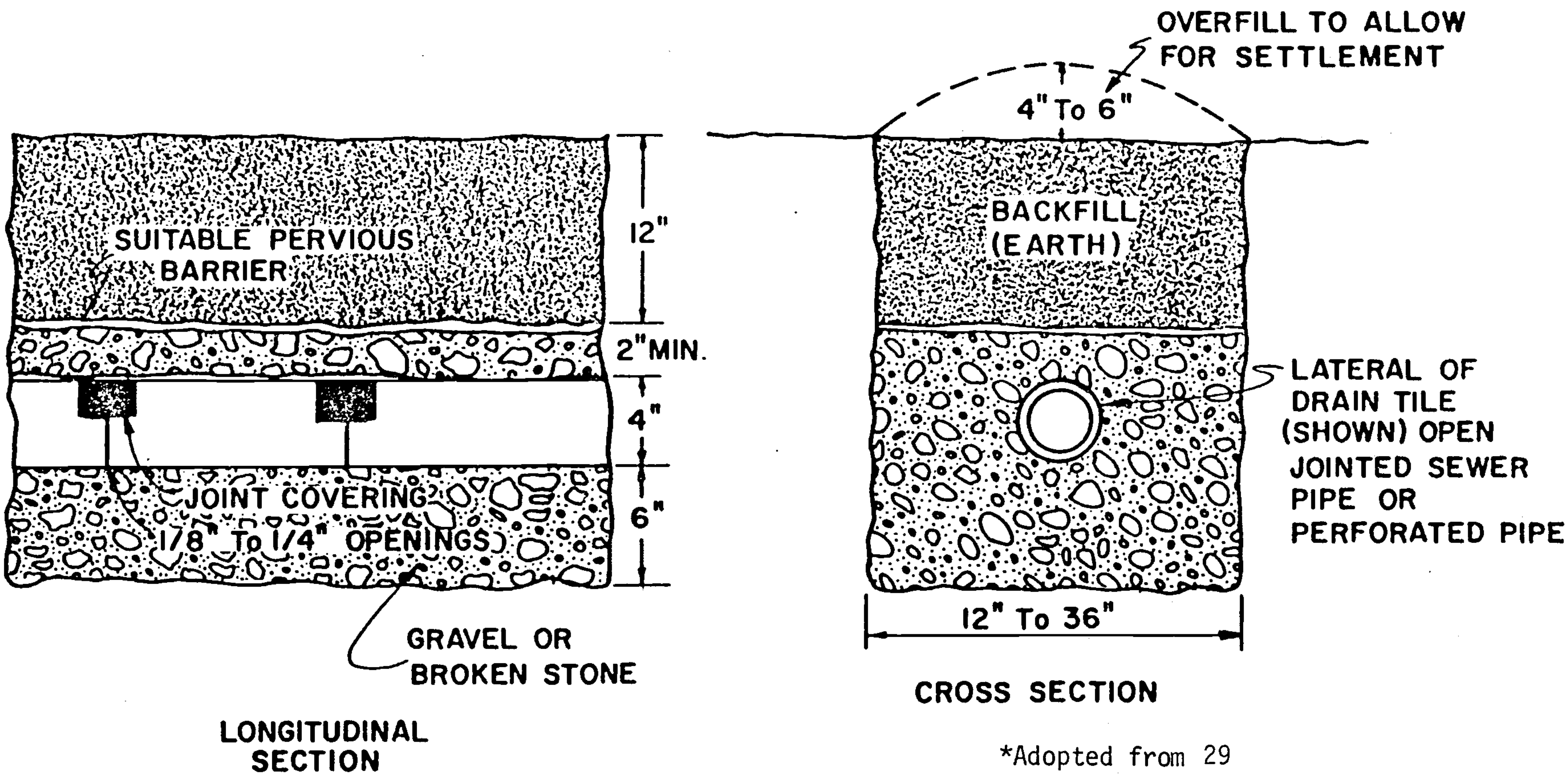
TYPICAL ONE COMPARTMENT SEPTIC TANK

Figure 4



a= scum clear space (3 inches minimum)
b= sludge clear space (12 inches minimum)
c= 40% of liquid depth

TYPICAL TWO COMPARTMENT SEPTIC TANK.



*Adopted from 29

FIGURE 5. Absorption trench and lateral.*

APPENDIX III

SOILS AND TOPOGRAPHY

BY THE 1968 SURVEY TEAM

(Soil Conservation Service
U. S. D. A.)

SOILS AND TOPOGRAPHY

Data concerning the soil types and topography and their ability to be utilized for subsurface sewage disposal systems were provided by the Soil Conservation Service, United States Department of Agriculture to the 1968 investigating team. The soils study showed that 13 different soil types were found in the survey area. Ten of the soil types were classified as soils which should not be utilized in housing developments with individual subsurface sewage disposal systems. Three soil types were rated by the Soil Conservation Service as soils which would present slight to moderate individual sewage disposal problems. The dispersion pattern of the different types of soils throughout the surveyed area indicates that variances to the building prohibition, at best, would be adding to the problem, both from the standpoint of land-use limitation and from an increased population density.

The topography of the area surveyed within the described boundaries was found to be variable. The elevations range from approximately 250 feet to 460 feet. The land may be described as ranging from low, relatively flat land with slopes of from 0% to 7% to gently rolling hills with grades ranging from 7% to 20%. However, in several instances, there are some steep slopes with residential lots ranging in grades from 20% upward.

In discussing the various soil classifications of the survey area, several factors are taken into consideration: the permeability of the soil, which is the factor that deals with the rate of water movement through the soil; and the land-use limitations, which relate to the suitability of the various soil classifications for individual subsurface sewage disposal systems. These land-use limitations are interpreted as follows:

1. Slight - soils present only minor problems with individual subsurface sewage disposal, but can be easily corrected.
2. Moderate - soils present problems with individual subsurface sewage disposal which must be recognized, but can be overcome.
3. Severe - soils present serious problems with individual subsurface sewage disposal and are difficult to overcome.
4. Very Severe - soils present very serious problems that are too difficult to correct; therefore, these soils should not be considered for use for individual subsurface sewage disposal systems.

There were approximately 13 soils classified in the 3.13 square miles of the survey area. They are: Amity silt loam, Bashaw clay, Bellfountain silty clay loam, Chehalis silt loam, Coburg silt loam, Concord silt loam, Dayton silt loam, Hazelair silt loam, Jory silty clay loam, Steiwer silt loam, Waldo silty clay loam, Willamette silt loam and Woodburn silt loam.

Starting with Country Club Heights, the soil classifications that predominate are Jory and Bellfountain silty clay loams.

Jory silty clay loam as classified in this area has a slope ranging from 7% to 12%. The soil is very deep and well drained. It is gently to strongly sloping, formed in colluvium from basic igneous and sedimentary materials (tuffs and basalts). The permeability is moderately slow. The depth to basalt bedrock ranges from 5 feet to 20 feet. The land-use limitation as related to individual subsurface sewage disposal is severe.

Bellfountain silty clay loam as classified in this area represents those elevations on the heights from approximately midway up the slope to the top. The slope through this area ranges from approximately 12% to 20%. This soil classification consists of deep, well drained, gently to steeply sloping soils formed from tuffs and basalt. The subsoil is clay underlain by sedimentary bedrock at a depth of from 30 inches to 48 inches. The permability is moderately slow. The land-use limitation as related to individual subsurface sewage disposal is severe.

From the base of Country Club Heights to a point approximately midway up the leading face (developed area) of the Heights, the soils are Waldo silty clay loam, Woodburn silt loam, Chehalis silt loam, Amity silt loam and Bellfountain silty clay loam which was discussed in the preceding paragraph.

Waldo silty clay loam is a poorly drained soil, the subsoil of which is high in clay content. The slope in this area ranges from 0% to 3%. The permeability is slow. Where this soil is found, the water table is at or near the surface of the ground most of the fall and winter. The land-use limitation as related to the installation of individual subsurface sewage disposal systems is very severe.

Woodburn silt loam is a moderately well drained soil which is very deep. The slope ranges from 0% to 3%. The permeability of this soil is moderate in the upper 30 inches and slow below 30 inches. The water table in this area is approximately 30 inches from the surface during the wet season. The land-use limitation for individual subsurface sewage disposal is moderate. Woodburn silt loam covers only a small portion of the area near the lower levels of Country Club Heights.

Chahalis silt loam covers a narrow strip across the lower levels of Country Club Heights. It is quite similar to Woodburn silt loam in that it is moderately well drained. The slope in this area ranges from 3% to 7%. In other areas where this soil is found, the slopes are considerably steeper. The permeability in the upper 30 inches is moderate while in the lower 30 inches it is slow. The water table is commonly around 30 inches of the surface during the wet season. The land-use limitation for the installation of individual subsurface sewage disposal systems in this soil is moderate.

Amity silt loam covers a large portion of the area at the base of Country Club Heights. The slope found in this particular area ranges from 0% to 3%. The soil is somewhat poorly drained. It is comprised of approximately 2 feet of silty loam underlain by approximately 1 foot of silty clay loam derived from mixed, very deep silty alluvium. Internal drainage is impeded by the silty clay loam subsoil. The water table is at or near the surface of the ground during the wet season which is the winter and spring. The land-use limitation as related to the installation of individual subsurface sewage disposal systems is very severe.

In and around the Fairhaven Heights development, then northwards to Country Club Way and westward to S.W. 53rd Street, the soils include large areas of Bellfountain silty clay loam, Hazelair silt loam, and Jory silty clay loam.

In the area west of S.W. 53rd Street from Plymouth Road to Country Club Way, the predominant soils include Steiwer and Willamette silt loams as well as Amity and Woodburn silt loams, both of which have been discussed herein. Each of the soils in the preceding paragraph and this paragraph will be discussed in respective order excluding those soils already described herein.

Hazelair silt loam is moderately deep and is from moderately well to somewhat poorly drained. It is a gently to strongly sloping soil formed on sandstone and shale. The permeability is moderately slow at the surface of the ground and very slow in the subsurface. The water table is at approximately 2 feet from the surface for short periods of time. This particular area has a slope that ranges from 7% to 12%. The land-use limitation is very severe.

Another predominant soil type is Steiwer silt loam which is moderately shallow and well drained. It occurs on gently to strongly sloping areas. It is formed in a thin mantle of alluvium and colluvium and sedimentary material on low foothills. In this particular area, the slope ranges from 7% to 12%. The permeability of the soil is moderately slow. The depth to bedrock ranges from 20 to36 inches.

The land-use limitation for this soil as related to the installation of individual subsurface sewage disposal is very severe.

Willamette silt loam is a very deep, well drained soil. The permeability of this soil is moderate; the water table is approximately 30 inches from the surface of the ground for about 1 week during the wet season. The slope of the area where this soil is variable, dependent on location, but in this specific area, it ranges from 0% to 3%. The land-use limitation for septic tank and tile fields in this soil is slight.

From Country Club Way northward to West Hills Road and from S.W. 45th Street to S.W. 53rd Street and westward approximately 1600 feet, the soil classifications include many soils already discussed, but one soil classification not yet discussed. Those soils discussed include Willamette, Woodburn, Amity and Steiwer silt loams and Waldo silty clay loam.

The soil classification not yet discussed is Dayton silt loam. It is poorly drained soil, the permeability of which is moderately slow. The water table is at the surface most of the winter. The slope of the ground herein ranges from 0% to 3%. Septic tank and tile field installations in this soil will create sewage problems that are too serious to correct on an individual basis.

The next discussion of soil classifications is from lands situated between the Southern Pacific Railroad right-of-way on the north, West Hills Road on the south, 35th Street on the east and 53rd Street on the west. As with the other areas herein, most of the soils classified in the above-described area have been previously discussed under the Soils & Topography section of this report. Only those soil classifications not heretofore described will be discussed.

Those soils in the above-described area that have been previously discussed are listed as follows: Willamette, Woodburn, Steiwer and Amity silt loams. One soil classification has not been been previously discussed, that being Bashaw clay.

Bashaw clay is a soil with a very high clay content. The slope of this soil in the described area is from 0% to 3%. The permeability of the soil is very slow; in fact, it is common to have water ponding or pooling at the surface. The soil, as indicated, is poorly drained and subject to overflow. The water table in this soil is at or near the surface for long periods of time. The land-use limitation as associated with septic tank and tile field installations is very severe.

The last area concerning the classification of soils extends from Oak Creek Road on the north to West Hills Road on the south and from S.W. 53rd Street on the east approximately 1600 feet west to the crest of the hills.

The previously described soils in this area include Willamette and Woodburn silt loam, Bellfountain and Waldo silty clay loam, and Bashaw clay. There are two soil classifications in this area that have not been discussed and they are Coburg silt loam and Concord silt loam.

Both Coburg and Concord silt loam are very similar. Both soil types are poorly drained and the permeability is slow. The water table is at or near the surface of the ground during most of the wet season. The land-use limitation for septic tank and tile field installations for both soils is very severe.

In summary, throughout the approximately 2000 acres of the survey area, 10 of the 13 soil types (Amity, Concord, Coburg, Dayton, Steiwer and Hazelair silt loams; Bellfountain, Jory and Waldo silty clay loams; and Bashaw clay) are classified as soils which should not be utilized in housing developments with individual subsurface sewage disposal systems.

The dispersion of the soils throughout the area is such that in certain small areas, as described herein, there may be as many as 7 different soil types. In all, there were only 3 soil types (Chahalis, Willamette and Woodburn silt loams) which were rated by the Soil Conservation Service as soils which would present slight to moderate individual sewage disposal problems.

Obviously, because of the dispersion pattern of different types of soils throughout the surveyed area, it must be stated that variances on the building prohibition, at best, would be adding to the problem, both from the standpoint of land-use limitation and from an increased population density. More homes and a higher population create greater water demand and usage resulting in larger amounts of sewage and waste water discharge which result in overcharging land masses with liquid wastes.